Development of a national strategy for adaptation to climate change adverse impacts in Cyprus

CYPADAPT

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Report on the future climate change impact, vulnerability and adaptation assessment for the case of Cyprus

DELIVERABLE 3.4

CLIMATE CHANGE ADAPTATION

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1. INTRODUCTION

This report is entitled “**Future climate change impact, vulnerability and adaptation assessment for the case of Cyprus”** and constitutes the fourth Deliverable of Action 3 of the CYPADAPT project on the “Development of a national strategy for adaptation to climate change adverse impacts in Cyprus”.

For the elaboration of this report, the project scientific team made use of the results of the report “Projection of climate change in Cyprus with the use of selected regional climate models” (Deliverable 3.2) of the CYPADAPT project and elaborated a future Impact Vulnerability and Adaptation (IVA) assessment for all of the 11 selected policy areas (Figure 1-1), based on the same methodology followed for the current IVA assessment carried out in the report “Climate change impact, vulnerability and adaptation assessment for the case of Cyprus” of the project (Deliverable 1.2). One sub-report has been elaborated for each of the selected policy areas (11 sub-reports in total).

In specific, the climate change vulnerabilities identified through the current IVA are re-assessed in view of the projected future climate changes as well as of other relative socio-economic projections for the period 2021-2050. Thus, by taking into consideration (i) the current vulnerability assessment, (ii) the magnitude of the projected future changes in the climatic parameters considered to affect each impact and (iii) other socio-economic projections relative to the impact, the future vulnerability to climate changes in Cyprus is assessed.

The selection of the policy areas that have been taken into consideration in the IVA assessment where based on the categorization of policy areas for integrating adaptation, as these were identified in the European Commission’s White Paper entitled “Adapting to climate change: Towards a European framework for action”. These policy areas where further categorized according to the specific characteristics of Cyprus, as illustrated in the following figure.

Figure 1-1: Selected policy areas in Cyprus for the IVA assessment

The methodology followed for the future IVA assessment in each of the 11 selected policy areas is structured upon 3 basic steps:

- **Step 1:** Recording of the baseline situation. During the step, several characteristics of the policy area under examination that are considered relevant for the IVA assessment are recorded, such as the resources available, demand, environmental condition, pressures, importance of each sector for the country, strategy plans and management measures etc. In addition, several socio-economic projections and future trends were also recorded.

- **Step 2:** Future impact assessment. In this step, a literature review is being made on the observed and expected impacts of climate changes worldwide and especially to the wider area where Cyprus is located. The impacts for the case of Cyprus are identified and relevant data are presented where available, such as the future changes in climate that are considered to affect the impacts under examination. Following, the trends of the observed impacts and the likelihood of the expected impacts are evaluated. It must be mentioned that although the methodology followed was the same with the one adopted in Deliverable 1.2, some of the impacts identified in this report have been further specified and categorized into other sub-impacts in order to better reflect the risks anticipated by climate changes.

- **Step 3:** Future vulnerability assessment. In this step, the future vulnerability of each of the identified impacts is assessed in terms of sensitivity, exposure and adaptive capacity of the sector to climate changes, based on the available quantitative and qualitative data for Cyprus. In particular, sensitivity is defined as the degree to which a system is affected by climate changes, exposure is the degree to which a system will be exposed to climate changes and their impacts, while the adaptive capacity is defined by the ability of a system to adapt to changing environmental conditions. Adaptive capacity is also enhanced by the relative existing and planned adaptation measures, according to their effectiveness.

For the assessment of sensitivity, exposure and adaptive capacity of each impact, a number of qualitative and quantitative vulnerability indicators were used. The regional climate models (RCM) used for the projection of future climate changes, were also used for the assessment of future vulnerability. In specific, the RCMs were used in order to calculate and plot certain vulnerability indicators which are associated with various climatic parameters. The assessment of overall vulnerability was based on the following qualitative equation:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity * Exposure$$

The general concept of the methodology followed was adopted by the "Impacts, Adaptation and Vulnerability" Assessment Reports of the Intergornmental Panel on Climate Change, while the assessment was further elaborated by the CYPADAPT team in order to prioritize the impacts of all sectors and identify the key vulnerabilities for Cyprus. For this to be achieved, sensitivity, exposure and adaptive capacity were evaluated with the use of a qualitative 7-degree scale ranging from "none" to "very high". The key vulnerabilities have been identified as those impacts gathering an overall vulnerability score ranging from "moderate" to "very high".

Overall, 56 future climate change impacts have been identified in the selected policy areas of Cyprus, from which 15 have been evaluated as key priorities for future adaptation action. In Table 1-1, the identified future climate change impacts in Cyprus as well as the future key vulnerability are presented, while in Annex I, the scores of sensitivity, exposure, adaptive capacity and vulnerability for each impact are presented.

Table 1-1: Future climate change impacts and prioritization of key vulnerabilities for the case of Cyprus

Sector	Future climate change impacts	Key vulnerabilities	Prioritization
Water resources	Water availability for domestic water supply in mountain areas	☆	(1)
	Water availability for domestic water supply in urban areas		
	Water availability for irrigation in mountain areas	☆	(1)
	Water availability for irrigation in plain & coastal areas	☆	(3)
	Water quality of surface water bodies		

Sector	Future climate change impacts	Key vulnerabilities	Prioritization
	Water quality of groundwater bodies	☆	(3)
	Droughts	☆	(3)
	Floods in urban areas		
	Floods in mountain areas		
Agriculture	Crop yield alterations	☆	(4)
	Soil fertility alterations		
	Increase in pests and diseases*		
	Damages to crops from extreme weather events	☆	(6)
	Alterations in livestock productivity*		
	Increase in costs for livestock catering *		
Forests	Dieback of tree species, insect attacks and diseases	☆	(3)
	Fires	☆	(3)
	Forest growth*		
	Floods		
Fisheries and aquaculture	Quantity and diversity of fishstocks		
	Fishstock physical environment		
	Costs implications for fishermen		
Coastal zones	Coastal erosion		
	Coastal storm flooding and inundation		
	Degradation of coastal ecosystems *		
Biodiversity	Distribution of plant species in terrestrial ecosystems	☆	(5)
	Distribution of animal species in terrestrial ecosystems	☆	(5)
	Freshwater biodiversity		
	Marine biodiversity		
Soils	Soil erosion (by wind and/or rain water)	☆	(6)
	Soil salinization – Sodification		
	Soil contamination		
	Desertification	☆	(1)
	Landslides		
Energy	Energy demand		
	Renewable energy yield		
	Efficiency of thermal power stations		

Sector	Future climate change impacts	Key vulnerabilities	Prioritization
Infrastructure	Damages to infrastructure due to urban floods		
	Damages to infrastructure due to sea floods		
	Damages to infrastructure due to landslides		
Tourism	Warmer summers		
	Warmer winters		
	Coastal erosion		
	Water availability for drinking water supply		
	Water availability for irrigation and other uses	☆	(2)
	Heat waves		
	Biodiversity attractions		
	Storms, waves and floods		
Public health	Deaths and health problems related to heat waves and high temperatures	☆	(6)
	Vector and rodent-borne diseases		
	Water- and food-borne diseases		
	Deaths, injuries and diseases from floods/storms		
	Air pollution-related diseases		
	Fire- related deaths and injuries		
	Climate-related effects upon nutrition		
	Landslide-related deaths and injuries		

* In absence of sufficient data for the evaluation of sensitivity and/or exposure, the overall vulnerability of this impact was not evaluated

However, it must be noted that, there were no sufficient scientific evidence and data to evaluate or correlate all impacts and indicators to climate changes. For that reason, a preliminary assessment of future vulnerability of Cyprus was made while where knowledge and research gaps were identified, suggestions were made for further research.

2 WATER RESOURCES

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Abbreviations and Acronyms

AR4	Fourth Assessment Report
DISMED	Desertification Information System to Support National Action Programmes in the Mediterranean
DMP	Drought Management Plan
EC	European Commission
EEA	European Environment Agency
ESA	Environmentally Sensitive Areas
FAO	Food and Agriculture Organization
FVI	Flow Variability Index
GSD	Geological Survey Department
GWW	Government Water Works
ICOLD	International Commission of Large Dams
IPCC	Intergovernmental Panel on Climate Change
JRC	Joint Research Centre
MANRE	Ministry of Agriculture, Natural Resources and Environment, Republic of Cyprus
MCA	Multi-Criteria Analysis
MSC	Meteorological Service of Cyprus
PRECIS	Providing Regional Climates for Impact Studies
RR	Precipitation
SDI	Sensitivity to Desertification Index
SPI	Standardized Precipitation Index
SUDS	Sustainable Urban Drainage Systems
SWV	Surface Water Vulnerability
TX	Maximum Temperature
VNZ	Vulnerable Nitrate Zones
WAI	Water Availability Index
WDD	Water Development Department
WEI	Water Exploitation Index
WFD	Water Framework Directive
WSI	Water Stress Index

2.1 Climate change and water resources

Climate changes such as increases in temperature, sea level and precipitation variability affect freshwater systems and their management (Kundzewicz et al., 2007) with a potential of high vulnerability not only for water resources but also to human societies and ecosystems as a consequence (Bates et al., 2008).

Water resources are closely interrelated with climate as the water cycle strongly depends on climate factors. The water cycle takes place through the physical processes of evaporation, condensation, precipitation, infiltration, runoff, and subsurface flow. Evaporation is strongly dependant on climatic factors such as temperature, radiation, vapor pressure and wind. In addition, climate affects soil moisture and consequently infiltration of water to groundwater bodies. Extreme climatic events such as heavy rainfall and flooding hamper water storage, resulting in significant water losses. Finally, water quality is also affected by climate factors such as temperature, droughts and sea level rise. Increased temperatures and decreased precipitation lead to increased evapotranspiration, condensation and eutrophication. Sea level rise threatens coastal groundwater bodies with salinization.

The water resources of Cyprus are considered vulnerable to climate changes, since they are limited due to the semi-arid climate that characterizes the island. Freshwater availability depends almost entirely on rainfall which is highly variable with frequent prolonged periods of drought.

In specific, the impact, vulnerability and adaptation assessment for the sector of water resources regarding climate changes that have occurred the recent years in Cyprus (CYPADAPT, 2012), showed that water availability for irrigation constitutes a key vulnerability of the sector to climate changes since the available water for irrigation is limited while water demand for agriculture is large in spite of the various measures implemented by the government and cannot be met most of the times. Droughts present an equally important vulnerability for the water sector, since droughts are a common phenomenon in Cyprus with detrimental effects for water availability in the island, while the measures that have been undertaken so far manage only to alleviate the problem but not to eliminate the adverse consequences. Groundwater quality is the next vulnerability priority for water resources since the majority of groundwater bodies are already in a bad qualitative situation mainly due to sea water intrusion caused by overdrilling while their replenishment ability is very slow. Water availability for domestic water supply is also substantially affected by climate changes since freshwater resources most of the times are not sufficient for satisfying drinking water demand. The Government of Cyprus has undertaken a series of drastic measures for the increase in water supply, such as the commissioning of desalination plants, thus relieving the island from such a pressure.

In the sections that follow, an attempt is being made to assess the impacts of future climate changes in Cyprus on the water sector based on the climate projections output produced by the PRECIS (Providing Regional Climates for Impact Studies) regional climate model as well as on other socio-economic projections for the period 2021-2050. The reason why PRECIS was selected to be used in the present study is that, unlike in other regional climate models, in PRECIS Cyprus lies at the center of the domain of the study. The future period 2021-2050 has been chosen, instead of the end of the twenty-first century as frequently used in other climate impact studies, in order to assist stakeholders and policy makers to develop near future plans.

2.2 Future baseline

Water cycle climatology is essential in water resources management and planning especially in view of climate changes. The meteorological output of regional climate models can be used as input in hydrological models to simulate the effects of climate change on hydrological regimes at various scales. More specific, hydrologic models simulate water balance through the transformation process of precipitation into evapotranspiration, runoff, streamflow and aquifer recharge. However, a large amount of hydroclimatic and topographic data are needed for model calibration (Xu et al., 2005).

In the context of this report, it is attempted to provide a rough estimation of the future water balance in Cyprus in light of future climate changes, as these were calculated with the use of the PRECIS regional climate model, while a detailed work is suggested to be carried out entailing the use of a specifically developed hydrologic model for the simulation of future climate change impacts on the water availability in Cyprus.

2.2.1 Hydrology

The main natural source of water in Cyprus is rainfall. According to a long series of observations, the mean annual precipitation for the period 1960-1990 was estimated at 503 mm. The rainfall is unevenly distributed geographically with the highest in the two mountain ranges and the lowest in the eastern lowlands and coastal areas.

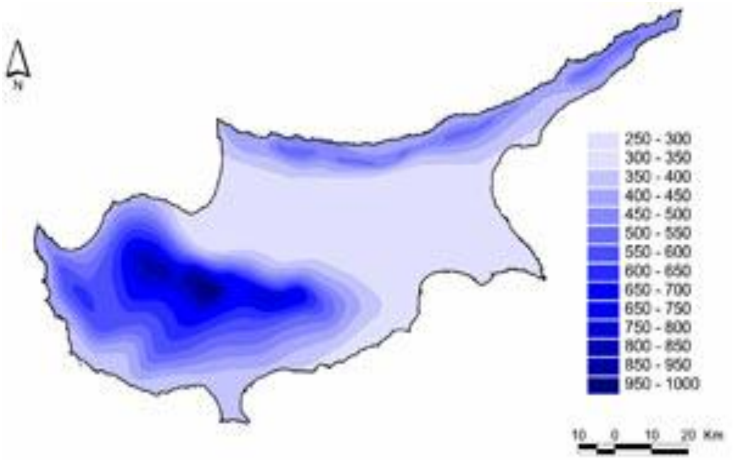

Figure 2-1: Spatial distribution of rainfall in Cyprus

Source: WDD (1)

According to the PRECIS model, all north coasts and especially Karpasia peninsula are expected to receive less annual total precipitation in the period 2021-2050 than that estimated for the recent past years 1961-1990. In all other parts of Cyprus, the annual total precipitation appears to have minor decreases or no changes at all with the exception of the area east from Paphos, which presents a minor increase in total annual precipitation (up to 5mm).

It is estimated that during the period 1971-2000, 86% of rainfall returned to the atmosphere as evapotranspiration (FAO, 2000). In general, evapotranspiration tends to decrease with reduced precipitation, but it increases with higher temperatures.

As the PRECIS model does not provide estimates for future evapotranspiration, the results of the KNMI model on future evapotranspiration in Cyprus are presented here, for indicative reasons only. The KNMI model predicts a general decrease in annual evapotranspiration ranging from -3% to -7% for the period 2021-2050 compared to the period 1970-2000. However, it must be highlighted here that the KNMI predicts higher decrease in precipitation and lower increase in temperature compared to the PRECIS model. This could indicate a smaller decrease in evapotranspiration or even an increase, based on the PRECIS model. For that reason, it is suggested to use a hydrological model to produce safer results of future evapotranspiration using PRECIS output as input to the model.

2.2.2 Water supply

The Republic of Cyprus in order to satisfy drinking water and irrigation demand has delivered a number of water works for the exploitation of the available freshwater resources, such as storage reservoirs. In addition, special emphasis was given to the exploitation of groundwater aquifers in which accumulated flows (> 1 year) are stored.

In spite of those measures the dependence of water availability to rainfall continues. The long and frequent drought periods have proven that the storage of rain water in dams does not ensure water sufficiency in the long term. For this reason, the exploitation of non freshwater resources (sea water, recycled water) has been promoted.

The Government Water Works (GWW) exploit water sources such as surface water and groundwater and distribute it together with the desalinated water and recycled water to its users (domestic sector, agriculture etc). Interconnection of reservoirs and conveyor systems allows distribution of water across the island and offer some flexibility in operation. Apart from the main GWW, the demand in drinking water is satisfied exclusively from the aquifers through drillings and springs.

According to the Water Development Department of MANRE (WDD, 2009a), during the period 2005-2007 only 45.9% of the total water consumption was provided by Government Water Works, while 49.9% was provided by non Government Water Works. The remaining 4.3% refers to recycled water. In particular, drinking water supply for the same period was provided by 86% from GWW and the remaining 14% by non GWW. On the contrary, irrigation water supply was provided by 73% from non GWW and the remaining 27% from GWW (mainly surface water). However, it is considered that since water supply from GWW has been augmented recently mainly due to the installation of new desalination plants, the contribution of GWW to the total water supply has also been increased.

The major water supplier among the GWW in Cyprus is the Southern Conveyor System which supplies approximately 76% of the total water supplied by GWW, followed by the Pafos WW which supplies 16% of the water and the Chrysochou WW which supplies 7% of the water while about 1% is supplied by other GWW (WDD, 2009a).

It is considered that the Southern Conveyor System in conjunction with the desalination plants of the area satisfy the drinking water demand of Nicosia, Limassol, Larnaca and the area of Famagusta which is under government control, as well as the irrigation water demand of 14,000 ha of agricultural land. In addition, the Vassilikos-Pentaschinos project was developed in order to supplement with irrigation water the agricultural development of the area and to augment the domestic water supply of Nicosia, Larnaka and Famagusta districts (WDD, 2011a– Annex VII).

The Pafos WW today in conjunction with the operation of the desalination plant at Kouklia is considered to fully satisfy the demand in drinking water of the greater area of Pafos, Pegeia and of some semi-mountain communities including the area of Pissouri. In addition, it satisfies the water demand of the Pafos irrigation area which, has been substantially reduced compared to the initial estimations (WDD, 2011a– Annex VII).

In addition, the Pitsilia Integrated Rural Development Project refers to a series of water works in the mountain and semi-mountain area of Troodos, which belong to the districts of Nicosia, Larnaca and Limassol. This project had as a goal to prevent the abandonment and desertification of rural areas due to internal migration (WDD, 2011a– Annex VII).

Notwithstanding the remarkable increase of water supply through GWW in the country, there are some areas mainly in the mountain regions which still experience water shortage during drought years since they are not connected to GWW or the GWW which are connected to, do not have access to desalination water which offers independency from rainfall. As dams in mountain areas are of limited capacity while the quality of water is suitable only for irrigation, the installation of water treatment plants in these areas is not economical. Thus, most of the mountain villages still rely on groundwater sources (springs, boreholes) leading to the depletion of aquifers.

Following, the freshwater and non-freshwater water resources in Cyprus are described in detail.

2.2.2.1 Surface water resources

A total of 108 dams and reservoirs have been constructed with a combined storage capacity of 332 Mm^3 (WDD, 2011a – Annex VII). By the standards of the International Commission of Large Dams (ICOLD), Cyprus is the first in Europe regarding the number of dams per square kilometer. The average annual inflow to the dams during the period 1971-2000 was approximately 130Mm^3. In order to estimate the inflow to the dams in the future, the relationship between precipitation and inflow for each of the dams was studied based on historical records. As every dam is characterized by different conditions (hydrological, topographic, etc), it was found that the inflow was affected by precipitation following a similar pattern for each dam. This pattern was depicted with the regression curves that best suited the relationship precipitation-inflow for each dam. Next, these relationships were used in order to predict future dam inflow based on the projected precipitation by PRECIS. The results showed a 23% decrease in the future total dam inflow (100m^3/y), although the average change in precipitation is -5%. However, it must be mentioned that this method does not take into account changes in evapotranspitation and runoff conditions in the future which could potentially further decrease inflow.

Table 2-1: Observed and future estimated precipitation and dam inflow in Cyprus for the periods 1970-2000 and 2021-2050 respectively

	Dam capacity		Precipitation (mm)			Dam inflow (Mm^3)		
Main dams	**Mm^3**	**Percent**	**1970-2000***	**2021-2050**	**Change**	**1970-2000***	**2021-2050**	**Change**
Kouris	115	41%	671	623	-7.1%	25.1	19.9	-20%
Asprokremmos	52	19%	604	611	1.1%	5.1	5.4	7%
Evretou	24	9%	809	773	-4.5%	5.4	4.9	-10%
Kannaviou	18	6%	695	664	-4.5%	6.7	5.7	-14%
Kalavasos	17	6%	542	509	-6.1%	35.6	23.1	-35%
Dipotamos	16	6%	462	444	-4.0%	4.8	4.3	-11%
Yermasoyia	14	5%	608	565	-7.1%	12.5	9.0	-28%
Arminou	4	2%	745	702	-5.8%	13.5	11.4	-15%
Polemidia	3	1%	520	483	-7.1%	2.7	2.0	-26%
Mavrokolympos	2	1%	564	529	-6.2%	1.3	1.1	-17%
Lefkara	14	5%	536	517	-3.5%	0.7	0.6	-11%
Sum	**279**	**84%**		**Average**	**-4.7%**			
					Sum	**113**	**87**	
Total dam capacity	**332**	**100%**			**Total dam inflow adjusted to 100%**	**128**	**99**	
							Average	**-22.8%**

* The data referring to the period 1970-2000 were sourced from WDD, 2011a – Annex II

2.2.2.2 *Groundwater resources*

As also mentioned previously, to estimate groundwater resources in the future, it is recommended to make use of a specialized hydrological model. However, in the context of this report a rough estimation of future groundwater resources will be attempted, based on the water balance in Cyprus for the period 1970-2000 (FAO, 2000). The water balance was adjusted based on the future dam inflows while the ratio between surface water, groundwater and losses to the sea was maintained. The available groundwater resources in the future, according to this water balance, are estimated to be 85Mm^3/y on average. Again, it must be mentioned that this method does not account for future changes in runoff which could increase water losses and decrease water storage.

Table 2-2: Observed and estimated water balance in Cyprus for the periods 1971-2000 and 2021-2050 respectively

Surface water			Groundwater		
	1970-2000*	2021-2050		1970-2000*	2021-2050
Storage in dams	128	99	Available (springs minus overdrilling)	110	85
Diversion	15	12			
Losses	48	37	Losses	70	54
Total	**191**	**148**	**Total**	**180**	**140**

* The data referring to the period 1970-2000 were sourced from WDD website

2.2.2.3 *Desalinated water*

The desalination capacity in Cyprus has increased from 40,000 m^3/d in 1997 when the first desalination plant in Cyprus operated to 182,000 m^3/d in 2011 and reached a capacity of 252,000 m^3/d or 92 Mm^3 in 2012 (WDD, 2011a – Annex VII). The contribution of desalination plants to domestic water supply for 2010 which was a relatively wet year amounted to 65% which equals 55.5 Mm^3, while in the future period (2021-2050) when the estimated average water demand from the domestic sector is estimated to be approximately 86Mm^3/year (see Section 2.2.3), the desalination capacity will outreach domestic water demand by 7%, provided that desalination capacity will not further increase. However, as mentioned earlier, not all population in Cyprus has access to desalinated water and thus domestic water demand is not possible to be fully satisfied by desalinated water. Table 2-3 summarizes the desalination plants and their respective capacities for the years 1997, 2011 and 2012.

Table 2-3: Desalination plants in operation for the years 1997, 2011 and 2012

Desalination plant	Capacity (Mm^3/y)		
	1997	2011	2012

Desalination plant	Capacity (Mm^3/y)		
	1997	2011	2012
Dekelia	14.6	21.9	21.9
Larnaca	-	22.63	22.63
Lemesos	-	-	14.6
Pafos	-	-	14.6
Moni (mobile)	-	7.3	-
Pafos (mobile)	-	10.95	-
Vasiliko	-	-	18.25
Garilli (mobile)	-	3.65	-
Total	**14.6**	**66.4**	**92.0**

Source: WDD, 2011a

2.2.2.4 Recycled water

Recycled water is a resource which has been given increased attention in recent years. Providing recycled water through Government Water Works reached 12 Mm^3 in 2010, from which 9 Mm^3 was supplied for irrigation and about 3 Mm^3 for artificial aquifer recharge (WDD, 2011a – Annex VII).

As shown in Table 2-4, the capacity of the Waste Water Treatment Plants (WWTP) in 2012 amounted to 59 Mm^3/y and will reach up to 65 Mm^3/y over the medium term (2015) and 85 Mm^3/y for long-term (2025). Assuming that the WWTP capacity represents approximately 130% of the average actual wastewater treated on an annual basis as WWTPs usually work under full capacity, it is expected that the amount of recycled water which will be produced in 2025 (65Mm^3) is expected to satisfy 43% and 34% of today's and future agricultural demand, respectively.

Table 2-4: Planned capacity of Wastewater Treatment Plants for the years 2012, 2015, 2025

	WWTP capacity (Mm^3/year)		
	2012	**2015**	**2025**
Municipal wastewater treatment plants	46	51	69
Rural wastewater treatment plants	13	14	16
Total	**59**	**65**	**85**

2.2.3 Water demand

The total annual water consumption for 2011 was estimated to be 252 Mm^3. The two major water consumers are the agriculture sector (irrigation) and the domestic sector, with a consumption of 60% and 30%, respectively. Domestic sector includes water consumption for permanent population (26%) as well as for tourism purposes (4%) (WDD, 2011a - Annex VII).

It must be mentioned that water demand exceeds the amount of available freshwater resources. For instance, the total demand for irrigation in agriculture is rarely met. After 1996, the demand in agriculture was fully met only during the hydrological year of 2004, when all dams had overflowed.

In order to examine the water balance in the future, apart from the future water supply it is necessary to estimate future water demand. In the following paragraphs an attempt is being made to estimate future water demand per water user (permanent population, agriculture, tourism, industry etc) based on several socio-economic projections.

Based on consumption data provided by the Water Supply Councils, the Central Water Supply System of the Water Development Department as well as the study of FAO, 2002, the daily water consumption per capita was estimated at 215 l/c/d. It is assumed that the daily demand per capita will not increase in the future, based on the fact that the increase in environmental awareness especially on the limited availability of water as well as the replacement of water networks for the minimization of losses will counteract any future increase in the per capita water consumption (WDD, 2011a - Annex VII).

Based on the A1B GHG emissions scenario of the IPCC which foresees that global population will peak in mid-century and decline thereafter, as well as the annual growth rate foreseen in *UN, 2010*, the average population in Cyprus during the period 2021-2050 is estimated to be 943,471. Considering the average daily amount of water consumption per capita, the average total domestic water demand from the permanent population of Cyprus during the period 2021-2050 is expected to reach 74 Mm^3, implying an increase of about 16% compared to 2011 (63.8 Mm^3).

As for the water demand in agriculture, there is no study on the projection of future crop trends, such as with population trends for example. Based on the aggregated macroeconomic and sectoral projections to 2030 for the EU Member States of the European Commission's Directorate-General for Economic and Financial Affairs, the Member States' stability programmes and long- term projections, the results of the study performed by WEFA[1], and the results of the GEM-E3 model[2] (European Commission, 2003), the Gross Valued Added of the agricultural sector (including livestock, fisheries and forestry) will increase by 50% to 2030 compared to 2010. It is assumed that water consumption from the

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[1] WEFA (now integrated into DRI-WEFA) is an economic consultancy company which was subcontracted by NTUA to deliver a consistent macro-economic and sectoral forecast for the EU Member States.

[2] The GEM-E3 model has been constructed under the co-ordination of NTUA within collaborative projects supported by Research DG involving CES-KULeuven and ZEW

sector will increase as the Gross Valued Added increases but with an almost logarithmic rate as water use will be more efficient. In particular, according to the Department of Agriculture of the Ministry of Agriculture, Natural Resources and Environment of Cyprus, the current trend in agriculture is characterized by the replacement of the water intensive crops with other more drought resistant crops and the use of more effective irrigation methods. On the other hand, it is expected that climate changes such as the increase in temperature and the decrease in precipitation, will increase irrigation demand. In the framework of this study, the estimation of the report of FAO (Rossel, 2002) that future demand in irrigation water will not substantially change in the future, is adopted. Taking also into account the increase in the Gross Value Added of agriculture (50%) in 2030, it is assumed that the average total water demand from agriculture in the period under examination (2021-2050) is expected to increase by 25% which in absolute numbers equals to 190Mm^3 in total. As far as water demand for livestock is concerned, it is expected that it will reach the amount of 11 Mm^3 (35% increase) on average during the period 2021-2050, considering a 50% increase in livestock capacity. It must be mentioned that, unlike crops, livestock's needs in water cannot be substantially reduced.

There are no data regarding the future trends of water consumption in industry. Based again on the report of the European Commission (2003), the Gross Value Added of the industry sector in Cyprus is expected to increase by 69% until 2030 compared to 2010. Water demand from the industry sector on the other hand is expected to increase as well, but with a substantially slower rate, provided that (i) not all industries are characterized by water-based production and that (ii) water use in industry will become more efficient in the future. Taking into account the above, it is assumed that water demand from the industrial sector will increase by 35% on average and will reach the amount of 11 Mm^3.

Table 2-5: Projection of Gross Value Added in Cyprus

Gross Value Added (000 M€05)	1990	2000	2010	2020	2030
Industry	0.9	1.1	1.3	1.7	2.2
Construction	0.9	0.8	1.1	1.6	2
Services	4.4	8.1	11	16.1	22.4
Agriculture	0.3	0.4	0.4	0.5	0.6
Energy	0.2	0.2	0.3	0.4	0.6
Total	**6.7**	**10.5**	**14**	**20.3**	**27.8**

Source: European Commission, 2003

According to the assessment of water demand in Cyprus carried out by WDD (WDD, 2011a - Annex VII), tourist overnights are expected to increase with an annual growth rate of 1.5%. Considering a daily water consumption per tourist of 350-727 l/c/d depending on the type of accommodation, it was estimated that water consumption in the tourism sector will amount to 12.3Mm^3 (27% increase) on average during the period 2021-2050. However, the estimation does not take into account a potential substantial increase in water demand from the tourist sector, due to an increase in the number of golf courses which require large amounts of water for irrigation.

In absence of relative data on the future water demand for landscape irrigation, it is assumed that the contribution of the category to the total water demand in the period 2021-2050 will remain the same with the 2011 estimations (i,e. 4%), thus reaching the amount of 12.5Mm^3 (25% increase).

The above assumptions for the future water demand per sector lead to an overall water demand of 311Mm^3 on average for the period 2021-2050, implying an increase of 23% compared to the 2011 estimations. The present and future water demand in Cyprus is depicted in detail in Table 2-6.

Table 2-6: Present and estimated future water demand per sector in Cyprus

Water users/uses	2011		2021-2050		Change
	Mm^3	Percent	Mm^3	Percent	
Permanent population	63.8	25%	74	24%	16%
Tourism	9.7	4%	12.3	4%	27%
Agriculture (crop irrigation)	152	60%	190	61%	25%
Agriculture (livestock breeding)	8.5	3%	11	4%	35%
Industry	8	3%	11	3%	35%
Landscape irrigation	10	4%	12.5	4%	25%
Total	**252**	**100%**	**311**	**100%**	**23%**

2.2.4 Water balance

For the period 2000-2010 the total average water demand was 250 Mm^3. However, the available surface and groundwater resources (217 Mm^3) could satisfy 87% of the total demand. This gap was covered by non-freshwater resources (desalination and recycled water)(WDD). As for the period 2021-2050, it is estimated that the average water demand will be 311Mm^3 while the water supply from freshwater resources will satisfy only 60% of the estimated future total demand. However, the existing and planned investments for the supply of non-freshwater resources (approx. 157Mm^3) are expected to fully satisfy future water demand, with a marginal surplus though. This prerequisites though that all water users will have access to non-freshwater resources, which is not the case for some mountain areas which depend solely on freshwater resources as they are not connected to GWW or the GWW which are connected to, do not have access to non-freshwater resources which offer independency from rainfall. As the quality of water from dams in mountain areas is suitable only for irrigation, due to the fact that the installation of water treatment plants in these areas is not economical, the only source of water for most of the mountain villages is groundwater (springs, boreholes).

Table 2-7: Water balance between average water supply and demand in the period 2021-2050

Water supply			Water demand		
Type	**Mm^3**	**%**	**User/use**	**Mm^3**	**%**
Surface water	99	31%	Permanent population	74	24%
Groundwater	85	26%	Tourism	12.3	4%
Desalinated water	92	29%	Agriculture (crop irrigation)	190	61%
Recycled water	65	13%	Agriculture (livestock breeding)	11	4%
			Industry	11	4%
			Landscape irrigation	12.5	4%
Total	**341**	**100%**	**Total**	**311**	**100%**

In addition, it is logical to assume that when reaching 2050, freshwater resources will be further reduced and water demand will further increase compared to the average estimation for the period 2021-2050, resulting in a higher marginal difference between water supply and demand, or even to a deficit.

However, it must be mentioned again that the projections in future freshwater supply and demand are rough estimations of the future and that, in general, long-term projections of this kind are characterized by high degree of uncertainty. For these reasons, it is imposed that a re-assessment of these projections must be made.

2.2.5 Summary of pressures on the water sector

The water sector currently experiences both quantitative and qualitative pressures from several environmental and socio-economic activities and practices.

The quantitative pressures are the result of the continuous increase in water demand for all uses and the deficits observed in the water balance. In addition, water resources are stressed due to excess groundwater abstractions. During the last decade, almost all the groundwater bodies are being overexploited, meaning that the amount of groundwater abstracted exceeded the sustainable limit. Furthermore, the consequences of greenhouse gas emissions from desalination plants deteriorate the position of Cyprus in terms of the total quantities of CO_2 emissions.

The qualitative stresses are mainly attributed to point pollution sources which, for the case of Cyprus can be summarized as follows:

- Municipal wastewater discharges
- The livestock waste in organized farms
- Industrial waste and waste from large technical installations
- The solid waste disposal sites
- The mining - quarrying to a lesser extent
- The aquaculture, brine discharge from desalination plants and ports to a lesser extent for the marine environment.

2.3 Future impact assessment

In this section, the climate change impacts on the water resources sector as these have been identified in Deliverable 1.2 “Climate change impact, vulnerability and adaptation assessment for the case of Cyprus” (CYPADAPT, 2012) will be reassessed in light of the climate projections for the future (2021-2050). The potential changes in climate and their respective impacts on water resources for the case of Cyprus are presented in Table 2-8.

Table 2-8 : Relationship between climate changes and impacts on the water sector

Potential climate changes	Impact
Increased temperature	- Increased water temperatures - Increase in evaporation
Increased evapotranspiration	- Water availability reduction - Lower replenishments rates (lower groundwater levels) - Salinisation of water resources
Decreased precipitation, including increased droughts	- Decrease in runoff - More widespread water stress - Increased water pollution and deterioration of water quality due to lower dissolution of sediments, nutrients, dissolved organic carbon, pathogens, pesticides and salt - Decreased rates of groundwater recharge - Salinisation of coastal aquifers due to overpumping motivated by insufficient water supply
Increase in interannual precipitation variability	- Increase in the difficulty of flood control and reservoir utilization during the flooding season
Increase in heavy precipitation events	- Flooding - Adverse effects in quality of surface water and groundwater - Contamination of water supply - Lower replenishment rates in the aquifers of the mountain areas due to steep slopes
Increase in surface water temperature	- Increased algae growth and reduced dissolved oxygen levels in water bodies which may lead to eutrophication and loss of fish - Prolonged lake stratification with decreases in surface layer nutrient concentration and prolonged depletion of oxygen in deeper layers - Changes in mixing patterns and self purification capacity - Salinisation of water resources
Sea level rise	- Salinisation of coastal aquifers (minor effect)

The future impacts of climate change on water resources are further analyzed in the following sections of this chapter. The impacts are presented according to their initial categorization in the current impact assessment, namely:

(i) decrease in water availability,

(ii) deterioration of water quality,

(iii) increase in flood frequency and intensity, and

(iv) increase in drought frequency and severity.

2.3.1 Decrease in water availability

Climate changes such as changes in temperature, precipitation patterns and snowmelt is projected to lead to major changes in yearly and seasonal water availability across Europe. More specifically, southern and south-eastern regions, which already suffer most from water stress, will be particularly exposed to reductions in water resources. Decreased summer precipitation results to a reduction of water stored in reservoirs fed with seasonal rivers. There is very high confidence that many of the areas located in the Mediterranean basin will suffer a decrease in surface and groundwater resources due to climate change (Kundzewicz et al., 2007).

According to PRECIS projections for the future period 2021-2050, the average annual temperature in Cyprus is expected to increase by 1 - 2°C with respect to the control period 1960-1990. As for the projections in annual precipitation according to the PRECIS model, minor changes or no changes at all are expected over the period 2021-2050. However, seasonal changes in precipitation may be discerned, with total winter and autumn precipitation presenting a decrease of 10-20mm per year and a minor increase in summer precipitation reaching 5 mm on average. Considering that the effect from future changes in precipitation is expected to be limited, increased temperatures are considered to play a more significant role in potential future changes in water availability.

The climate changes are anticipated to have also an effect on evapotranspiration as well as on soil moisture, infiltration and runoff, together with the increase in water demand will in turn have a significant effect on water availability.

Surface water resources

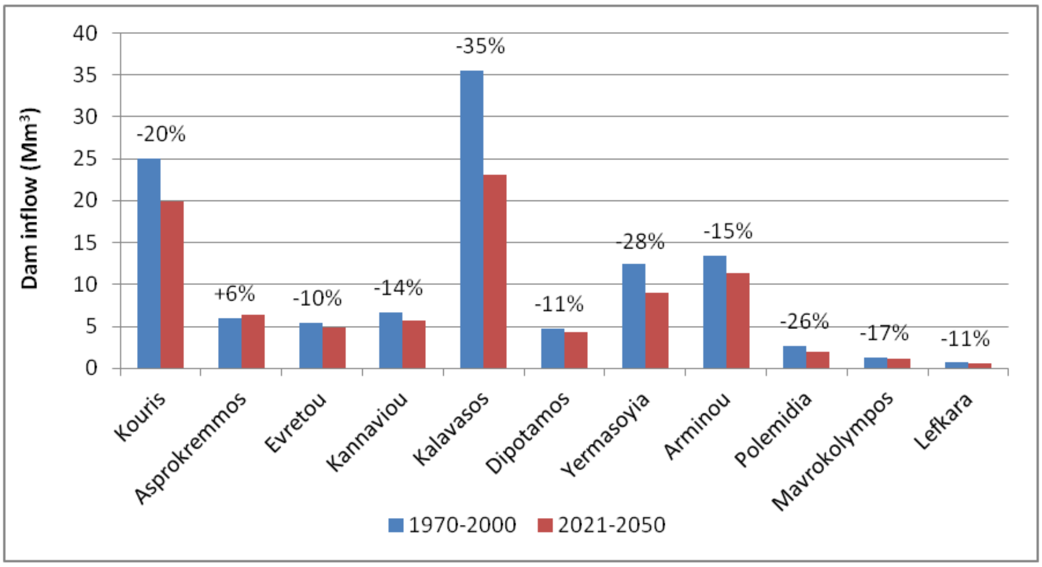
Changes in river flows due to climate change depend primarily on changes in the volume and timing of precipitation, as well as on changes in evapotranspiration (Milly et al., 2005). However, an increase in extreme high river flows is also projected for large parts of Europe due to the increase in heavy rain events, even in regions that will become drier on average. Climate change is projected to result in strong changes in the seasonality of river flows across Europe with decreasing summer flows in most of Europe (EEA/JRC/WHO, 2008).

As mentioned above, the changes in evapotranspiration and in the heavy rain events are expected to have an additional impact on river flows.

However, the PRECIS model does not provide estimates for future evapotranspiration. For indicative reasons only, the results of the KNMI model on future evapotranspiration in Cyprus are presented here. The KNMI model predicts a general decrease in annual evapotranspiration ranging from -3% to -7% for the period 2021-2050 compared to the period 1970-2000. However, it must be highlighted here that the KNMI predicts higher decrease in precipitation and lower increase in temperature compared to the PRECIS model. This could indicate a smaller decrease in evapotranspiration or even an increase, based on the PRECIS model. For that reason, it is suggested to use a hydrological model to produce safer results of future evapotranspiration using PRECIS output as input to the model.

The indicator related to heavy rain events which was provided by PRECIS refers to the annual maximum total precipitation over one day, shows minor increases in heavy rain events in the future period (2021-2050) ranging from 2 to 5 mm.

In Cyprus, the mean quantity of dam inflow during the period 1971-2000 reduced by 40% compared to the design estimates of the period 1917-1970 while the mean precipitation reduction was around 13% (Rossel, 2002). The respective change in dam inflow in the period 2021-2050 compared to the period 1970-2000 is expected to be -23% while the mean change in precipitation is estimated according to PRECIS at -5%. In Figure 2-2 the change in the inflow to the main dams of Cyprus for the period 1970-2050 is presented.



* 1970-2000: Actual dam inflow (WDD, 2011a), 2021-2050: Projection

Figure 2-2: Change in inflow to the main dams of Cyprus for the period 1970-2050

Groundwater resources

The reduction in precipitation and the increase in evaporative demand will also lead to a reduction in groundwater levels. Also a change in the amount of effective rainfall and in the duration of the recharge season will alter recharge rates (Kundzewicz et al., 2007). In addition, high intensity precipitation favors runoff against groundwater recharge.

From the monitoring of the 19 groundwater bodies of Cyprus during the period 2000-2008, it was observed that the level of 10 groundwater bodies had a downward trend and only 3 groundwater bodies had an upward trend while the rest groundwater bodies had a fluctuating trend (WDD, 2011a – Annex VII).

The available groundwater resources in the future, according to the water balance presented in Section 2.2.2.2, are estimated to be reduced by 23% on average. Again, it must be mentioned that this method does not account for future changes in runoff which could increase runoff and water losses and decrease water storage.

Regarding future changes in high intensity precipitation, as also mentioned earlier, minor increases ranging from 2 to 5 mm in the annual maximum total precipitation over one day are expected in the future period (2021-2050) according to PRECIS.

2.3.2 Deterioration of water quality

According to the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC), it is believed with high confidence that higher water temperatures, increased precipitation intensity, and longer periods of low flows exacerbate many forms of water pollution. However, there is no evidence for climate related trend in water quality (Parry et al., 2007).

Surface water bodies in Cyprus are mainly the storage reservoirs with no inflows during the summer months. As a result there is no dilution and combined with high evapotranspiration rates their quality is bound to be deteriorated. In addition increasing temperatures will result to increased eutrophication rates, stratification and low levels of dissolved oxygen. Furthermore, the low recharge rate of aquifers in combination with the low permeability of some sedimentary aquifers in Cyprus, results in the dissolution of soluble salts and the increase in salinity (WDD, 2008).

However, it must be mentioned that a trend in water quality deterioration is mainly observed in groundwater resources. The rapid urbanization in various parts of Cyprus during the last 30 years as well as the discharge of wastewater, gradually deteriorated the quality of Cyprus' groundwater. Nitrate pollution problems appeared in the aquifers of major residential areas due to the disposal of wastewater in septic tanks and absorbent cesspools. Intensive cultivation and excessive use of fertilizers contributed to the pollution of groundwater with nitrates. Also, increased salinity has been observed in the coastal aquifers, caused by human activity due to over-pumping (WDD, 2008). The deterioration of groundwater quality worsens by climate factors which lead to a low recharge rate, as the latter leads to the increase of pollutants concentration in groundwater.

Next, the future climate changes that are considered to be associated with the impact of water quality deterioration are presented in brief.

The most relative indicator which PRECIS provides regarding precipitation intensity refers to the annual maximum total precipitation over one day. The PRECIS results show minor increases in the precipitation intensity in the future period (2021-2050) ranging from 2 to 5 mm on average.

As for changes in water temperature, these are related to the changes in air temperature. According to PRECIS projections for the future period 2021-2050, the average annual temperature in Cyprus is expected to increase by 1 - 2°C with respect to the control period 1960-1990.

As far as the periods of low flows or dry spells in the future (2021-2050), it is projected that there will be a range of changes from slight decreases to an increase of up to 12 days/year on average.

The abovementioned changes in climate as these were projected by the PRECIS model for the future period 2021-2050 are anticipated to intensify the impact of water quality deterioration. However, in absence of a correlation indicator connecting climate factors with water quality, no assessment of the impact can be done.

In order to extract safer conclusions regarding the impact of future climate changes on water quality, the following are considered necessary:

- Data availability from a long monitoring period
- Correlation of water quality with climatic conditions and clear distinction of the effect from human activities

2.3.3 Increase in flood frequency and intensity

Despite the considerable rise in the number of reported major flood events and economic losses caused by floods in Europe over recent decades, no significant general climate related trend in extreme high river flows that induce floods has yet been detected. Although there is yet no proof that the extreme flood events of recent years are a direct consequence of climate change, they may provide an indication of what can be expected: the frequency and intensity of floods in large parts of Europe is projected to increase (Lehner *et al.*, 2006; Dankers and Feyen, 2008). In particular, flash and urban floods, triggered by local intense precipitation events, are likely to be more frequent throughout Europe (Christensen and Christensen, 2007; Kundzewicz *et al.*, 2006). Flood hazard will also probably increase during wetter and warmer winters, with more frequent rain and less frequent snow (Palmer and Räisänen, 2002)(EEA/JRC/WHO, 2008).

Cyprus in spite of the fact that is characterized by long and frequent dry periods, also suffers from flooding events. From Figure 2-3, it can be seen that the frequency of flooding events has increased considerably during the period 2000-2010 in comparison with the period 1970-2000, as 61% of the total flooding events refer to that period.

According to the IPCC, increases in the intensity of precipitation, may result in more frequent and hazardous flooding events. Pluviometrical data from the meteorological station in Nicosia (1930-2007) show an increase in the intensity and quantity of precipitation of 37-49% for the period 1970-2007 in comparison with the period 1930-1970 for a duration of precipitation between 5 minutes and 6 hours (Pashiardis, 2009). Historical records of the Water Development Department (WDD) on flooding events for the period 1859-2011 (WDD, 2011b – Annex III), show an increase in the flooding events in Cyprus for the same period, as 71 flooding events (mostly flash floods) were recorded during the period 1930-1970, while in the period 1971-2010 recorded flooding events have tripled (207 flooding events). However, it must be mentioned that the data recorded during the period 1930-1970 are not considered exhaustive, as the recording mechanisms at that time were inadequate. Furthermore, this increase is attributed mainly to a number of other factors such as urbanization (increase of the built-up urea) and changes in land uses without taking the appropriate measures (river bed protection zones, flood protection works), and secondarily to climate changes.

The number of flooding events in Cyprus during the period 1971-2010 as well as their hazard ranking (very low, low, moderate, high) in terms of adverse consequences for human health, the environment, cultural heritage and economic activity are presented in the following figure.

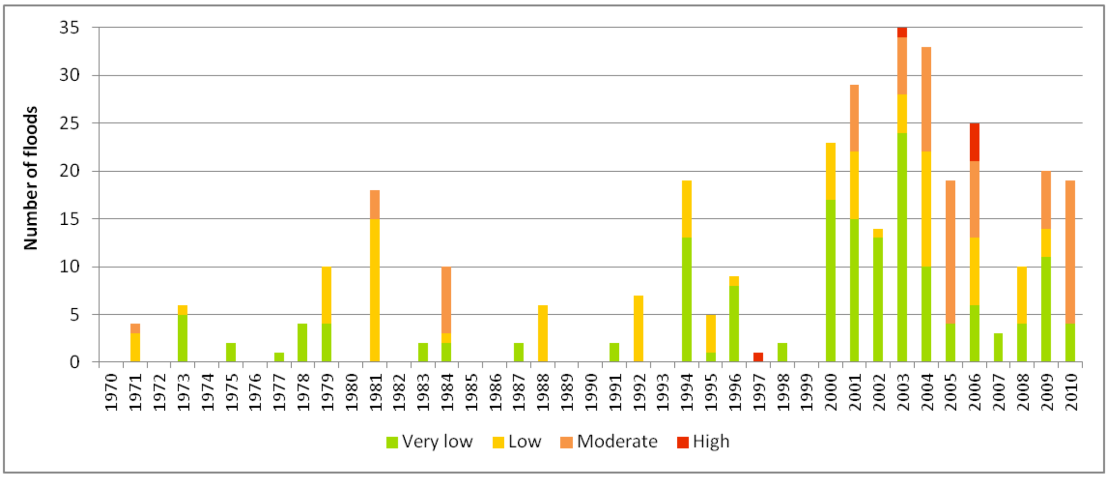


Figure 2-3: Number of flooding events per year in Cyprus (1971-2010) (CYPADAPT)

Source: WDD, 2011d

As for the future climate changes associated with the impact of floods, the most relative indicator which PRECIS provides refers to the annual maximum total precipitation over one day. The PRECIS results show minor increases in the precipitation intensity in the future period (2021-2050) ranging from 2 to 5 mm on average. Although a minor change, it is expected that it will further intensify the phenomenon.

2.3.4 Increase in drought frequency and severity

Droughts affect water availability and water quality. Southern and south-eastern regions in Europe show significant increases in drought frequencies (Kundzewicz et al., 2007). During 2000-2009, Europe has been affected repeatedly by drought. In 2008, Cyprus suffered a fourth consecutive year of low rainfall and the drought situation reached a critical level in the summer of that year (EEA, 2010).

Another study of the EC (2007) shows that Cyprus registered among the highest frequencies of droughts in Europe in the period 1976 to 2006, with a large part of its territory being affected whenever droughts occurred (Figure 2-4).

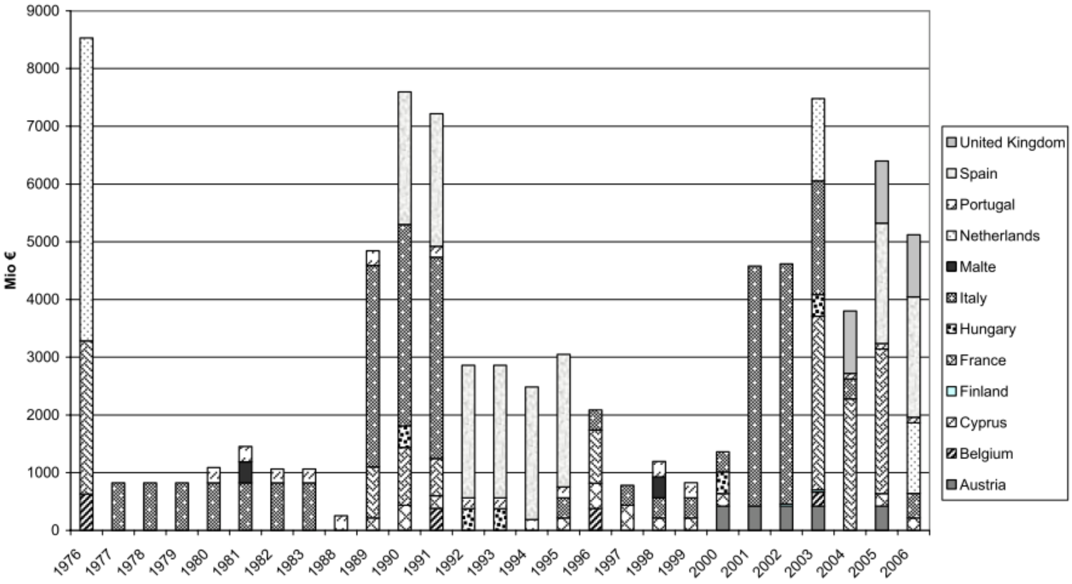
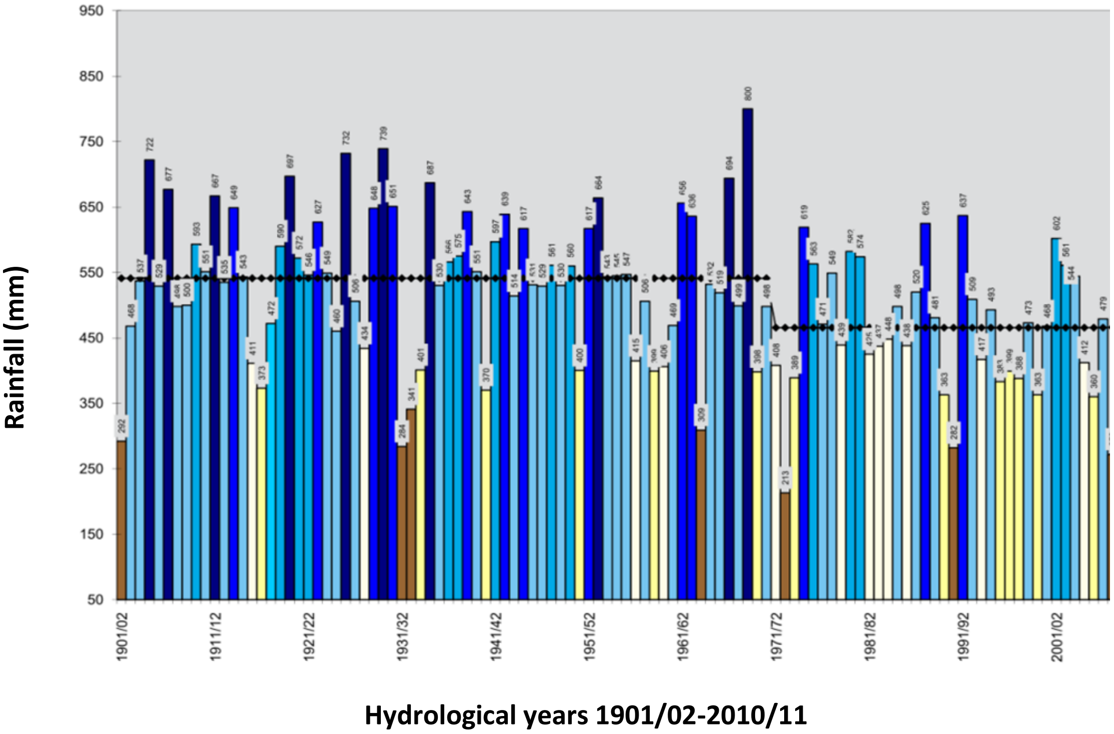


Figure 2-4: Drought impact per year and Member State (1976 – 2006)

Source: EC, 2007

In Cyprus, droughts may last one or several years. The Meteorological Service of Cyprus categorized the hydrological years based on the normal precipitation of the period 1961-90 (503mm). From Figure 2-5, it can be seen that the years with precipitation above normal appear to decline or even to extinguish the last decade as the last "extreme wet" year was observed in 1968-69, the last "wet" year in 1991-92 and the last "above normal" year in 2002-03. On the other hand, many years with precipitation below normal were observed during the last decade with the year 2007-08 being characterized as a year of severe drought (<70% normal) and 2005-06 as a year of drought (71-80% normal).



🟦	*Extreme wet (>130% normal)*	⬜	*Below normal (81-90% normal)*
🟦	*Wet (121-130% normal)*	🟨	*Drought (71-80% normal)*
🟦	*Above normal (111-120% normal)*	🟫	*Severe drought (<70% normal)*
🟦	*Around normal (91-110% normal)*	◆	*Average*

Figure 2-5: Mean annual precipitation in Cyprus (area under Government control)

Source: WDD (5)

As for the future climate changes associated with the impact of droughts, the PRECIS results show that the length of the drought periods is projected to increase up to 12 days/year on average.

2.4 Future vulnerability assessment

In this section, the future vulnerability of water resources to climate change impacts is assessed in terms of their sensitivity, exposure and adaptive capacity, based on the available quantitative and qualitative data for Cyprus and the climate projections for the period 2021-2050. In particular, sensitivity is defined as the degree to which water resources will be affected by climate changes, exposure is the degree to which water resources will be exposed to climate changes and their impacts while the adaptive capacity is defined by the ability of water resources as a system to adapt to changing environmental conditions as well as by the effectiveness of the relative existing and planned adaptation measures.

For the assessment of future vulnerability, the same indicators used in the current vulnerability assessment (CYPADAPT, 2012) were used, provided that the necessary data were available. These indicators are summarized in Table 2-9.

Table 2-9: Indicators used for the vulnerability assessment of climate change impacts on the water resources of Cyprus

Vulnerability variable	Selected Indicators
Water availability	
Sensitivity	– Sensitivity of runoff to changes in rainfall – Dam inflow variability – Number of groundwater bodies overexploited – Number of groundwater bodies in bad quantitative status – Freshwater availability per capita – Water Exploitation Index – Water availability index – Number of years water demand exceeded amount of available freshwater resources
Exposure	– Number of dams presenting decreasing trend – Number of groundwater bodies in bad quantitative status
Adaptive capacity	– Increase water storage capacity – Inter-basin water transfer – Artificial aquifer recharge – Water import – Use of desalinated water – Use of treated water – Stormwater use – Replacement of networks – Improving water use efficiency in irrigation – Water allocation

Vulnerability variable	Selected Indicators
	– Control groundwater overexploitation – Use of water supply meters – Redistribution of irrigated land – Water pricing – Subsidies for drinking water savings – Awareness campaigns – Improving monitoring and forecast
Water quality	
Sensitivity	– Effect of climatic factors, such as temperature and rainfall, on the quality of water resources – Reduction of the rate of aquifer replenishment – Overexploitation of aquifers due to water scarcity
Exposure	– Changes in air temperature – Changes in annual precipitation – Changes in the length of drought periods – Changes in heavy precipitation events – Changes in sea level – Percent of river water bodies in bad ecological and chemical status – Percent of lake water bodies in bad ecological and chemical status – Percent of coastal water bodies in bad ecological and chemical status – Number of surface water areas identified as sensitive according to the Directive 91/271/EEC – Surface Water Vulnerability (SWV) Index – Number of groundwater bodies with excess pollutant concentrations – Number of groundwater bodies declared as Vulnerable Nitrate Zones (VNZ), according to the Directive 91/676/EEC – Number of groundwater bodies salinized – Number of groundwater bodies in bad qualitative status
Adaptive capacity	– Designation of protected areas – Protection from point source discharges likely to cause pollution to water – Action Programme to prevent or reduce water pollution from nitrates – Protection from point source discharges likely to cause pollution to water – Protection of groundwater bodies from salinization – Expansion of existing sewage treatment plants
Floods	
Sensitivity	– Percent of very high and high hazard flooding events taking place in Cyprus

Vulnerability variable	Selected Indicators
Exposure	– Changes in heavy precipitation events – Areas with potential significant flood risk in Cyprus
Adaptive capacity	– Development of a separate drainage system for the collection of stormwater – Implementation of Sustainable Urban Drainage Systems – Identification of flood risk areas – Preparation of Flood Risk Management Plans
Droughts	
Sensitivity	– Sensitivity to Desertification Index – Percent of areas characterized as semi arid with an increased sensitivity – Percent of areas immediately threatened
Exposure	– Number of consecutive years of drought – Amount of deficit during drought periods – Frequency of drought periods – Standardized Precipitation Index (SPI)
Adaptive capacity	– Elaboration and implementation of a Drought Management Plan

*There were no data regarding this indicator

The relationship between sensitivity, exposure and adaptive capacity is based on the following qualitative equation:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity * Exposure$$

Sensitivity, exposure and adaptive capacity are evaluated on a 7-degree qualitative scale ranging from “none” to “very high”.

In the sections that follow, the vulnerability is assessed for each of the impact categories presented in Section 2.3:

1. Water availability
2. Water quality
3. Floods
4. Droughts

In must be noted that, further research is required in order to correlate the status of water resources with climate change impacts and indicators and to provide concrete information for a more detailed assessment of the vulnerability of the sector. Nevertheless, an attempt was made to provide a preliminary assessment of future vulnerability.

2.4.1 Water availability

2.4.1.1 Assessment of sensitivity and exposure

Sensitivity and exposure of water availability to future climate changes in Cyprus is assessed by the sensitivity of runoff to changes in rainfall which results in increased flow variability and by the degree of exposure to limited water supply. Additional exposure to pressures, imposed on freshwater resources by non climatic factors, such as water demand and groundwater overexploitation also increase the vulnerability of the sector. In the following sections, the indicators used for the evaluation of sensitivity and exposure are presented.

Sensitivity of runoff to changes in rainfall

River flows in arid and semi-arid regions like Cyprus are highly sensitive to changes in rainfall. A given percentage change in rainfall can produce a considerably larger percentage change in runoff. As shown in Figure 2-6, the total surface runoff in Cyprus during the hydrological years 1987/88-2010/11 decreased at a higher rate than the reduction in precipitation, which is best represented with a logarithmic trendline.

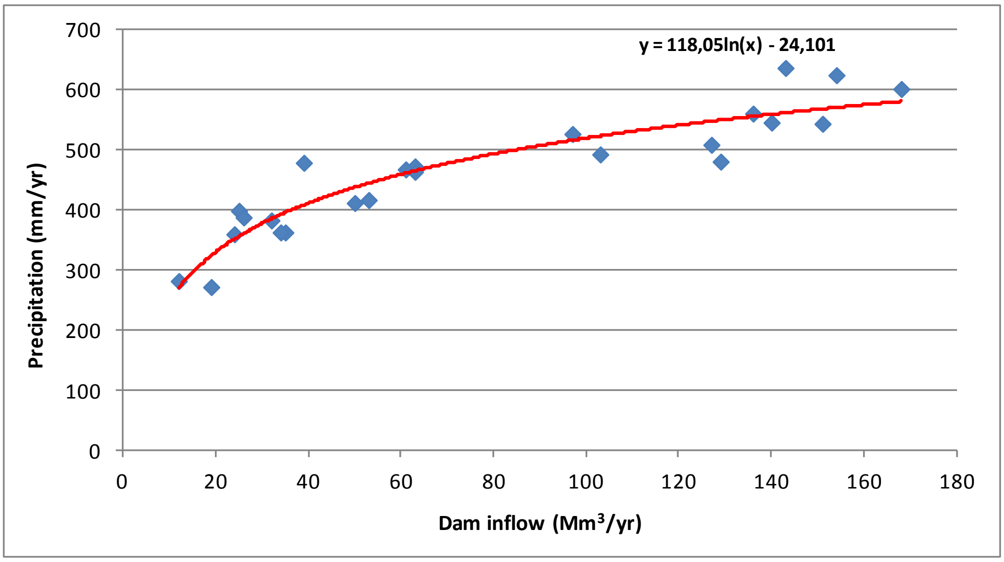


Figure 2-6: Relationship of rainfall and dam inflow in Cyprus (1987/88-2010/11) (CYPADAPT)

During the period 1971-2000 the total quantity of water impounded in the 15 main reservoirs of Cyprus, as well as, runoff reduced by 40% compared with the design estimations for the period 1917-1970 with a respective mean precipitation reduction around 13% (Rossel, 2002). The relationship rainfall-inflow for each dam was also used in order to estimate future changes in dam inflow for the period 2021-2050, based on the future precipitation data provided by PRECIS. The results showed a 23% decrease in the future total dam inflow compared to the period 1970-2000, although the average change in precipitation is -5%. However, it must be mentioned that this method does not take into account changes evapotranspiration and runoff conditions in the future which could potentially further decrease inflow. In Table 2-10 the change in rainfall and inflow to the catchment area of the main dams of Cyprus for the period (1970-2000)-(2021-2050) is presented.

Table 2-10: Change in rainfall and inflow to the catchment area of the main dams of Cyprus (1970-2050) (CYPADAPT)

Dam catchment area	Change (%)(1970-2000)-(2021-2050)	
	Dam inflow	Rainfall
Mavrokolympos	-17%	-6.2%
Lefkara	-11%	-3.5%
Evretou	-10%	-4.5%
Kannaviou	-14%	-4.5%
Asprokremmos	6%	1.1%
Arminou	-15%	-5.8%
Kouris	-20%	-7.1%
Polemidhia	-26%	-7.1%
Yermasogeia	-28%	-7.1%
Kalavasos	-35%	-6.1%
Dhypotamos	-11%	-4.0%
Average	**-23%**	**-5%**

As it can be seen in Table 2-10, all main dams in Cyprus are expected to be exposed to changes in inflow, with the magnitude of exposure ranging from -35% to +6% in the period (1970-2000)-(2021-2050) (high exposure).

Figure 2-7 shows, as an example, the relation between annual rainfall and runoff for the catchment of the Kouris dam for the period (1970-2000)-(2021-2050), where a 20% decrease in annual runoff was observed for a 7% decrease in annual rainfall for this catchment.

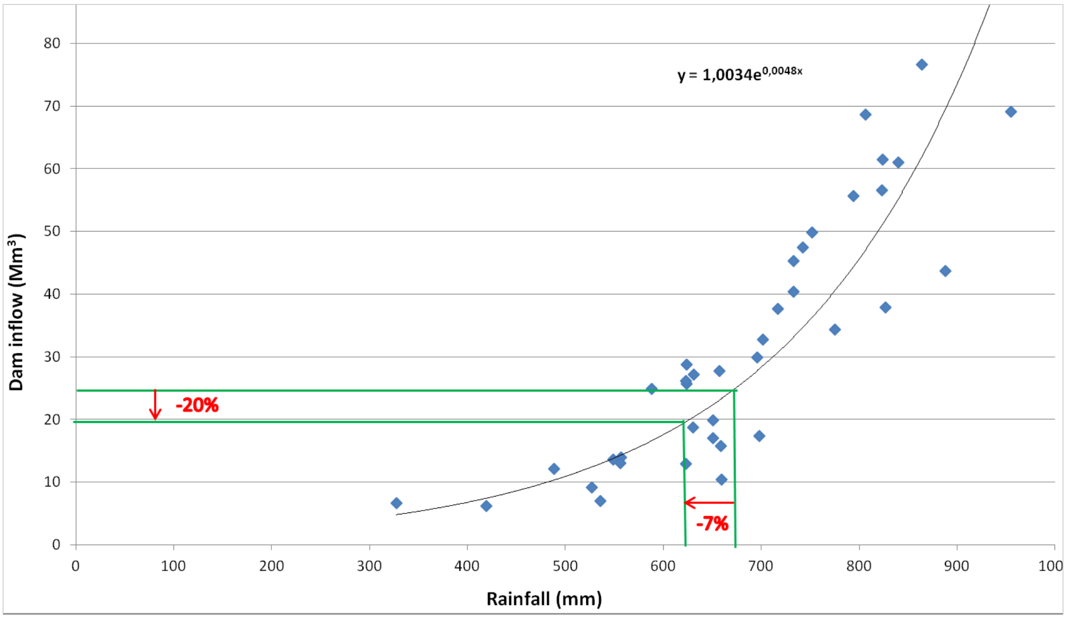


Figure 2-7: Relation between annual precipitation and annual inflow to the catchment area of the Kouris dam for the period (1970-2000)-(2021-2050) (CYPADAPT)

Dam inflow variability

The Flow Variability Index was used to estimate water supply safety for Cyprus. This indicator is calculated by estimating the standard deviation of annual inflows to the dams of Cyprus. A low value indicates a low variability of runoff and thus reduced sensitivity of water availability, while high variability indicates increased sensitivity in this aspect. In Figure 2-8 it can be seen that there is high variability in dam inflow for the period 1969-2007 (average dam inflow: 120 Mm^3/yr, standard deviation: 76 Mm^3/yr) and thus high sensitivity of Cyprus surface water resources to climate changes.

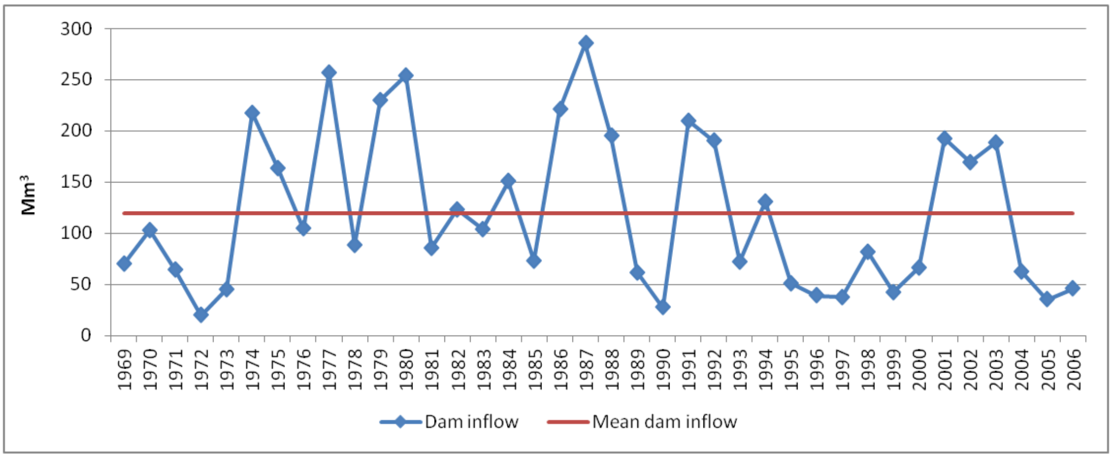


Figure 2-8: Variability of flow into the dams of Cyprus for the hydrological years 1969-2006 (CYPADAPT)

Source: WDD

Groundwater overexploitation

Diminishing precipitation and increased evapotranspiration with consecutive years of drought led to the depletion of surface water stored in reservoirs and the exploitation of aquifers (direct climate change effect) especially for agriculture as the irrigation period elongated. Furthermore, cuts in water supply by Government works imposed in periods of drought or high water pricing have often led private water consumers to illegally abstract water from boreholes (indirect climate change effect), which resulted in further deterioration of groundwater quantitative status.

Figure 2-9 shows that only 2 from the 19 groundwater bodies in Cyprus are not over-pumped (non sustainable abstraction[3]) revealing the intense pressure posed on them.

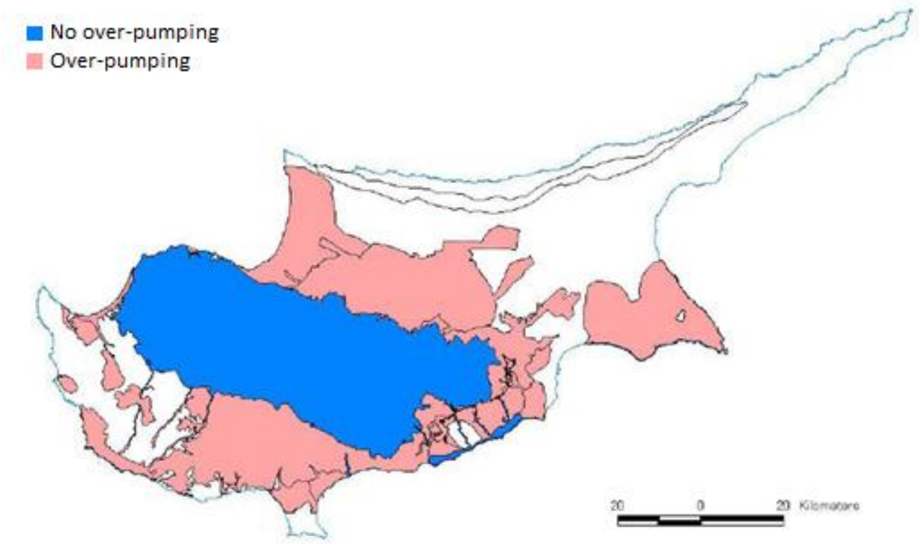


Figure 2-9: Over-pumping in the groundwater bodies of Cyprus

Source: WDD, 2008

According to the Water Framework Directive, which takes into consideration the trends in groundwater bodies level as well as the amount of unsustainable groundwater abstraction, 11 from 19 groundwater bodies are considered to be in bad quantitative condition (Table 2-11). In addition, it is considered that groundwater levels will follow a decreasing trend in the future which, if it is assumed that the ratio between surface water and groundwater will be maintained, will reach -23%. Given that a large percent of groundwater bodies have been already exposed directly or indirectly to climates changes, Cyprus' groundwater resources are characterized by high exposure to climate change.

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[3] Non sustainable abstraction refers to the amount of water that is abstracted in excess of the sources' recharge as a fraction of the total water abstractions.

Table 2-11: Quantitative status of groundwater bodies in Cyprus, 2000-2008

No of groundwater body	Groundwater level trend	Over-pumping (Mm^3/yr)	Condition
CY_1 Kokkinochoria	Upward-Fluctuating	4.5	BAD
CY_2 Aradippou Gypsum	Downward-Fluctuating	0.5	GOOD
CY_3 Kiti-Pervolia	Fluctuating	1.1	BAD
CY_4 Zigi-Softades	Steady-Fluctuating	0.7	BAD
CY_5 Maroni Gypsum	Steady or Downward	0.7	GOOD
CY_6 Mari-Calo Chorio & Chirokitia Sandstone	Downward	0.4	BAD
CY_7 Germasogeia	Steady-Controlled	0	GOOD
CY_8 Limassol	Fluctuating	0.9	BAD
CY_9 Akrotiri	Fluctuating-Upward	2.4	BAD
CY_10 Paramali-Avdimou	Fluctuating-Downward	0.7	BAD
CY_11 Paphos	Fluctuating-Downward at eastern parts	0.5	GOOD
CY_12 Letimvou-Giolou	Steady-Upward	0.1	BAD
CY_13 Pegeia	Downward	1.1	BAD
CY_14 Androlikou	Steady-Upward	0	GOOD
CY_15 Chrisochou-Gialia	Downward	0.3	GOOD
CY_16 Pyrgos	Downward at coastal parts	0.3	GOOD
CY_17 Central and Western Mesaoria	Downward	6.7	BAD
CY_18 Lefkara-Pachna	Downward-Fluctuating	3	BAD
CY_19 Troodos	Fluctuating	3	GOOD

Source: WDD, 2011a

Freshwater stress indicators

Water stress is often related to the deterioration of fresh water resources in terms of both quantity and quality (Hochstrat & Kazner, 2009). Already stressed water resources are considered more vulnerable to climate changes. The difficulty facing Cyprus in order to meet water demand either for satisfying drinking water supply or for other purposes such as agriculture, tourism and industry, due to water stress, indicates the sensitivity of the sector to climate changes.

Following, the indicators used for the quantification of future water stress caused by the decreased quantity of available freshwater resources in Cyprus are presented. It is noted that, these indicators refer exclusively to the exploitation of freshwater resources, while non freshwater resources (desalinated water, recycled water) are not taken into account.

Freshwater availability per capita

The Falkenmark Water Stress Indicator (Falkenmark, 1989) divides the volume of available water resources for a country by its population. Its threshold values indicate that water availability of more than 1,700m³/capita/year is defined as the threshold above which water shortage occurs only irregularly or locally. Below this level, water scarcity arises in different levels of severity. Below 1,700m³/capita/year water stress appears regularly, below 1,000m³/capita/year water scarcity is a limitation to economic development and human health and well-being, and below 500m³/capita/year water availability is a main constraint to life. However, the above index does not take into consideration the available amount of non-freshwater resources in a country.

The Water Stress Indicator (WSI) per capita was calculated for the part of Cyprus which is under Government control, by dividing the average annual quantity of available freshwater resources (surface water stored in reservoirs and groundwater) in the free part of Cyprus (2000-2010) by the population of the Republic of Cyprus. Given that there were available data on population from two censuses (2001, 2011), their average was used for the estimation of WSI in order to best reflect the population of the period under examination. In addition, the respective WSI for the future period (2021-2050) was calculated based on the projections made in Sections 2.2.2.1 and 2.2.3. The estimated current and future WSIs were 284 m^3/c/y and 195 m^3/c/y respectively, both of which are considered very low, indicating that it is not possible for the case of Cyprus to rely exclusively on freshwater resources in the current situation and even more in the future.

$$WSIcurrent = \frac{available\ freshwater\ resources\ (avg. 2000 - 2010)}{population\ (avg. 2001 - 2011)} = \frac{217\ Mm^3}{764{,}231}$$
$$= 284\, m^3/capita\ /year$$

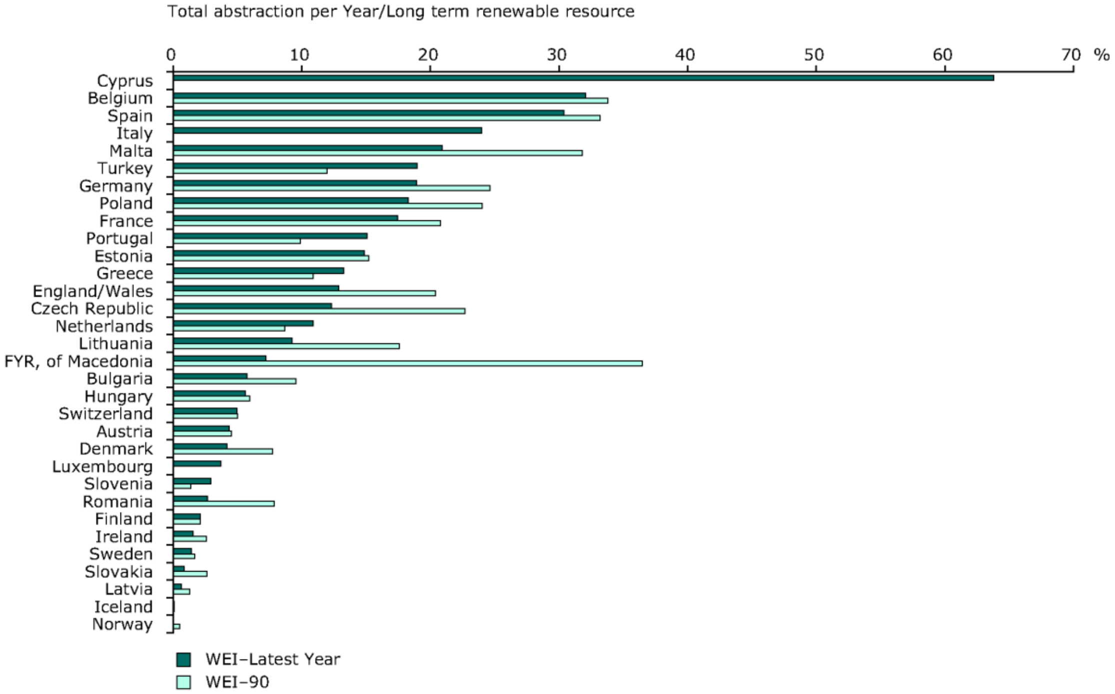
$$WSIfuture = \frac{available\ freshwater\ resources\ (avg. 2021 - 2050)}{population\ (avg. 2021 - 2050)} = \frac{184\ Mm^3}{943{,}471}$$
$$= 195\, m^3/capita\ /year$$

Water Exploitation Index

One relatively straightforward indicator of the pressure or stress on freshwater resources is the Water Exploitation Index (WEI). It relates water availability and water use and is defined as the ratio of annual water withdrawal from ground and surface water to the total renewable freshwater resources. Hence high water stress indices can either be caused by low availability and/or excessive high water demand (EEA, 2010b).

$$WEI = \frac{total\ freshwater\ abstractions}{total\ renewable\ resources}$$

A WEI above 20 % implies that a water resource is under stress and values above 40 % indicate severe water stress and clearly unsustainable use of the water resource (Raskin *et* *al.*, 1997). As shown in Figure 2-10, the WEI of Cyprus for the year 2007 was 64%, which is by far the highest WEI value among the European countries.



Note: Annual total water abstraction as a percentage of available long-term freshwater resources around 1990 (WEI-90) compared to latest year available (1998–2007) (WEI-Latest Year).

(WEI Latest year, WEI-90) = Cyprus (2007, -); Belgium (2005, 1994); Spain (2006, 1991); Italy (1998, -); Malta (2007, 1990); Turkey (2001, 1990); Germany (2004, 1991); Poland (2005, 1990); France (2006, 1991); Portugal (1998, 1990); Estonia (2007, 1990); Greece (2007, 1990); UK* (England/Wales) (2006, 1990); Czech Republic (2007, 1990); Netherlands (2006, 1990); Lithuania (2007, 1990); FYR, of Macedonia (1990, 2007); Bulgaria (2007, 1990); Hungary (2002, 1992); Switzerland (2006, 1990); Austria (1999, 1990); Denmark (2004, 1990); Luxembourg (1999, -); Slovenia (2007, 1990); Romania (2007, 1990); Finland (1999, 1990); Ireland (2007, 1994); Sweden (2007, 1990); Slovakia (2007, 1990), Latvia (2007, 1991); Iceland (2005, 1992); Norway (- , 1985)

Figure 2-10: Water exploitation index (WEI) in Europe (1990-2007)

Source: EEA, 2010c

Water availability index

The Water Availability Index, WAI (Meigh et al., 1999) takes into account surface water and groundwater resources, and compares the total amount to the demands of all sectors, i.e. domestic, industrial and agricultural demands. The index is normalised to the range –1 to +1. A score of –1.0 indicates that there is negligible water available to meet demands, whilst a score of 0.0 indicates that the available water meets the demands and a score of 1.0 indicates that the available water is much greater than the demands (WSM, 2004). In the case of Cyprus, WAI is estimated to be approximately -0.1 for the period 2000 – 2010

(WDD[4]) and -0.26 for the period 2021-2050, indicating that the demand is higher than the availability of freshwater sources and that this inadequacy will be magnified in the future.

$$WAIcurrent = \frac{available\ freshwater\ resources - demand}{available\ freshwater\ resources + demand} = \frac{217\ Mm^3 - 249\ Mm^3}{217\ Mm^3 + 249\ Mm^3} = -0.07$$

$$WAIfuture = \frac{available\ freshwater\ resources - demand}{available\ freshwater\ resources + demand} = \frac{184\ Mm^3 - 311\ Mm^3}{184\ Mm^3 + 311\ Mm^3} = -0.26$$

Decreased precipitation and increased evapotranspiration due to temperature increase led to decreased water availability, while the increase in demand due to population increase and the rising of living standards added an extra pressure in the already limited freshwater resources. From Figure 2-11 it can be seen that water demand exceeded available freshwater resources in the period 2000-2010, 7 out of 11 years.

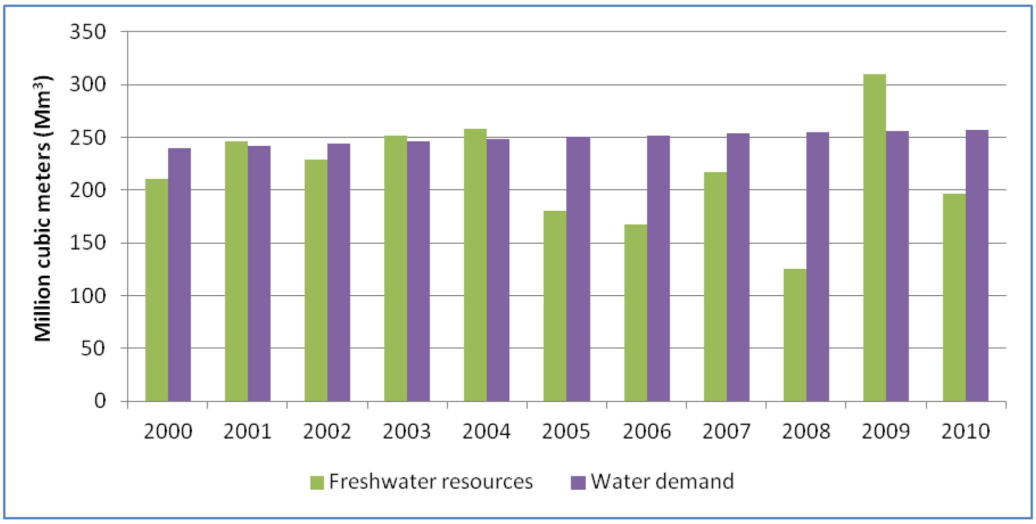


Figure 2-11: Water demand and freshwater resources in Cyprus for the period 2000 – 2010

Source: WDD[4]

Taking into consideration the above, Cyprus' water availability is considered to have **very high** sensitivity to current and future climate changes, as the quantity of water resources is directly linked with changes in rainfall and evapotranspiration resulting in increased flow variability, limited water supply safety and overexploitation of freshwater resources.

Furthermore, water availability in Cyprus is considered to have **very high** exposure to climate changes, as the reserves of all reservoirs and the majority of groundwater bodies in Cyprus has been already reduced and are expected to be further reduced in the future.

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[4] Unpublished data provided by Mr. Dimitriou Charalambos, Water Development Department of the Ministry of Agriculture, Natural Resources and Environment

2.4.1.2 Assessment of adaptive capacity

In Cyprus the continuous expansion of population and industry resulted in the increase of water demand, while the impacts from climate change have reduced the country's water supply. In order to combat this gap, several measures, plans and water works have been implemented by the Government. The Programme of Measures defined in the Cyprus River Basin Management Plan includes inter alia measures which are expected to reinforce Cyprus' adaptive capacity to the decreasing availability of freshwater resources and thus to climate change.

The adaptation measures as well as their status of implementation are presented in Table 2-12, while in the following sections a brief assessment of the effectiveness of the main measures is conducted.

Table 2-12: List of measures to adapt Cyprus' water management to climate change impacts

Adaptation measures	Implemented	Planned	Prescriptive	Legally binding	Incentives
Measures to increase freshwater supply					
Reservoirs	X				
Inter-basin water transfer	X				
Artificial recharge of aquifers	X	X			
Water import	X				
Diversification of water resources utilisation					
Water reuse	X	X			
Desalination	X	X			
Stormwater harvesting		X			
Measures to decrease water consumption					
Replacement of networks	X	X			
Water allocation/cuts	X	X			
Use of water meters	X	X			
Land consolidation	X	X			
Increasing efficiency of irrigation	X	X	X		X
Control groundwater abstractions	X			X	
Changes in crop patterns		X	X		X
Awareness raising campaigns	X				X
Economic/legal instruments					
Subsidies	X	X			X
Water pricing	X	X			
Over consumption penalties	X	X			
Other instruments					
Improving forecasting, monitoring, information - alert system	X	X			

2.4.1.2.1 Measures to increase freshwater supply

Reservoirs

The capacity of dams has significantly increased since 1960 from 6 Mm^3 to 332 Mm^3 (Figure 2-12). As a result, the accumulated storage capacity in 2010 was able to cover 4 times the average annual dam inflow of the period 1987-2010 (78.5 Mm^3). This practice has reached physical limits as favourable sites are not available and even more because, as presented in previous sections, there is no increasing trend in precipitation and natural run-off expected. However, main aim of the construction of a plethora of dams is to capture as must as possible of the surface runoff and to eliminate water losses to sea.

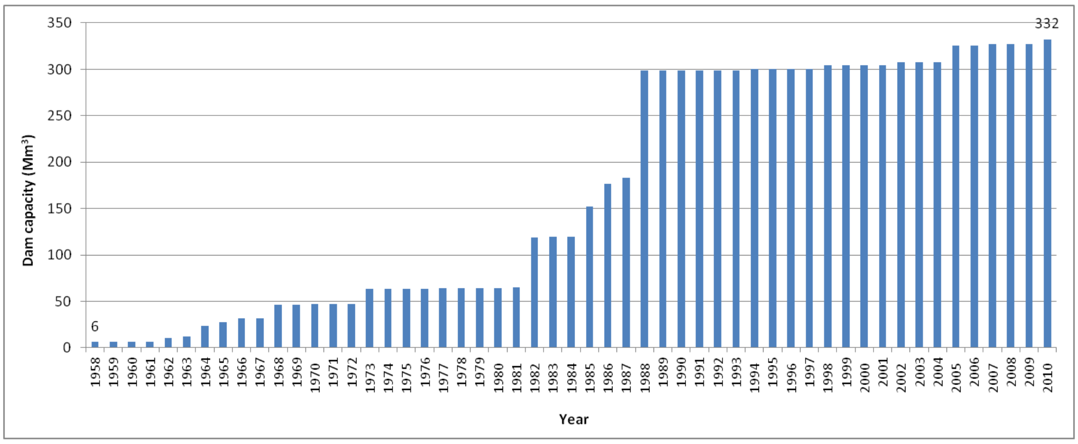


Figure 2-12: Accumulated capacity of dams in Cyprus for the period 1958 – 2010

Inter-basin water transfer

The interconnection of reservoirs and conveyor systems allows distribution of water across the island and offer some flexibility in operation. Existing water infrastructure involves large inter-basin transfers in the South-South-eastern (South Conveyor Project - SCP) and in the South West-Western (Pafos Irrigation Project) parts of the island. This allows for considerable flexibility in water management and allocation in most areas.

Exploitation of water resources

The major water supplier among the GWW in Cyprus is the Southern Conveyor System which supplies approximately 76% of the total water supplied by GWW, followed by the Pafos WW which supplies 16% of the water and the Chrysochou WW which supplies 7% of the water while about 1% is supplied by other GWW (WDD, 2009a).

It is considered that the Southern Conveyor System in conjunction with the desalination plants of the area satisfy the drinking water demand of Nicosia, Limassol, Larnaca and the area of Famagusta which is under government control, as well as the irrigation water demand of 14,000 ha of agricultural land. In addition, the Vassilikos-Pentaschinos project was developed in order to supplement with irrigation water the agricultural development of the area and to augment the domestic water supply of Nicosia, Larnaka and Famagusta districts (WDD, 2011a– Annex VII).

The Pafos WW today in conjunction with the operation of the desalination plant at Kouklia is considered to fully satisfy the demand in drinking water of the greater area of Pafos, Pegeia and of some semi-mountain communities including the area of Pissouri. In addition, it satisfies the water demand of the Pafos irrigation area which, has been substantially reduced compared to the initial estimations (WDD, 2011a– Annex VII).

A critical issue focuses on the supply with drinking water of the greater area of Chrysochou at the northwestern part of the island. The area which already presents significant amounts of water consumption, is developing rapidly both with touristic infrastructure and with holiday residences. In addition, a potential direct road connection with Nicosia must be taken into account, as it will lead to further water stress caused by developmental pressures. As far as the supply in irrigation water in the greater area of Chrysochou is concerned, this is less compared to the originally planned amount of irrigation water which would be necessary to satisfy the demand of the recorded irrigated areas. However, no deficits are reported since the area has undergone major land use changes mainly from rural to urban use (WDD, 2011a– Annex VII).

In addition, the Pitsilia Integrated Rural Development Project refers to a series of water works in the mountain and semi-mountain area of Troodos, which belong to the districts of Nicosia, Larnaca and Limassol. This project had as a goal to prevent the abandonment and desertification of rural areas due to internal migration. However, the recorded irrigated areas are more than double compared to the dimensioning of the water works. Respectively, the conservatively estimated water supply from the Pitsilia WW is three times smaller compared to the estimated water demand of the irrigated areas. According to the abovementioned facts, it is obvious that the total water demand in the area of Pitsilia cannot be satisfied exclusively by the available water works (WDD, 2011a– Annex VII).

Following, a map of Cyprus depicting the major Government Water Works and the respective irrigated areas is presented.

Figure 2-13: Major Government Water Works in Cyprus

Source: WDD

Artificial aquifer recharge

The construction and operation of a large number of dams in conjunction with the increasing demand and abstractions, has led to reduced natural recharge of downstream aquifers. Artificial recharge includes all works relating to the deliberate acceleration of recharge rate of aquifers from surface water sources and constitutes a key priority in the management of groundwater resources in Cyprus. However, it must be mentioned that in order to fully replenish the water lost from the aquifers it is expected to take at least 12 years assuming that no water is being extracted from the aquifer during that period.

Water import

Emergency water was shipped into the island from Greece during summer 2008. This unprecedented action was vital to supply Limassol with drinking water and earmarked the extraordinary severity of the drought. A total of 8 Mm^3 was planned to be delivered from June to November for a total expenditure of around 40 million EUR. In fact the daily delivery was only 35,000 m^3. According to the Water Development statistics, the imported amount in 2008 was 3.3 Mm^3 (Hochstrat & Kazner, 2009).

2.4.1.2.2 Measures for the diversification of water resources

The use of non conventional water resources such as desalinated water, treated water from WWTPs, grey water and stormwater in water supply for various uses can substantially alleviate the pressures on the freshwater resources which are already high in Cyprus (see Section 0: Freshwater stress indicators). Following, the progress made so far in Cyprus regarding the use of non conventional water resources is presented.

Desalination

Desalination constitutes a secure source for safe drinking water supply, once demand management measures are fully implemented. Government policy of Cyprus is the complete independence of the water supply of the urban and tourist areas from rainfall and the satisfaction of the maximum demand during the summer period, using desalination plants. Within this framework, the Water Development Department put in operation 5 Permanent Desalination Plants by 2012, with a total production of 252,000 m^3/day. The contribution of desalination plants to domestic water supply for 2010 amounted to 65% which equals 55.5 Mm^3 (WDD, 2011a). During the period 2021-2050, when the estimated average water demand from the domestic sector is estimated to be approximately 86Mm3/year (see Section 2.2.3), the total (existing and planned) desalination capacity (92Mm3) is expected to outreach domestic water demand by 7%. However, as mentioned earlier, not all population in Cyprus has access to desalinated water and thus domestic water demand is not possible to be fully satisfied by desalinated water.

In addition, desalination is an energy intensive process producing a residue (brine) that must be carefully treated and disposed in order to prevent environmental degradation. Hence, desalination could be considered a mal-adaptation measure unless certain requirements are taken into account, such as the use of renewable energy and the proper treatment and disposal of brine produced.

Use of treated municipal effluents

The use of treated wastewater provides additional drought-proof water supply, favours a more local sourcing of water and avoids the use of high quality water sources where this is not necessary. The potential for water reuse depends on the availability and accessibility of wastewater, hence the wastewater infrastructure, and the acceptability by potential end-users and consumers. Providing recycled water for irrigation through Government Water Works, began in 1998, with a small amount of around 1.3 Mm^3 and reached 12 Mm^3 in 2010, from which 9 Mm^3 was supplied for irrigation and about 3 Mm^3 for artificial recharge of aquifers.

There is an immense potential for growth of water reuse practices driven by both the demand for water and the increasing volumes of treated effluent. Aiming for compliance with the Urban Wastewater Treatment Directive (91/271/EEC) requirements, the wastewater collection and treatment infrastructure is being significantly expanded and upgraded. The capacity of the new Waste Water Treatment Plans in 2012 amounted to 59 Mm^3 per year and will reach up to 65 Mm^3 per year over the medium term (2015) and 85

Mm³ for long-term (2025)(WDD, 2011a- Annex VII). Assuming that the WWTP capacity represents approximately 130% of the average actual wastewater treated on an annual basis as WWTPs usually work under full capacity, it is expected that the amount of recycled water which will be produced in 2025 ($65Mm^3$) is expected to satisfy 43% and 34% of today's and future agricultural demand, respectively.

In general, the treatment of wastewater in Cyprus includes tertiary processes followed by filtration. Treated wastewater is used for the irrigation of green spaces, athletic fields and crops (excl. edible raw vegetables) as well as for aquifer recharge. Further treatment of certain quantities of the effluent with the process of reverse osmosis (RO) is under consideration, in order for water salinity to be reduced and the final effluent to be used for the irrigation of sensitive soils and crops. At the same time, the reverse osmosis process is expected to enable the integrated management of all irrigation water resources. However, the application of reverse osmosis presents some disadvantages, such as the high costs for the construction and operation of RO plants, and more significantly, the difficulty in selecting a management option for the brine produced which will be both techno-economically feasible and socially accepted. For example, the suggestion for thermal treatment of the brine from the RO plant, which is proposed to be constructed in the area of Aradippou, is socially acceptable but is quite expensive, while the conventional disposal of the untreated brine is not considered (WDD, 2011A – Annex VII).

General aim is to use the increasing quantities of treated effluents produced for the irrigation of the agricultural crops thus substantially alleviating the pressures posed to the sector due to water scarcity.

Furthermore, treated wastewater is also used in Cyprus for aquifer recharge. So far, treated wastewater from Paphos and Agia Napa-Paralimni is used for the recharge of Ezousa's aquifer. The expansion of this measure to the aquifer of Kiti and Kokkinochoria is under investigation as well. This will be decided on the basis of the quality of the treated (WDD, 2011A – Annex VII).

Aquifer recharge offers an opportunity to store water in order to use it in periods of decreased availability and/or increased demand. However, there is stakeholder opposition to groundwater recharge due to water quality concerns related to the risk of drinking water resources pollution. However, it must be mentioned that discharges of industrial waste are not allowed to the municipal wastewater collection system. Given that the quality of reclaimed water has always been an issue, the problem of micro-pollutants has to be considered. Though reclaimed water has to be analysed for bulk parameters and selected metals, no organic micropollutants are being monitored so far (Hochtsrat & Kazner, 2009).

Stormwater use

The use of storm water can result in further savings in fresh water consumption. The last two decades, a separate drainage system is being developed in Cyprus in order to collect stormwater. So far, the drainage network in the majority of the big urban centres of Cyprus has been completed.

Furthermore, the Sewerage Board of Limassol-Amathus in cooperation with the five municipalities of the Greater Limassol area as well as the wider area of Paphos began the implementation of Sustainable Urban Drainage Systems (SUDS). SUDS are actually a sequence of management practices, control structures and strategies designed to efficiently and sustainably drain surface water. Up to now, no suitable measures have been identified for the case of Larnaca due to its topography (low-lying area).

Further research must be made on this field for the evaluation of the potential use of storm water. In this framework, a study was conducted by the WDD (WDD, 2009b) in order to explore the potential use of storm water.

Reassessment of water availability

Taking into account the measures undertaken so far in Cyprus for the diversification of water resources as well as the planned ones that are expected to be in place in the future period under examination (2021-2050), the freshwater stress indicators estimated in Section 2.4.1.1 could be reassessed as water stress indicators (including both freshwater and non freshwater sources) in order to estimate adaptive capacity. In specific, the estimated future Water Stress Index (WSI) which includes the contribution of desalinated and recycled water is:

$$WSIfuture = \frac{available\ freshwater\ resources\ (avg.2021{-}2050) + non\ freshwater\ resources}{population\ (avg.2021{-}2050)} = \frac{184\ Mm^3 + 157Mm^3}{943{,}471} = 361\ m^3/capita\ /year$$

Considering that the estimated current and future WSIs were 284 m^3/c/y and 196 m^3/c/y respectively, the new WSI for the future period which includes both freshwater and non-freshwater resources (361 m^3/c/y) appears to be substantially increased, however still below the lowest limit of 500 m^3/c/y.

The future Water Availability Index (WAI) which includes the contribution of non-freshwater resources to the available water resources is:

$$WAIfuture = \frac{available\ freshwater\ resources + non\ freshwater\ resources - demand}{available\ freshwater\ resources + non\ freshwater\ resources + demand} = \frac{184\ Mm^3 + 157\ Mm^3 - 311\ Mm^3}{184\ Mm^3 + 157\ Mm^3 + 311\ Mm^3} = -0.046$$

Considering that the estimated current and future WAIs were -0.1 and -0.3 respectively, the new future WAI which includes both freshwater and non-freshwater available resources (-0.05) appears to be substantially increased, however still below the score of 0.0 which indicates that the available water meets the demands.

2.4.1.2.3 Measures to decrease water consumption

Replacement of networks

Water losses in domestic water distribution networks, mainly in rural areas, are quite high. The “unaccounted for” water in the main urban domestic supply distribution networks is estimated in the range of 15 to 20% and about 20 to 30% in the rural areas. Therefore, an additional effort should be made for the timely identification and replacement of defective pipes and for developing a more conscious attitude towards water conservation.

Water saving from the replacement of networks is expected to be very important compared to other possible water saving measures. From research conducted during the period 2009 – 2010 for the Water Supply networks of the municipalities (that does not belong to Water Supply Boards), more than 80% of the networks have been replaced for the 63.4% of the municipalities (WDD, 2011c).

Improving water use efficiency in irrigation

A Water Use Improvement Project has been implemented by the Department of Agriculture since 1965. According to this project, the government provided farmers with technical and financial assistance to turn from traditional surface irrigation methods to modern irrigation methods. The progress in the irrigation efficiency from less than 45% in 1960, reached 71% in 1980, 80% in 1990, 84% in 2000 and 90–95% in 2010. The on-farm irrigation systems comprise 90% micro-irrigation, 5% sprinkler irrigation and 5% surface irrigation (WDD, 2011c).

The *Water Efficiency Index* allows the monitoring of progress in terms of the water saved as a result of demand management by reducing loss and wastage during both the transport and use of water. It is subdivided into total and sectoral efficiency (drinking water, agriculture and industry). In Cyprus water efficiency in irrigation is lower in comparison to that of drinking water (Figure 2-14). As shown in Figure 2-15, total water use efficiency in Cyprus rose from 65% in 1995 to 82% in 2005-2010. In addition, in the same figure it can be seen that Cyprus is placed among the first two countries as regards water use efficiency (Plan Blue, 2011).

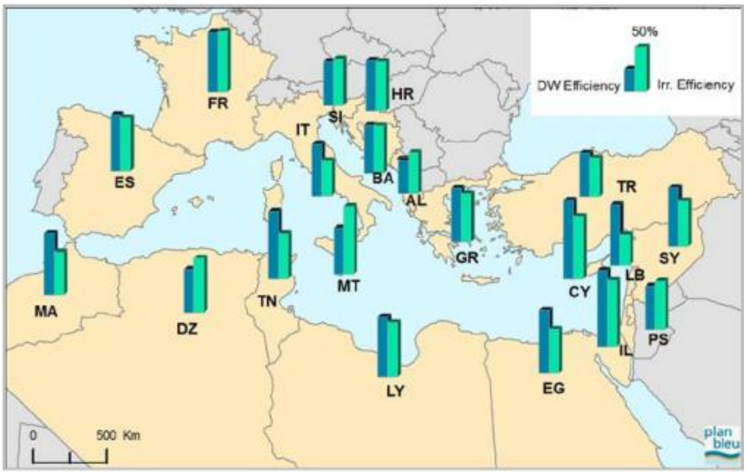


Figure 2-14: Water use efficiency in two sectors (drinking water and irrigation) in 2010

Source: Plan blue, 2011

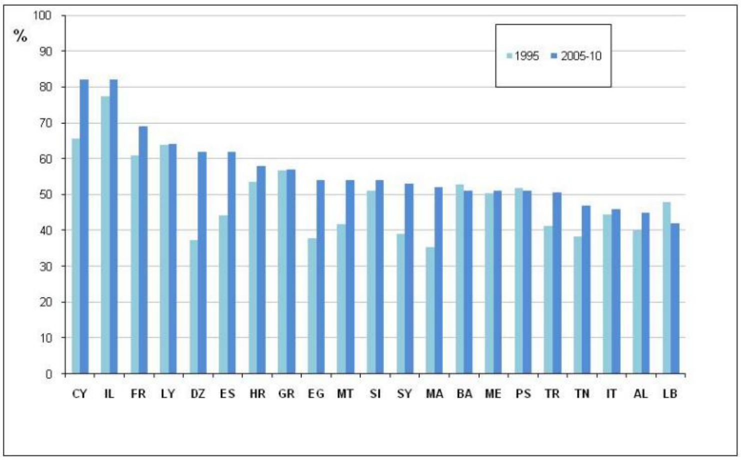


Figure 2-15: Total water use efficiency in Mediterranean countries (1995, 2005-2010)

Source: Plan blue, 2011

Water allocation

Water allocation mechanisms under drought conditions (water rationing) have been established to provide priority to maintaining domestic and municipal water supplies. The second priority is to maintain supplies to perennial crops at 80% of the recommended application levels. Seasonal vegetable crops constitute the third priority. The water cuts in irrigation from the South Conveyor System during the period 2000-2010 ranged from 10% to 90% with the exception of 2004 where the water cuts were equal to zero. The cuts in the drinking water supply ranged from 13% to 23% for the same period (WDD, 2011c).

Control groundwater abstractions

The Law on the Integrated Water Management 79(I)/2010 which has been enforced in Cyprus since 2010, sets the requirements for the granting of permissions regarding borehole drilling and pumping. The Law also foresees the installation and monitoring of water meters in boreholes, in order for the quantities of water pumped not to exceed the limits set. It is expected that with the new Law a considerable number of violations, that have been made in the past, will be eliminated. Furthermore, a proposed amount of annual abstraction from each aquifer is set in order to establish a positive balance between natural recharge and abstractions.

Use of water supply meters

Metered supply allows users to observe their consumption and to follow up effects of water saving measures. The installation of individual water supply meters from the drinking water consumers in Cyprus is almost catholic, while for irrigation purposes it is restricted mainly in areas supplied with water from Government Water Works or from boreholes in certain groundwater bodies that are under Special Water Savings Measures. It has been observed that only the introduction of water meters could achieve water savings of 10 – 25% of the total consumption (WDD, 2011c).

Land consolidation

Land consolidation constitutes another measure which is directly linked with the decrease in water demand, through the reduction in the fragmentation of agricultural holdings, the opportunity for scale economies in irrigation works and the achievement of significant water savings. Since 1969, 62 out of 73 submitted consolidation plans referred in irrigated land and 3 in mixed, irrigated and rainfed land. In addition, another 12 plans are in progress and 27 under examination, both referring in irrigated land.

It is difficult to estimate the efficiency of the consolidation of small pieces of irrigated land and its contribution as a water saving measure. However, irrigated areas that have been consolidated have shown increased irrigating efficiency mainly because the application of improved irrigation systems is more feasible in that case, thus resulting in savings in irrigation water (WDD, 2011c).

Water pricing

The water pricing system, as applied today in Cyprus, is not considered to be an effective tool for achieving water savings. It was found that there is no elasticity in water demand in relation to its current price, both in drinking and irrigation water, as the variations in water prices had not affected average water demand. Actually, reductions in water demand were observed during periods of intense water scarcity, which is attributed mainly to the raising awareness campaigns. It must also be mentioned that with the introduction of the new desalination plants, the costs of water production and supply will change significantly and the pricing system will move to a new balance. For that reasons, the Water Development Department has assigned a study for the implementation of appropriate pricing policies of water services as well as for the implementation of penalty charges for overconsumption (quota system). The current pricing system as well as the proposed one is presented below (WDD, 2011a – Annex II):

- *Supply of drinking water from Government Water Works*: So far, drinking water is supplied from Government Water Works to all Districts for a fixed price (the same price was charged to all Districts except Pafos District). The Water Supply Boards, Municipalities and Municipal Boards in their turn charged different block tariffs for the further distribution of water. The new pricing policy is based on increasing block rates and on the full recovery of cost (including the environmental and resource cost).

- *Supply of freshwater for irrigation from Government Water Works*: For the supply of irrigation water, lower prices have been set for uses of high social value (e.g. agriculture) and higher prices for uses of lower social value (e.g. golf courses). The pricing system of irrigation water is based on a two part tariff, the first one being a fixed price reflecting the fixed costs and the second one being a variable cost (volumetric pricing) reflecting the variable costs. However, as a large part of the charge could be covered from the fixed charge, the system was considered ineffective in preventing excessive water use. For that reason, the charges with the new pricing policy were adjusted, reducing fixed cost to 15% of the initial price.

- *Supply of recycled water for irrigation from Government Water Works*: The use of recycled water in irrigation is encouraged, as the charging of this source does not enhance the cost of its production and supply. In order to further promote the use of recycled water with the new pricing system, its price is proposed to be set at 75% of the freshwater price.

- *Drinking water outside GWW*: So far water from private boreholes is not charged. With the new pricing policy, the abstraction of groundwater will be charged, taking into account the environmental and resource cost of groundwater.

It is expected that with the implementation of the new pricing policy additional water savings will be achieved.

Subsidies for drinking water savings

The WDD has been offering subsidies in order to reduce drinking water consumption mainly in households with the use of untreated groundwater or greywater in certain uses as well as the recycling of hot water. The water-saving subsidies are for (i) the drilling of boreholes for watering gardens, car wash etc, (ii) the installation of a grey water treatment system for watering gardens, (iii) the installation of a hot water recirculator and (iv) the connection of the borehole with the toilet cisterns. In 2009, 1331 applications were approved, the majority of which (594) were for drilling boreholes (WDD, 2011c).

Awareness campaigns

Awareness campaigns are essential in order to achieve water savings. During the last decade the awareness campaigns have been intensified by the WDD, with lectures in schools, advertisements, distribution of informative leaflets and other initiatives. It is difficult to estimate their efficiency in actual water savings, however a downward trend in water consumption was observed during the period 2004-2009 when the campaigns have intensified (WDD, 2011c).

Improving monitoring and forecast

As most problems in the water supply are related to the scarcity of the resource, a close monitoring of the relevant meteorological parameters and the inflow to the dams has been established. Yet in urban areas the rainfall stations should be more numerous to better follow especially heavy rainfall events (Rossel, 2002). The observation of groundwater resources has been less well attended to in the past, which has led to excessive over-pumping of aquifers. Improved monitoring networks are required to collect sufficient and robust data to base an indicator system for the state of the resources on it. The application of leak detection, real time telemonitoring and tele-control to optimize operation and maintenance of networks is among the envisaged measures (Hochstrat & Kazner, 2009).

Table 2-13 lists the demand management measures along with the estimated savings (Mm^3/yr) and the time period (years) used for the estimations. It was estimated that these measures could save a total of 91.4 Mm^3/yr.

Table 2-13: Water demand management measures and estimated savings

Measure	Water savings (Mm^3/yr)	Data coverage (years)
Replacement of water supply networks	3.3	2000-2010
Use of non-conventional water resources		2005-2008
Recycled water	12.5	
Desalinated water	55.5[1]	
Stormwater	0	
Subsidies for reducing domestic water demand		1997-2010
Borehole drilling	1.3	
Borehole connections with toilets	0.3	
Grey water recycling	0.03	
Hot water circulators	0.05	
Water allocation and cuts	41.5	2000-2010
Use of water meters	8	1986-2009
Redistribution of irrigated land	4.4	1991-2009
Irrigation systems	20	1960-2000[2]
Total	**91.4**	

[1] Desalinated water supply was not included in the demand savings total.

[2] The period 1960-1974 include also the Turkish occupied areas.

Source: WDD, 2011c

Many of the measures adopted have already alleviated the problem of water scarcity, as continuous water supply to the domestic sector has been secured by desalination plants and significant savings have been achieved in water consumption. As for the future situation is concerned, the sum of the average estimated freshwater and non-freshwater resources for the period 2021-2050 (341Mm^3) is expected to fully satisfy future water demand from all sectors, with a marginal surplus though. In specific, it is estimated that the amount of water produced from the desalination plants will outreach domestic water demand by 7%. However desalinated water is distributed mainly in the urban centers of Cyprus through Government Water Works (GWW) while other areas, such as the mountain communities, depend solely on freshwater resources (mainly groundwater) for meeting their drinking water needs, which is derived either from GWW or from private boreholes (non GWW). The percentage of population in Cyprus which is connected to GWW is shown in a study of WDD (2009a), which reports that during the period 2005-2007 drinking water supply was provided by 86% from GWW and the remaining 14% by non GWW (WDD, 2009a).

Therefore, Cyprus' future adaptive capacity to water availability for domestic water supply in the plain and coastal areas is considered to be **high to very high** while the future adaptive capacity to water availability for domestic water supply in the mountain areas is considered as **limited to moderate**.

On the other hand, the measures applied have not yet managed to fully satisfy water demand for irrigation as agriculture constitutes the main water consumer in Cyprus. Given that agriculture requires a great amount of water (over 60% of total water demand), restrictions in water supply for irrigation are a common phenomenon especially during summer when the water resources are limited. Assuming that the average future (2021-2050) demand for irrigation water, which is estimated to reach 202.5Mm^3 (190Mm^3 crop irrigation and 12.5Mm^3 landscape irrigation), will be satisfied by the available freshwater resources in the future (184Mm^3) and by recycled water (65Mm^3), total future water supply (249Mm^3) will exceed future water demand by 23%.

However, water is not evenly distributed whether it is freshwater or recycled water. In particular, recycled water is distributed through GWW only in the plain and coastal areas while the sole GWW for irrigation in mountain areas are storage reservoirs which are of limited capacity and during drought periods their reserves are depleted. This has led farmers especially in mountain areas to depend on private boreholes (non GWW) in order to meet their irrigation needs, thus resulting in the overexploitation of aquifers. This is also proved by the study of WDD (2009a), which reports that during the period 2005-2007 irrigation water supply was provided by 73% from non GWW (mainly groundwater) and the remaining 27% from GWW (mainly surface water). However, it is considered that since water supply from GWW has been augmented recently mainly due to the installation of new desalination plants, the contribution of GWW to the total water supply has also been increased. Finally, it must be mentioned that recycled water is distributed mainly in the coastal and plain areas where there is the necessary infrastructure for its transfer while in mountain areas this is not economical.

Therefore, the future adaptive capacity of Cyprus to water availability for irrigation in the plain coastal areas is considered as **moderate** while the future adaptive capacity to water availability for irrigation in the mountain areas is considered as **limited to moderate**.

In addition, it is logical to assume that when reaching 2050, freshwater resources will be further reduced and water demand will further increase compared to the average estimation for the period 2021-2050, resulting in a higher marginal difference between water supply and demand or even to a deficit.

However, it must be mentioned again that the projections in future freshwater supply and demand are rough estimations of the future and that in general, long-term projections of this kind are characterized by high degree of uncertainty. For these reasons, it is imposed that a re-assessment of these projections must be made.

Following, additional recommended adaptation measures (Shoukri & Zachariadis, 2012) that are considered to further enhance adaptive capacity towards this impact, are presented indicatively. Nevertheless, their assessment and final selection for implementation will be made through the use of the Multicriteria Analysis (MCA) tool which will be developed and implemented in the framework of Actions 4 and 5 of the CYPADAPT project.

- Maintenance and repair of the water distribution systems and related infrastructure (adoption of technologies for leakage detection and control)
- Prioritization of sea water desalination as an ultimate solution and preferably by renewable energy
- Installation of water saving equipment (set as mandatory in new buildings)
- Adoption of efficient water consumption standards
- Mandatory greywater recycling for new houses/ buildings
- Collection and use of rainwater
- Enhance water use efficiency in agriculture, households and buildings
- Replenishment of coastal aquifers
- Review of the Water Policy
- Incentives for the reuse of “grey water” in industry
- Control of high water demanding developments in areas of inadequate water resources (golf courses and tourist developments)
- Preparation of risk assessment studies for water-poor areas threatened by desertification
- Feasibility studies for water transfer in areas threatened by desertification
- Reduction of irrigated areas on the basis of the potential of each area

2.4.2 Water quality

2.4.2.1 Assessment of sensitivity and exposure

Water bodies in Cyprus are sensitive to eutrophication, stratification and low levels of dissolved oxygen as a result of increased water temperatures and decreased water flows due to reduced precipitation. In addition, heavy precipitation events and flooding adversely affect water quality. The reduction in the recharge rates due to reduced precipitation is more intense in the case of groundwater bodies, thus being more sensitive to climate changes. In addition, coastal aquifers are highly sensitive to salinization due to sea intrusion caused by their over-exploitation.

Considering the above, it was estimated that surface water bodies have **moderate to high** sensitivity to pollution due to climate changes while groundwater bodies have **high to very high** sensitivity.

In order to examine the exposure of water to future climate changes that could deteriorate its quality, first the climate changes of decreased precipitation and increased droughts, the increase in heavy precipitation events, the increase in surface water temperature and the sea level rise in Cyprus in the future (2021-2050) will be presented.

According to the PRECIS model, all north coasts and especially Karpasia peninsula are expected to receive less annual total precipitation in the future than that estimated for the recent past years 1961-1990. In all other parts of Cyprus, the annual total precipitation appears to have minor decreases or no changes at all. The only region with an increase in total annual precipitation, minor though (up to 5mm), is the area east from Paphos.

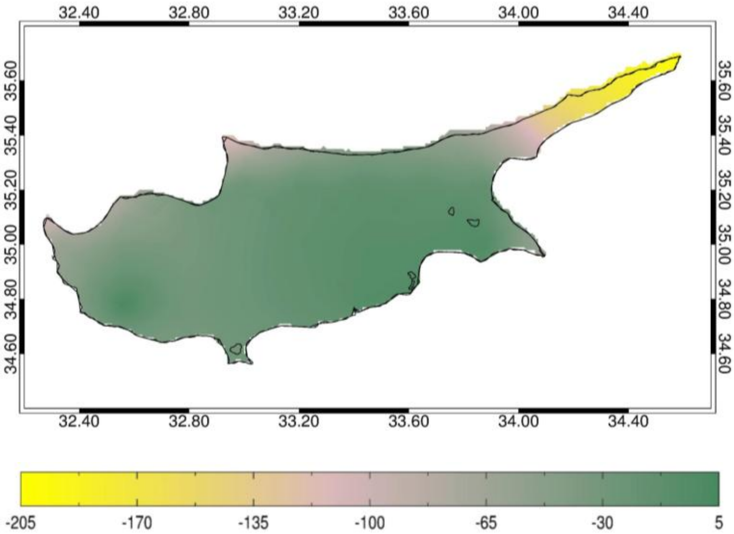


Figure 2-16: Changes in annual total precipitation between the future (2021-2050) and the control period (1961-1990)

As far as the length of drought periods (consecutive days with precipitation<0.5mm) in the future (2021-2050), it is anticipated that the western coastal and higher elevation regions of Cyprus, as well as the Karpasia peninsula and the area of Ayia Napa, will have slight decreases or no changes in the maximum length of drought periods. On the other hand, the central part of Cyprus will face an increase in the maximum length of drought. In particular, the increase of this index will be about 15 days/year in the continental areas near Nicosia and Larnaca and approximately 20 days/year in the eastern part of Troodos (north from Limassol).

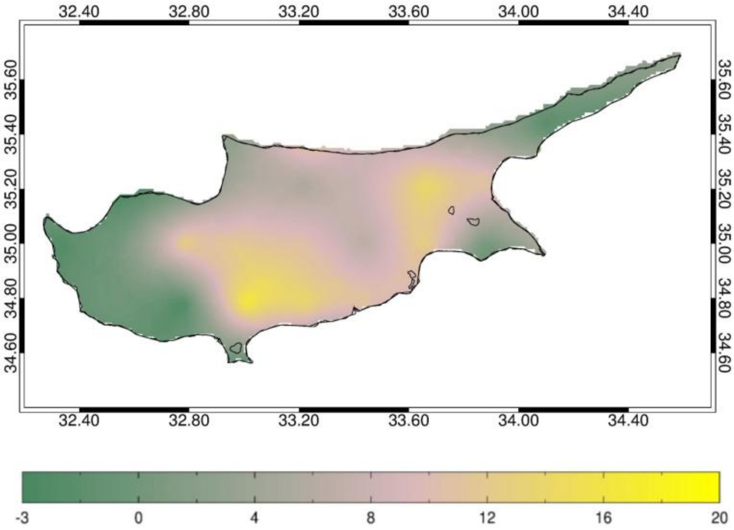


Figure 2-17: Changes in maximum length of dry spell (RR<0.5mm) between the future (2021-2050) and the control period (1961-1990)

As for the heavy precipitation events in the future (2021-2050), the PRECIS model showed that there will be no significant changes to the annual maximum total precipitation over one day (heavy rainfall index). In particular, a slight increase of about 2-4 mm is anticipated in western, inland and mountain regions. Additionally, southern and southeastern areas present an increase of about 1 mm.

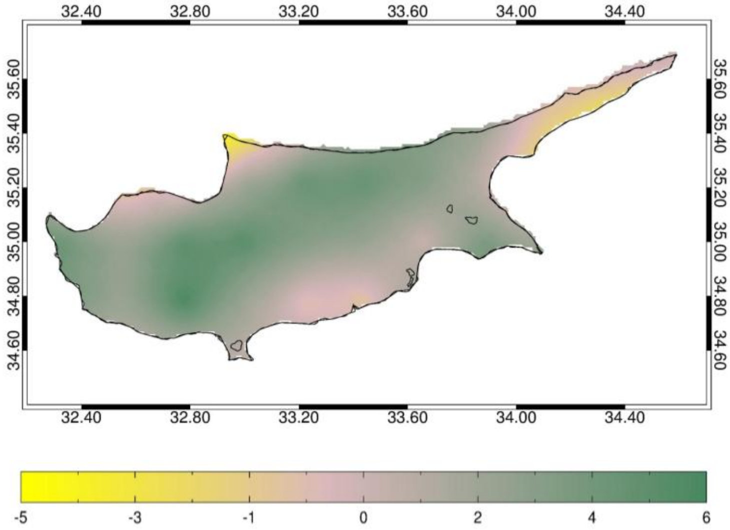


Figure 2-18: Changes in annual maximum total precipitation over 1 day between the future (2021-2050) and the control period (1961-1990)

As for changes in water temperature, these were related to the changes in air temperature. Projections for the period 2021-2050 according to the PRECIS model indicate that the average change in annual maximum temperature (TX) will range from +1.0°C at the eastern and northern coasts to +2.0°C in higher elevation areas and especially at the southwestern side of Troodos. The lowland and continental areas in the central part of the country present also notable changes in the average annual TX (mainly more than +1.5°C), followed by the western and southern coasts with a temperature increase limited to 1.3-1.7°C. It is considered that rivers and storage reservoirs with low flows will be more exposed to changes in air temperature due to their lower specific heat capacity. In general, it is expected that water temperature will rise as air temperature rises, with a slower rate though.

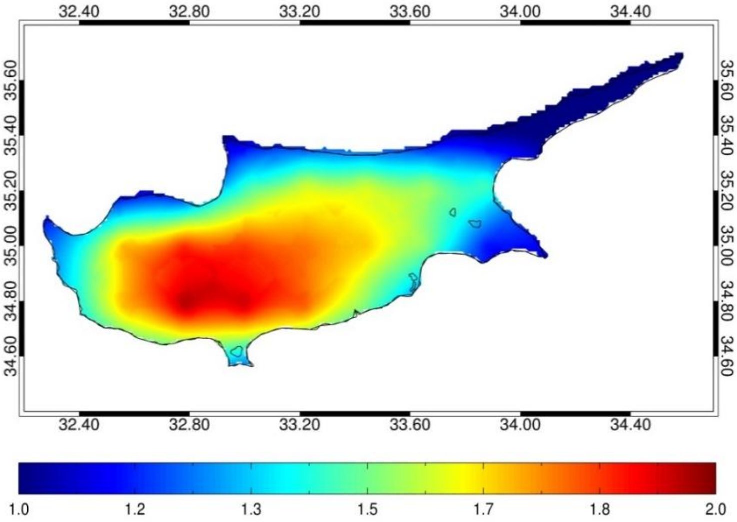


Figure 2-19: Changes in average annual maximum TX between the future (2021-2050) and the control period (1961-1990)

Sea level changes in Cyprus as observed during the period 1993 and 2000 show an increase of 5-10 mm/year. Taking into consideration the land lift up of 0-1 mm/year that Cyprus is experiencing, the future exposure of Cyprus to sea lever rise is considered as moderate.

The exposure of the quality of water bodies in Cyprus will be also estimated based on their existing qualitative status, given that the water bodies that are already in bad qualitative condition are considered more vulnerable to climate change impacts. In the following sections the qualitative status of Cyprus' water resources for each type of water body is presented in order to assess their exposure.

2.4.2.1.1 Surface water bodies

<u>Status of river water bodies</u>

Based on the results of the monitoring program of Cyprus' water bodies, 68 out of the 216 river water bodies (31.5%) were classified in the category of good ecological status / good ecological potential, 76 (35.2%) in moderate, 16 (7.4%) in poor, 3 (1.4%) in bad, while 56 river water bodies (24.5%) remained unclassified (Figure 2-20).

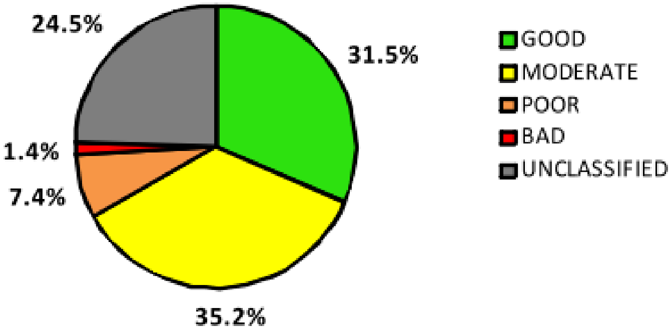


Figure 2-20: Ecological status of river water bodies, (%) number of bodies

Source: WDD, 2011a

Concerning the chemical status of the river bodies, 71.3% were classified in the category of good chemical status and only 4.2% in less than good chemical status, while 24.5% remained unclassified (WDD, 2011a).

<u>Status of lake water bodies</u>

Based on the results of the monitoring program of Cyprus water resources, 10 lake bodies (56%) were classified in the category of good ecological status, 6 (33%) in moderate status, 1 (5,5%) in bad status while 1 (5,5%) was not ranked in any category (Figure 2-21).

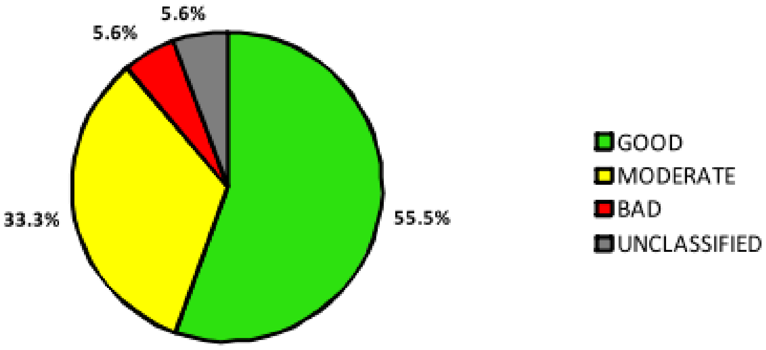


Figure 2-21: Ecological status of lake water bodies, (%) number of bodies

Source: WDD, 2011a

Concerning their chemical status, 72.2% of the lake bodies were found to be in a good chemical status and only 16.7% in a less than good chemical status (5% of the total area of the lake bodies) while 11.1% remained unclassified (WDD, 2011a).

In the following figures (Figure 2-22 and Figure 2-23), the ecological and chemical status of river and lake bodies of Cyprus are depicted in the form of maps.

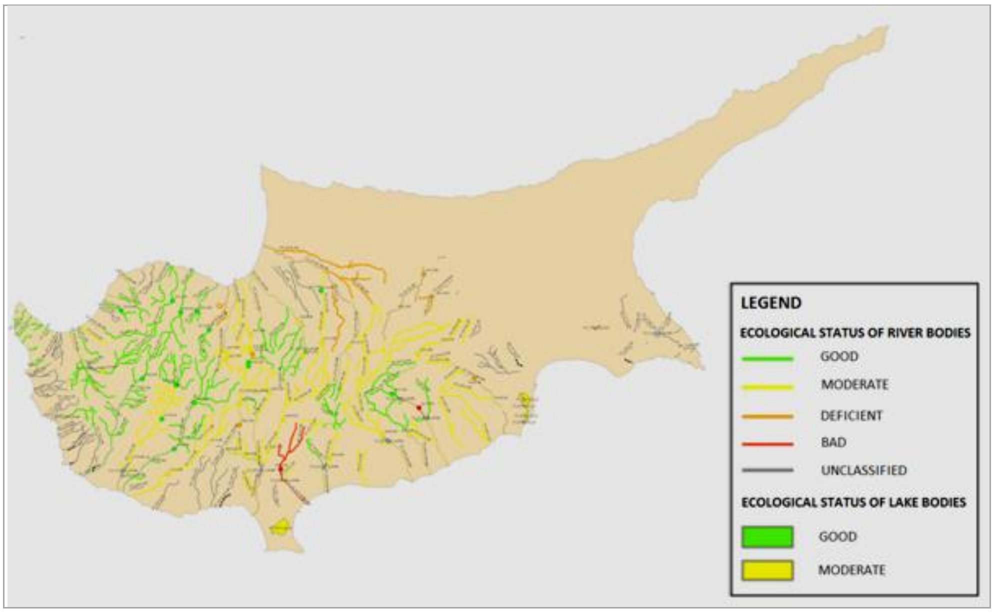


Figure 2-22: Map of the ecological status of river and lake bodies in Cyprus

Source: WDD (7)

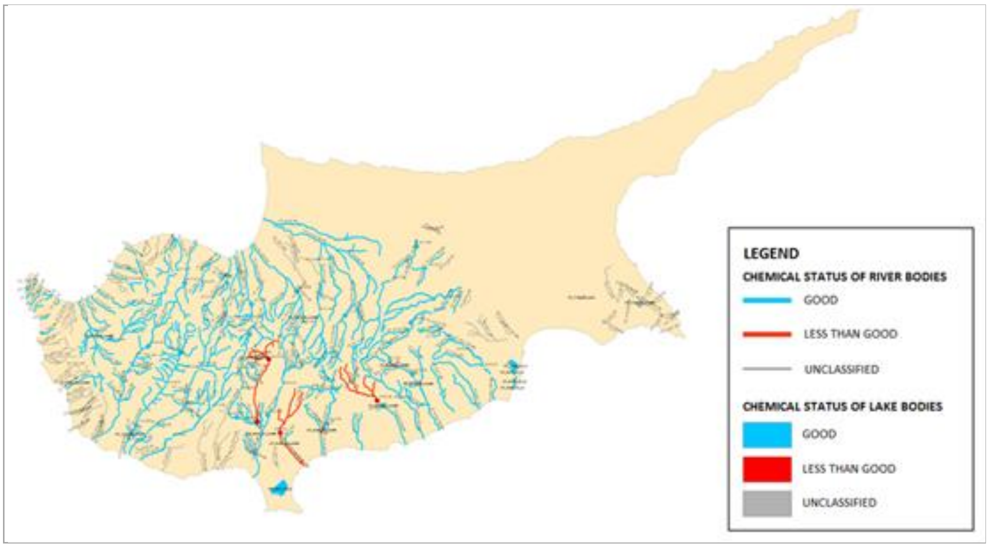


Figure 2-23: Map of the chemical status of river and lake bodies in Cyprus

Source: WDD (8)

As it can be seen, the majority of river and lake bodies of Cyprus were classified in a good or moderate ecological and chemical status.

Status of coastal water bodies

According to data provided from the Department of Fisheries and Marine Research of MANRE, all 25 coastal water bodies were found in good or high ecological status or good ecological potential. Similarly, their chemical status was good (WDD, 2011a).

Sensitive water bodies to pollution from wastewater

Furthermore, in Cyprus two surface water areas, in which direct or indirect disposal of urban waste water takes place, have been identified as sensitive according to the Directive 91/271/EEC. The criteria for the characterization of surface waters as sensitive are the eutrophication or risk of eutrophication, the increased presence of nitrates in water intended for human consumption and the need for further processing to meet requirements of other Directives. These areas are the 'Polemidhia Storage Reservoir' and the 'Coastal Area between Cape Pyla and Paralimni' (see Figure 2-26) (WDD, 2011a – Annex I).

Pollution potential of surface water bodies

Following, the Surface Water Vulnerability (SWV) Index as it was estimated for the case of Cyprus in the framework of the Pig Wasteman project (LIFE Third Countries) is presented. The SWV Index defines the pollution potential of a surface water body and is based on four basic parameters of equal weight, among which one is a climate parameter. The parameters used are the quantity of annual rainfall inducing runoff, the texture of soil which affects the runoff coefficient, the topography in terms of the slope of site from the pollution source toward the surface water, and the distance from the pollution source to the nearest surface water**.** The higher the index is, the greater the relative pollution potential (PigWasteMan, 2007). As it is shown in the figure that follows, the surface waters most vulnerable are located in the central and north-western part of Cyprus.

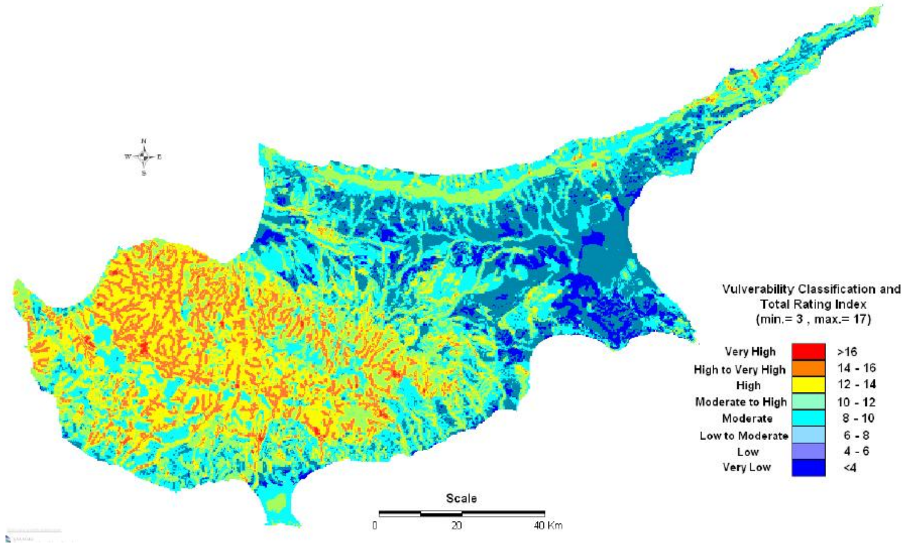


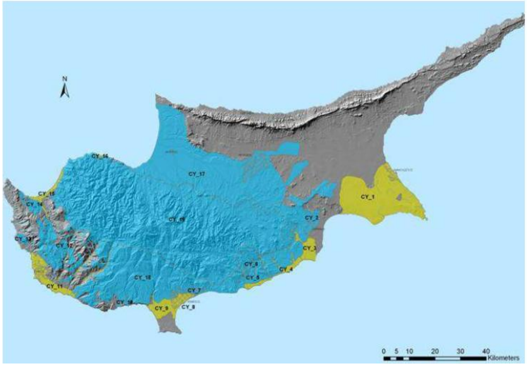
Figure 2-24: Map of surface water vulnerability to pollution

Source: PigWasteMan, 2007

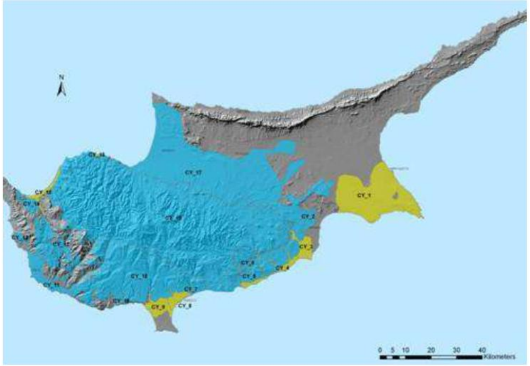
Considering the existing situation of surface water bodies as well as their exposure to future climate changes that are expected to affect them, it is estimated that the exposure of surface water bodies to pollution is **limited to moderate**.

2.4.2.1.2 Groundwater bodies

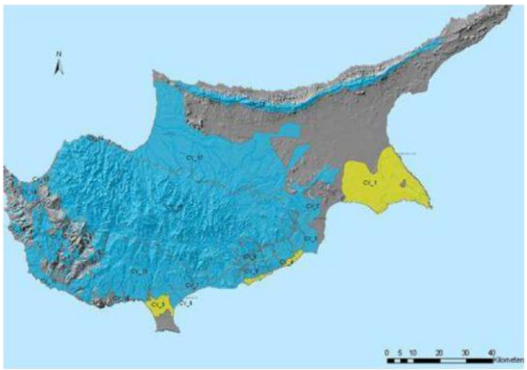
The main matters which have arisen from the results of the monitoring of groundwater quality in Cyprus, were the increased nitrate and chloride concentrations (above the limits) which were found in seven water bodies, while another water body in Paphos is stll under investigation. In addition, increased concentrations of sulphates, ammonium, arsenic, pesticides and increased conductivity were found in several groundwater bodies (see Figure 2-25). The main causes of pollution in Cyprus are agriculture, seawater intrusion and wastewater disposal, while industry constitutes a less significant source of pollution as the number of industries in Cyprus is limited. Moreover, the quality of groundwater in Cyprus is affected by natural causes like geological formations which release sulphate and chloride salts of sodium and boron.



Nitrates

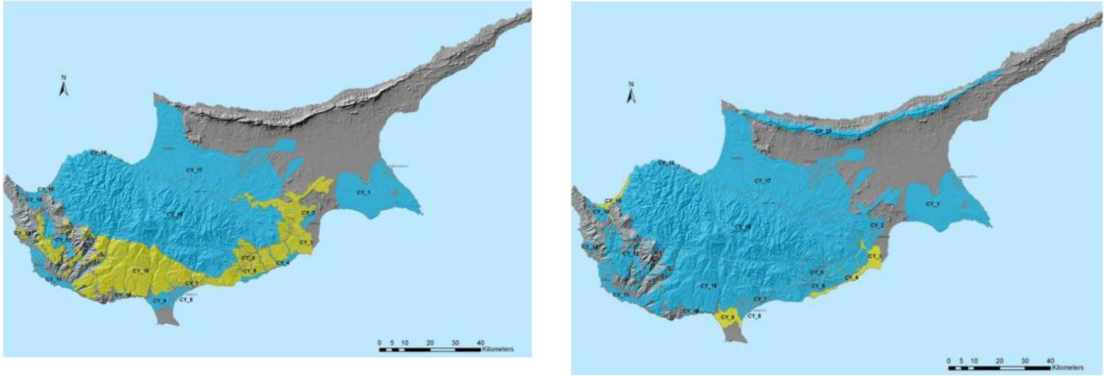


Chlorides



Sulphates

Ammonium (under investigation)



Pesticides

Conductivity

🟨 **Excess concentrations**

Figure 2-25: Excess values of selected parameters in the groundwater bodies of Cyprus

Source: WDD, 2011 – Annex VII

Furthermore, five (5) areas in Cyprus which drain into waters vulnerable to pollution from nitrogen compounds have been declared as Vulnerable Nitrate Zones (VNZ), according to the Directive 91/676/EEC. The five areas are the aquifers of Kokkinochoria, Kiti-Pervolia, Akrotiri, Paphos and Poli Chrisohous, and cover a total area of 419 km^2. By the end of 2010 another VNZ, that of Orounda, has been delineated within the Western Mesaoria Groundwater Body. According to the available data, the total agricultural area that is located in vulnerable zones is approximately 200 km^2. Approximately 80% of this land is irrigated with intensive agricultural practices taking place (GSD, 2008). Figure 2-26 shows the designated Vulnerable Nitrate Zones and Sensitive Areas in Cyprus.

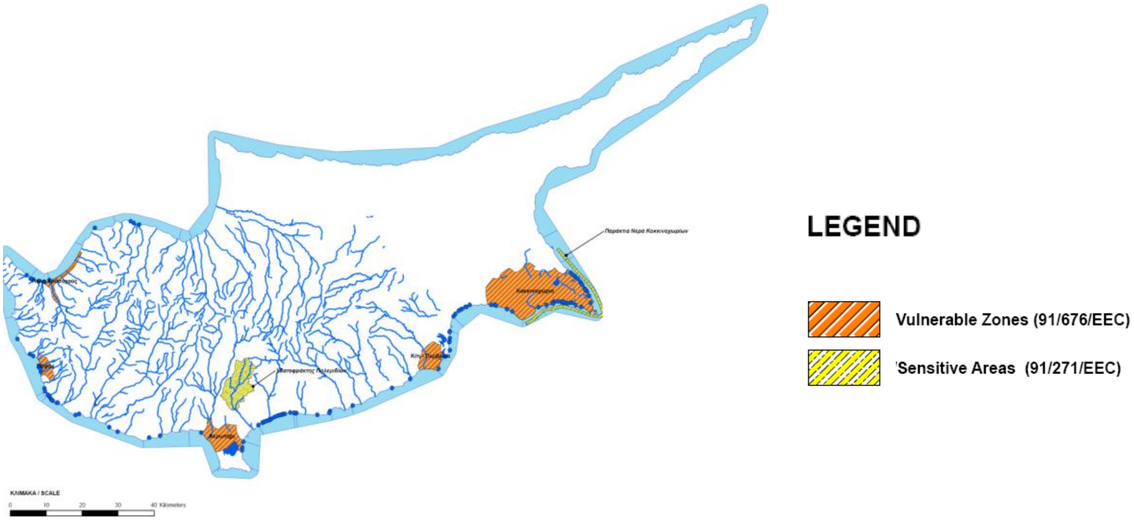


Figure 2-26: Vulnerable Nitrate Zones and Sensitive Areas in Cyprus

Source: WDD (9)

As regards to aquifer salinization, the aquifers located at the coasts – i.e. all major aquifers of Cyprus - are exposed to seawater intrusion and especially those located in low-lying areas (e.g. Larnaca). As a result, 12 out of 19 groundwater bodies in Cyprus have been exposed to saline intrusion while the coastal zones of several aquifers in Cyprus have been abandoned due to this phenomenon. It must also be noted that a potential sea-level rise would increase the amount of seawater intruded into freshwater aquifers.

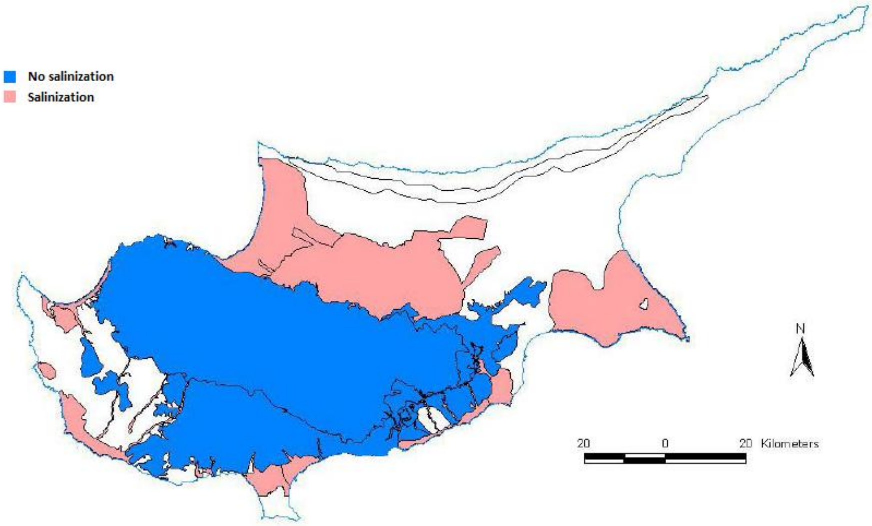


Figure 2-27: Salinization in the groundwater bodies of Cyprus

Source: WDD, 2008

To sum up, from the monitoring of the 19 groundwater bodies during the period 2000-2008, 8 groundwater bodies (42%) were characterized according to the Water Framework Directive as in bad qualitative condition, based on the results of chemical analysis in the salinity levels and/or the levels of pollutants present in the groundwater bodies (Table 2-14). In other words, the quality of groundwater bodies can be characterized as moderate to bad.

Table 2-14: Qualitative status of groundwater bodies

Groundwater body	Saline intrusion	High concentrations and/or excess	Condition
CY_1 Kokkinochoria	YES	Cl, SO_4, NO_3, NH_4,EC	BAD
CY_2 Aradippou Gypsum	NO		GOOD
CY_3 Kiti-Pervolia	YES	Cl, NO_3, EC, Pesticides	BAD
CY_4 Zigi-Softades	YES	Cl, SO_4, NO_3, EC	BAD
CY_5 Maroni Gypsum	NO	Pesticides	GOOD
CY_6 Mari-Calo Chorio & Chirokitia Sandstone	NO	As,NH_4,Pesticides	GOOD
CY_7 Germasogeia	YES		GOOD
CY_8 Limassol	YES	Cl, NO_3	BAD
CY_9 Akrotiri	YES	Cl, SO_4, NO_3,EC	BAD
CY_10 Paramali-Avdimou	YES		GOOD
CY_11 Paphos	YES	NO_3 locally	GOOD
CY_12 Letimvou-Giolou	NO	NH_4	BAD

Groundwater body	Saline intrusion	High concentrations and/or excess	Condition
CY_13 Pegeia	YES	Pesticides	GOOD
CY_14 Androlikou	NO	As	GOOD
CY_15 Chrisochou-Gialia	YES	Cl, NO_3, EC	BAD
CY_16 Pyrgos	YES	Cl, NO_3, NH_4	BAD
CY_17 Central and Western Mesaoria	YES	NH_4	GOOD
CY_18 Lefkara-Pachna	NO	As, NH_4	GOOD
CY_19 Troodos	NO		GOOD

Source: WDD, 2011a (Annex VII)

Taking into account the existing situation of groundwater bodies as well as their exposure to future climate changes that are expected to affect them, the exposure of the groundwater bodies in Cyprus to deterioration of their quality is characterized as **high to very high**.

2.4.2.2 Assessment of adaptive capacity

To protect freshwater from pollution, a wide range of legislation has been established in Europe. Most notably, the Water Framework Directive (WFD), which represents the single most important piece of EU legislation relating to the quality of fresh and coastal waters, aims to attain good ecological and chemical status by 2015. The Programme of Measures defined in the annual report of the Cyprus River Basin Management Plan (WDD, 2011a – Annex III) includes the establishment of regulations or basic measures that should be implemented in order to achieve the objectives set out for 2015.

2.4.2.2.1 Protected areas

In compliance with the Article 6 of the Water Framework Directive (WFD), Cyprus has created a register of all areas lying within its river basin district, which were considered requiring special protection under specific Community legislation for the protection of surface water and groundwater or for the conservation of habitats and species directly depending on water. The register includes all water bodies identified under Article 7 of the WFD and all protected areas covered by Annex IV of the WFD, namely:

i) Areas designated for the abstraction of water for human consumption in accordance with the Article 7 of the WFD;
ii) Areas designated to protect economically significant aquatic species (areas protected under Freshwater Fish Directive 78/659/EEC and Shellfish Directive 79/923/EEC);
iii) Water bodies designated as recreational waters, including areas designated as bathing waters, in accordance with the Directive 2006/7/EC;
iv) Areas designated as sensitive to nutrient pollution, including areas designated as vulnerable zones under the Nitrates Directive 91/676/EEC and areas designated as sensitive areas under the Urban Wastewater Treatment Directive 91/271/EEC;

v) Areas designated for the protection of habitats or species where maintaining or improving water status is important for their protection, including the sites of the "NATURA 2000" network, established under the Directives 92/43/EEC and 79/409/EEC.

Following, each of the aforementioned protected areas in Cyprus are presented.

(i) Areas designated for the abstraction of water for human consumption

The water resources used in Cyprus for drinking water abstraction are surface waters (dams-reservoirs) and groundwater. The protected areas under Article 7 of the WFD include 5 surface water bodies and 13 groundwater bodies (WDD, 2011a – Annex I). For each of the protected areas, in addition to meeting the objectives of Article 4 of the WFD for surface water bodies, Cyprus is engaged to ensure that, in the applied water treatment regime and in accordance with Community legislation, the resulting water will meet the requirements of Directive 80/778/EEC as amended by Directive 98/83/EC on the quality of water intended for human consumption.

(ii) Areas designated to protect economically significant aquatic species

No such areas have been identified in the river basin district of Cyprus.

(iii) Areas designated as recreational waters, including bathing waters

The harmonization of the national legislation of Cyprus with the Directives 76/160/EEC and 2006/7/EC on the management of bathing water quality was made by the Law on Water Pollution Control 106(I)/2002, the Decree on Water Pollution Control (Quality of Bathing Water) 99/2000 and the Law on the management of bathing water quality 57(I)/2008. For the implementation of Directive 2006/7/EC, Cyprus designated in 2010, 113 bathing water areas. These bathing water areas refer to almost all coastal water bodies of Cyprus (WDD, 2011a – Annex I).

(iv) Areas designated as sensitive to nutrient pollution, including vulnerable and sensitive areas

The Directive 91/676/EEC on the protection of waters against pollution caused by nitrates has been harmonized in the legislation of Cyprus with the Law on Water Pollution Control No. 106(I)/2002. For the protection of the Vulnerable Nitrate Zones identified in Cyprus, the Department of Agriculture of MANRE has established (a) a Code of Good Agricultural Practice as well as (b) an Action Programme to prevent or reduce water pollution from nitrates.

a) Code of Good Agricultural Practice

The Code of Good Agricultural Practice which has been enacted in Cyprus by the Presidential Decree No. 263/2007 aims to reduce nitrate pollution from fertilizer use and livestock waste and the introduction of acceptable practices for the use of recycled water in irrigation and municipal sludge in agriculture that protect public health and the environment. However, the compliance with the guidelines of the code is prescriptive.

b) Action Programme to prevent or reduce water pollution from nitrates

The implementation of the Action Programme to prevent or reduce pollution is already mandatory in the designated Nitrate Vulnerable Zones (NVZ). According to the action plan, farmers who use agricultural land located within nitrate vulnerable zones are required to comply with the relevant provisions of the Action Programme concerning the use and storage-transport of fertilizers, the use and storage of livestock waste / sludge, the monitoring and control, the irrigation methods as well as the chemical analyses.

For the protection of the two sensitive areas designated in Cyprus in compliance with the Directive 91/271/EEC on Urban Wastewater Treatment, a more stringent treatment of urban waste water entering collecting systems before discharge into the sensitive areas is required (WDD, 2011a – Annex I).

(v) Areas designated for the protection of habitats or species depending on water

These protected areas include the areas of Natura 2000 network, when the maintenance or improvement of water status is important for their protection, and the areas protected by national legislation. The Natura 2000 network consists of two types of areas, namely the Special Protection Areas (SPAs) for birds as defined in Directive 79/409/EEC, and the Sites of Community Importance (SCIs) as defined in Directive 92/43/EEC. In Cyprus, 35 areas of the Natura 2000 network include habitats or species directly depending on water (WDD, 2011a – Annex I). Figure 2-28 depicts these Natura 2000 areas on the map of Cyprus.

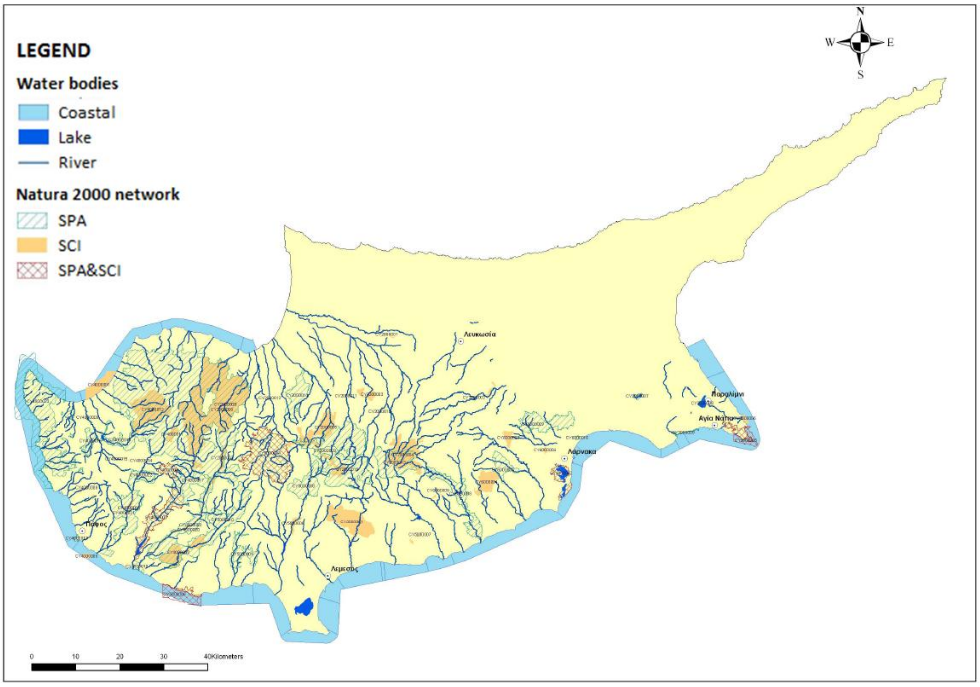


Figure 2-28: Map of Natura 2000 areas in Cyprus depending on water

As it can be seen, a considerable number of river, lake and coastal bodies in Cyprus are included in the Natura 2000 network.

2.4.2.2.2 Protection from point source discharges likely to cause pollution to water

The legislation of the Cypriot Government referred as “Water Pollution Control Laws 2002-2009” is the main tool with which all issues related to water pollution control from industrial and other activities are regulated. Article 6 of the Water Pollution Control Law (No. 106(I)/2002) prescribes that the discharge or disposal of any substances potential to cause pollution to water and soil is illegal without previous permission. Especially for installations included in the provisions of the IPPC Directive (large units with significant pollution potential), the Law No. 56(I)/2003 for Integrated Prevention and Pollution Control is applied.

Furthermore, aiming for compliance with the Urban Wastewater Treatment Directive (91/271/EEC) requirements, the wastewater collection and treatment infrastructure is being significantly expanded and upgraded. The capacity of the new Wastewater Treatment Plans in 2012 amounts to 59 Mm^3 per year and will reach up to 65 Mm^3 per year over the medium term (2015) and 85 Mm^3 for long-term (2025). The pollution load to be treated is set to 675,000 population equivalent (p.e.) of which 80% are generated in urban agglomerations, which are the greater areas of Nicosia, Larnaca, Limassol and Paphos, and the municipalities of Ayia Napa and Paralimini (WDD, 2011a – Annex VII).

2.4.2.2.3 Protection of groundwater bodies from salinization

The water policy of Cyprus on the salinization of groundwater bodies, is based mainly on the prevention of seawater intrusion with the achievement of a positive balance between the abstractions and recharge, by setting proposed volumes of abstraction for each of its aquifers according to their quantitative condition. Furthermore, the measures foreseen for the achievement of a good chemical status of Cyprus groundwater bodies until 2015, in compliance with the Water Framework Directive, also contribute to this direction.

However, it must be noted that the rehabilitation of a groundwater body heavily affected by sea intrusion is a very slow process and sometimes almost impossible [5]. Consequently, the adaptive capacity of groundwater to salinization is characterized by low likelihood of reversibility or even irreversibility. Last but not least, it prerequisites the moratorium of abstractions. The time required may shorten by the application of artificial recharge with water rich in Ca^{2+} (Voudouris et al., 2005).

The implementation of these measures is expected to have a central role in improving qualitative water status. However, it is recognized that the hydrologic processes are such,

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[5] For the case of the sea intruded coastal aquifers in South Greece, this time was estimated to be some 180-600 years, given the complete cessation of abstractions (Voudouris et al., 2005).

that it may be many years before protective measures actually lead to improvements in water quality and thus the adaptive capacity is characterized by delayed reversibility.

Pollution prevention and quality monitoring and restoration of groundwater are even more difficult than for surface waters mostly due to its inaccessibility. Its “hidden” character makes it difficult to adequately locate and quantitatively appreciate pollution sources and impacts, resulting in a lack of awareness and/or evidence regarding the extent of risks and pressures. In addition, groundwater usually reacts slower than surface water as processes (movement/pollution) usually take more time in groundwater and subsequently, recharge and remediation take much more time. Especially in slow moving groundwater, pollutants can persist indefinitely.

Consequently, it was estimated that the future adaptive capacity of water quality to climate changes is **moderate** for the case of surface water and **limited to moderate** for groundwater.

Following, additional recommended adaptation measures (Shoukri & Zachariadis, 2012) that are considered to further enhance adaptive capacity towards this impact are presented indicatively. Nevertheless, their assessment and final selection for implementation will be made through the use of the Multicriteria Analysis (MCA) tool which will be developed and implemented in the framework of Actions 4 and 5 of the CYPADAPT project.

- Proper waste management to avoid surface and ground water pollution
- Sound use of fertilisers and pesticides to protect surface and ground water quality
- Replenishment of coastal aquifers

2.4.3 Floods

2.4.3.1 Assessment of sensitivity and exposure

The distribution of floods according to their flood hazard (very low, low, moderate, high) in Cyprus in terms of adverse consequences for human health, environment, cultural heritage and economic activity for the period 1859-2011 is presented in Figure 2-29.

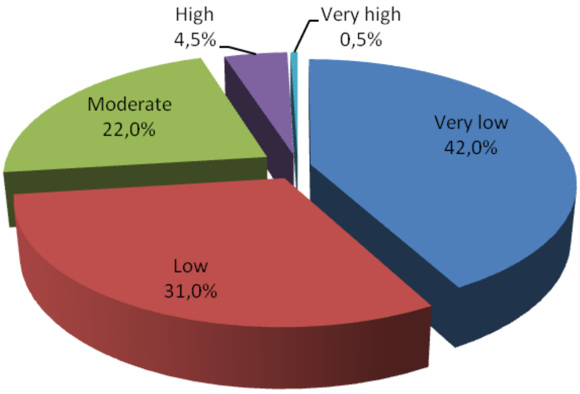


Figure 2-29: Hazard ranking of flooding events during the period 1859-2011

As it can be seen from the figure above, most of the flooding events in Cyprus are characterized as of "Very low" hazard (42%) and "Low" hazard (31%), while 4,5% of the events are characterized as of "High" hazard and only 0,5% as "Very high".

The damages caused by a flooding event with a given amount of precipitation depend on four factors: (i) the existing flood protection works, (ii) the degradation of the natural environment resulting in the increase of flooding runoff volume and the decrease of the time of water flow, (iii) the intensity of human activity in flood risk areas (exposure) and (iv) the vulnerability of assets exposed to floods. The current vulnerability of Cyprus regarding flooding events will worsen with climate changes (WDD, 2011d).

According to WDD, the recorded floods in Cyprus for the period 1859-2011 are characterized as urban floods (37%), flash floods (20%), river or fluvial floods (16%), pluvial or ponding floods (13%), or a combination of the above (WDD, 2011d).

The urban centers of Larnaca, Limassol and Nicosia are sensitive to flood risks mainly due to their dense structuring and the restriction of green space, the elimination of natural waterways for the construction of roads, the deficient or even absent stormwater drainage system and the covering of waterways and drain entrances with garbage. On the other hand, mountain areas are less sensitive to floods, given that the inclination of terrain together with the infiltration capacity of forested areas do not allow for flooding events to take place. To sum up, urban areas are considered to present **moderate to high** sensitivity to floods while mountain areas present **limited** sensitivity to floods.

In compliance with the Floods Directive 2007/60/EC, the Water Development Department of MANRE through its report "Preliminary Flood Risk Assessment" identified 19 areas around the island as "Areas with Potential Significant Flood Risk". Those areas have a total length of 135 km and are distributed uniformly to all urban centers of Cyprus (no mountain areas included). They mainly refer to river parts that pass through built-up areas and are characterized by frequent and significant flash floods. In addition, the areas of Larnaca, Tremithos and Alambra are included in order to be taken into consideration in the next 5-

year planning in case the projected flood protection works in Larnaca and Alabra and the existing protection zone of Tremithos river bed do not reduce the problem (WDD, 2011d).

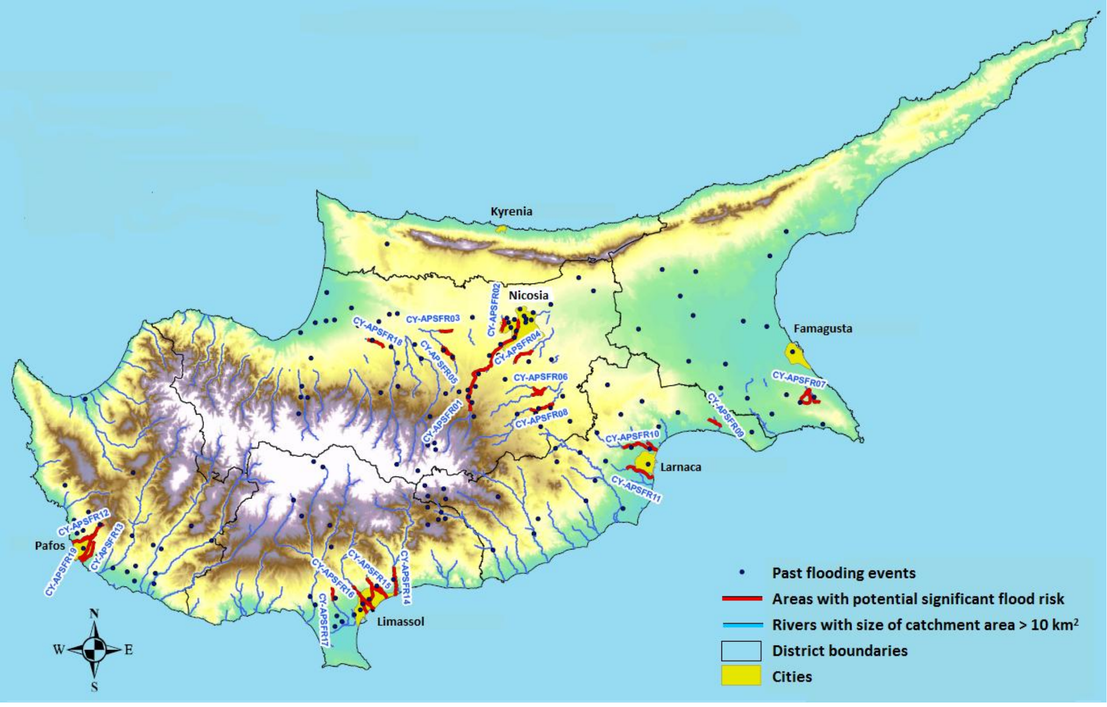


Figure 2-30: Areas with potential significant flood risk in Cyprus

Source: WDD (10)

As it can be seen from the map (Figure 2-30) the areas susceptible to floods are mainly the urban centers.

The climate projection model used for the case of Cyprus does not provide estimates for the frequency and intensity of floods in the future. Nevertheless, there is an indicator referring to the annual maximum total precipitation over one day indicating heavy rainfall, which could also be associated with flood risk. However, the PRECIS model showed that there will be no significant changes to this indicator in the future period (2021-2050). In particular, a slight increase of about 2-4 mm is anticipated in western, inland and mountain regions. Additionally, southern and southeastern areas present an increase of about 1 mm. It must be noted though that this indicator alone is not sufficient for estimating flood risk since other factors play an important role as well.

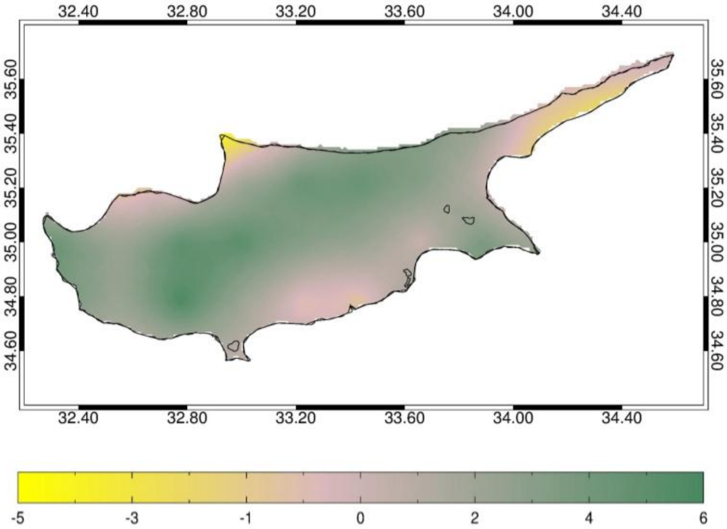


Figure 2-31: Changes in annual maximum total precipitation over 1 day between the future (2021-2050) and the control period (1961-1990)

Considering that the main areas that are expected to be exposed to increased precipitation intensity in the future, with a minor difference though, are concentrated in the greater area of Troodos mountain, it is considered that the exposure to floods of the mountain areas of Cyprus is expected to be **moderate** while the exposure of urban areas is considered to be **limited**.

2.4.3.2 Assessment of adaptive capacity

Cyprus' adaptive capacity to the increasing frequency and intensity of flooding events can be estimated by the existing flood protection works and the river protection zones as well as by the projected plans for the management of future flood risks.

The last two decades, a separate drainage system is being developed In Cyprus in order to collect stormwater. So far, the drainage network in the majority of the big urban centres of Cyprus has been completed. Furthermore, the Sewerage Board of Limassol-Amathus in cooperation with the five municipalities of the Greater Limassol area as well as the wider area of Paphos began the implementation of Sustainable Urban Drainage Systems (SUDS). Sustainable Urban Drainage Systems (SUDS) are used for the reduction of flood risks and the exploitation of stormwater for aquifer recharge. For example, in Limassol the construction of four stormwater retention ponds is promoted, with a total capacity of 200,000 m^3. The first pond has already been formed in part of the flood protection work west of the port. The second pond has been scheduled as part of the flood protection works in the area west of the A'Industrial Zone of Limassol. In the Paralimni lake there is channel system which controls the water outflow from the lake (flood protection work), recharges the aquifer and sends water to dam. Moreover, the area of Paphos has been identified as a suitable area for the implementation of SUDS while for the case of Larnaca due to its topography, no suitable measures have been identified. In Nicosia, no such initiatives have been implemented yet (WDD, 2009b).

In addition, it must be mentioned that storage reservoirs act as a flood control measure as the water is impounded in the dam and its downstream release is regulated even in the case of an overflow.

The Law 70(I)2010 on the Flood Risk Assessment, Management and Preparedness, which harmonizes the Floods Directive 2007/60/EC with the Cypriot legislative framework states that Flood Hazard maps and Flood Risk maps must be prepared by the end of 2013, while Flood Risk Management Plans must be prepared by the end of 2015. As it was mentioned in previous section of this report, the WDD has already implement preparatory steps in conformity with the EU Directive for the Preliminary Assessment of Flood Risks and has identified 19 areas in Cyprus as areas for which Potential Significant Flood Risks exist or might be considered likely to occur. It is expected that the identification of those areas will motivate the relevant authorities in order to implement all the necessary flood protection works in the framework of the Flood Risk Management Plans.

Considering the above, the adaptive capacity of Cyprus to urban floods is estimated as **moderate**.

In addition, the adaptive capacity of mountain areas to floods is estimated by their inherent ability to absorb water due to the high infiltration capacity of vegetated areas and thus to prevent flooding. Thus the adaptive capacity of mountain areas to floods in mountain areas is considered **high**.

The maintenance and restoration of wetlands and riverbeds as natural defense against floods constitute an additional recommended adaptation measure that is considered to further enhance adaptive capacity towards this impact. Nevertheless, its assessment and final selection for implementation will be made through the use of the Multicriteria Analysis (MCA) tool which will be developed and implemented in the framework of Actions 4 and 5 of the CYPADAPT project.

2.4.4 Droughts

2.4.4.1 Assessment of sensitivity and exposure

Cyprus with very limited water resources is vulnerable to droughts as it has exploited most of all its natural water resources, with most of its aquifers depleted, and no perennial rivers. In order to estimate sensitivity to droughts in Cyprus, the **Sensitivity to Desertification Index** (SDI) is used. This index has been used in the project "Desertification Information System to Support National Action Programmes in the Mediterranean" (DISMED), where the EEA is involved, in order to map sensitivity on desertification and drought. The index was obtained from the geometrical average of three indexes of the soil quality, climate and vegetation.

Although Cyprus was not included in this study, a study was assigned to I.A.C.O. Ltd by the Department of Environment of MANRE in 2007 in order to designate the sensitive areas to desertification in Cyprus. The designation of the areas threatened by desertification, under the concept of Environmentally Sensitive Areas (ESA), was made by analyzing factors and processes leading to desertification based on available data in Cyprus and international references. For the detailed designation of the ESAs, accepted indices for the evaluation of potential desertification have been used (MEDALUS, European Commission) after adjustment to the Cyprus conditions.

Employing the definition for the areas sensitive to desertification (FAO-UNESCO) by using the bioclimatic index P/ET_0, where P is the mean annual rainfall and ET_0 the potential evapotranspiration, showed that in Cyprus there are two climatic zones that are considered as sensitive to desertification; the semi-arid area which extends over the larger part of the island and the arid sub-humid area which covers the slopes of the Troodos range to the higher parts of the Kyrenia range.

The areas that do not face any desertification problem (values >0,65) are only 1,5% located at the highest parts of the Troodos Mountains. This area is enveloped by a sub-humid area (4,5%) of a reduced sensitivity. The largest part of the remaining areas (91%), are characterized as semi arid with an increased sensitivity while 3% are immediately threatened. Figure 2-32 presents the designation of the ESAs in Cyprus.

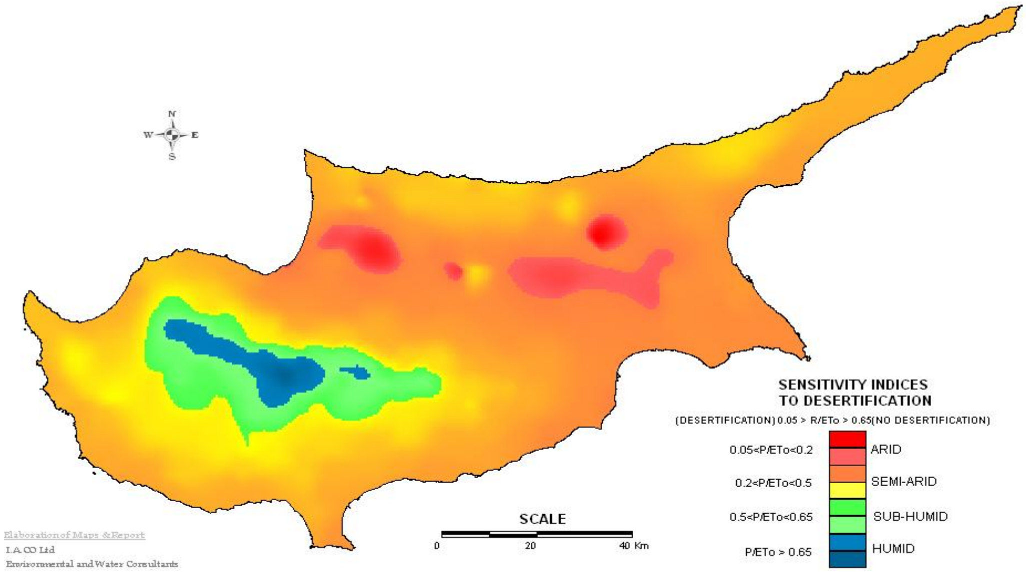


Figure 2-32: Environmentally Sensitive Areas to Desertification

Source: I.A.C.O. Ltd, 2007

Given that 91% of the total area of Cyprus was characterized as critical or sensitive, Cyprus' sensitivity to drought is considered to be **very high**.

During the period 1969-2010, Cyprus has suffered from a number of severe droughts. In all cases, the events initiated as meteorological droughts but very quickly they developed into hydrological droughts since Cyprus has no perennial rivers and the rivers length is very short. As shown in Table 2-15, drought phenomena in Cyprus are very frequent, persistent and severe since reduced precipitation in relation to the average precipitation of 1961-1990 (503 mm) was observed for up to 8 consecutive years with the deficit reaching 640 mm. In view of the possible future increases in drought frequency not only in the Mediterranean region but across Europe as well as a consequence of climate change, Cyprus vulnerability to drought may increase.

Table 2-15: Consecutive years with precipitation below normal (<503 mm) in Cyprus, 1969-2010

Hydrological year	Mean precipitation (mm)	Difference from normal (mm)	Remarks
1969/70	398.4	-104.6	5 consecutive years Deficit: 608.5 mm
1970/71	497.9	-5.1	
1971/72	408.3	-94.7	
1972/73	212.7	-290.3	
1973/74	389.2	-113.8	
1981/82	424.7	-78.3	5 consecutive years Deficit: 271.6 mm
1982/83	437.5	-65.5	
1983/84	448.3	-54.7	
1984/85	497.9	-5.1	
1985/86	435.0	-68.0	

Hydrological year	Mean precipitation (mm)	Difference from normal (mm)	Remarks
1988/89	480.5	-22.5	3 consecutive years Deficit: 384.1 mm
1989/90	362.5	-140.5	
1990/91	281.9	-221.1	
1993/94	416.7	-86.3	8 consecutive years Deficit: 640.6 mm
1994/95	493.0	-10.0	
1995/96	383.0	-120.0	
1996/97	399.0	-104.0	
1997/98	387.8	-115.2	
1998/99	473.0	-30.0	
1999/00	363.2	-139.8	
2000/01	467.7	-35.3	
2004/05	412.1	-90.9	4 consecutive years Deficit: 488.2 mm
2005/06	360.1	-142.9	
2006/07	479.3	-23.7	
2007/08	272.3	-230.7	

Source: Meteorological Service of Cyprus

During the extended drought period of 2004/05–2007/08, lower than average rainfall resulted in minimal flow of water in the dams. By the beginning of 2008, water reserves in dams were almost depleted, giving rise to the need to adopt costly temporary measures in order to meet consumers needs for drinking water during the summer of 2008 (e.g. import of drinking water with tankers from Greece, imposition of severe cuts to water supply to households and to agriculture), which resulted in the dramatic reduction of farmers' yields. Households were supplied with water for around 12 hours a day, three times a week (EEA, 2010).

With the use of PRECIS regional climate model, the future changes (2021-2050) in the maximum length of the period with consecutive dry days (precipitation<0.5mm) per year were calculated. Figure 2-34 depicts that the areas of Nicosia and Larnaca reveal increases of about 10 days and Limassol presents an increase of about 12 days, while the western area of Paphos shows no increases. As a result, the maximum length of dry spell per year is expected to reach 110 days in Larnaca and Nicocia Districts and 80 days in Limassol District in contrast with the control period where the maximum length of dry spell is 100 days and 70 days respectively (Figure 2-33). Consequently, the areas of Larnaca, Nicosia and Limassol are expected to be under severe drought stress in the future.

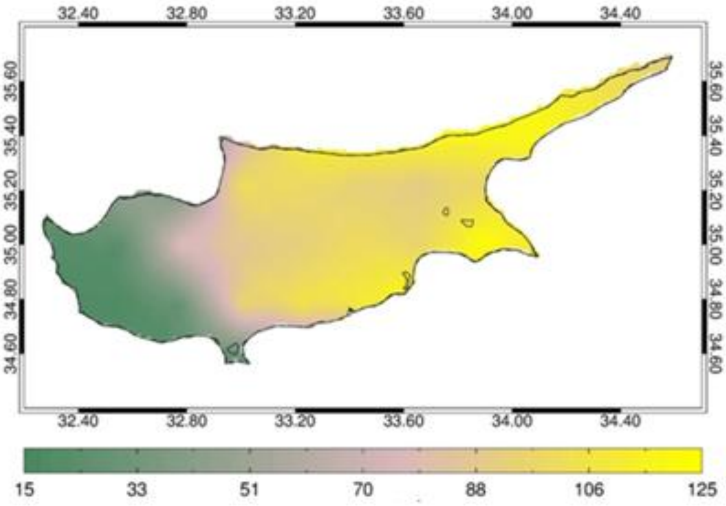


Figure 2-33: Maximum length of dry spell (RR<0.5mm), control period (1961-1990)

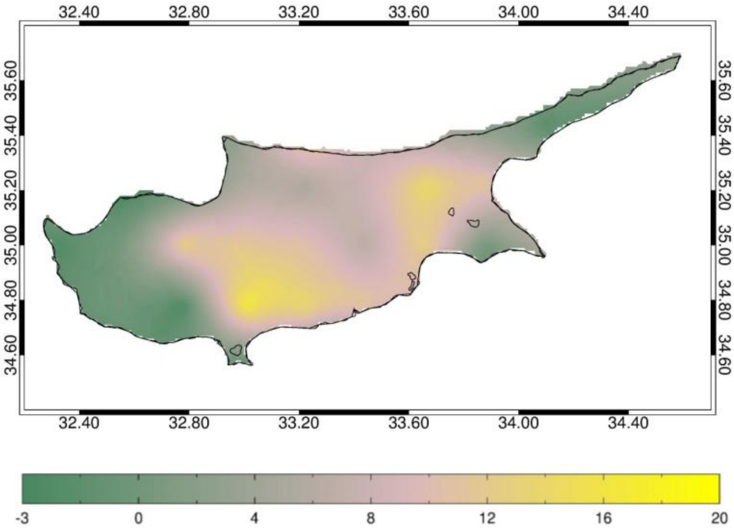
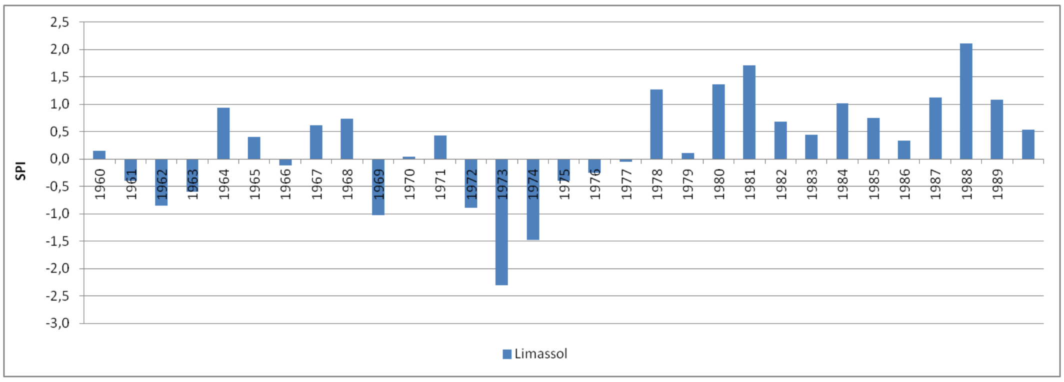
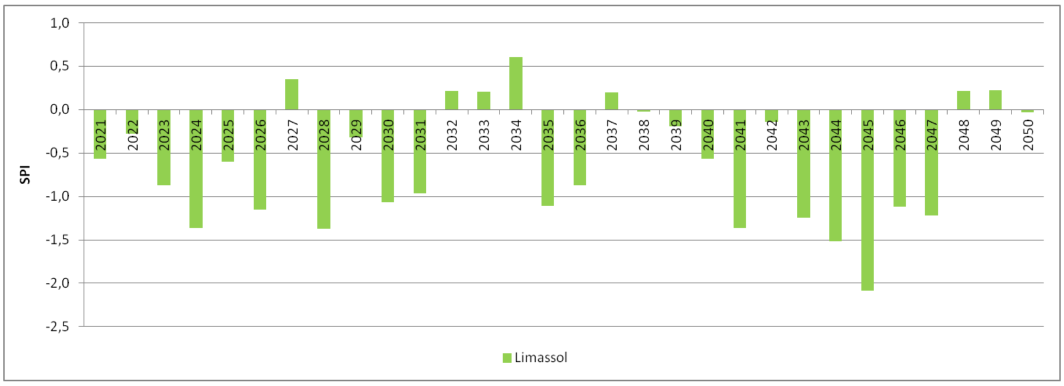
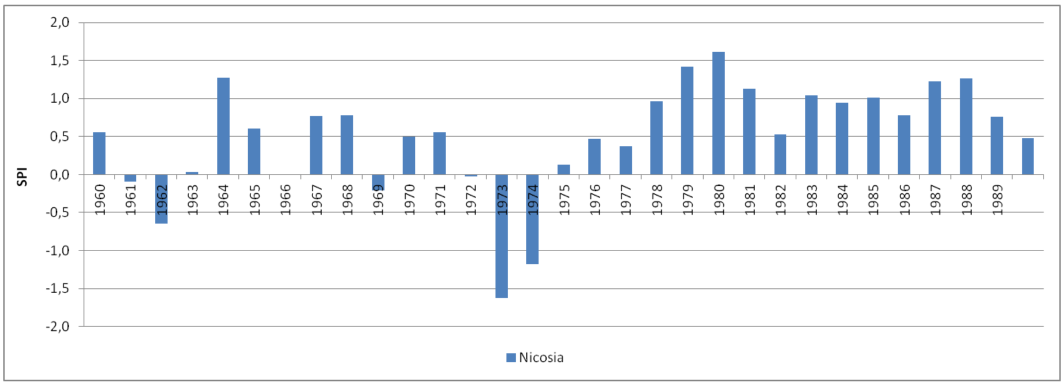


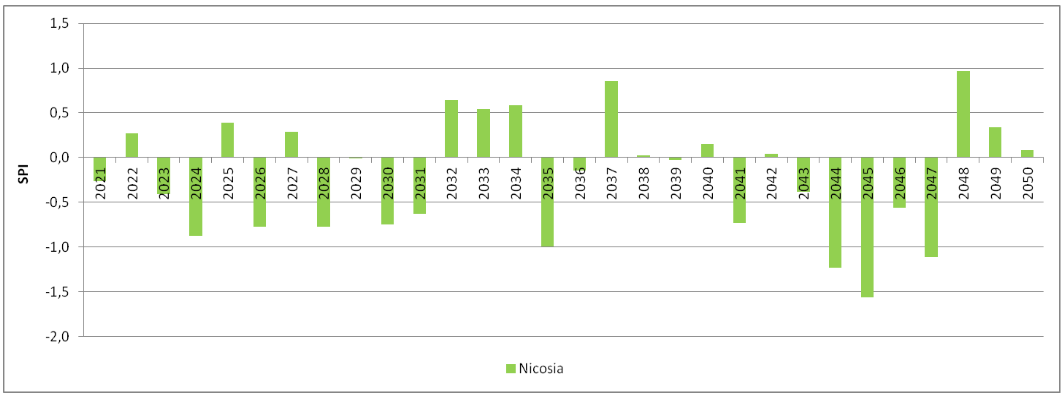
Figure 2-34: Changes in maximum length of dry spell (RR<0.5mm) between the future (2021-2050) and the control period (1961-1990)

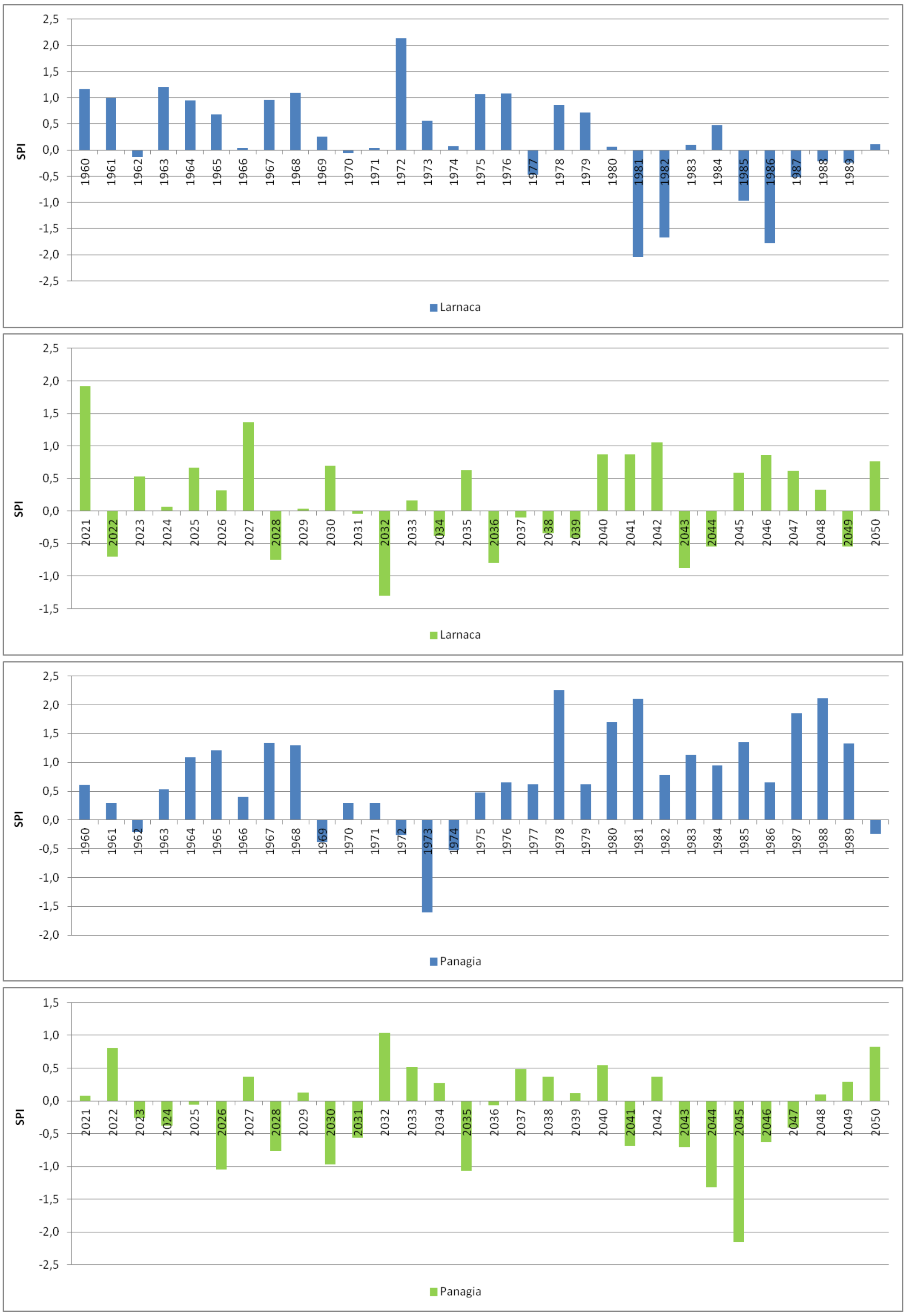
The Standardized Precipitation Index (SPI) (McKee et al., 1993) is designed to quantify the precipitation deficit for multiple time scales (3 – , 6 – ,12 – , 24 – , and 48 – month time scales). These time scales reflect the impact of drought on the availability of the different water resources. Soil moisture conditions respond to precipitation anomalies on a relatively short scale. Groundwater, streamflow, and reservoir storage reflect the longer - term precipitation anomalies. For these reasons, the SPI for the 12 month time scale was computed for four different areas in Cyprus (Limassol, Nicosia, Larnaca, Panagia), using as input the precipitation projection produced by PRECIS. Positive SPI values indicate greater than median precipitation, and negative values indicate less than median precipitation. Because the SPI is normalized, wetter and drier climates can be represented in the same way, and wet periods can also be monitored using the SPI. In the following figure, the differences between the control period (1960-1990) SPI and the future period (2021-2050) SPI are depicted.











	SPI Value	Characterization
	0 - (-0,99)	Mild drought
	(-1) - (-1,49)	Moderate drought
	(-1,5) - (-1,99)	Severe drought
	< (-2)	Extreme drought

Figure 2-35: Standard Precipitation Index for Limassol, Nicosia, Larnaca, Panagia for the periods 1960-1990 and 2021-2050

As can be seen in Figure 2-35, during the period 1960-1990 the area of Limassol which is located at the southern coast of Cyprus was characterized by 9 years of mild drought, 1 year of moderate drought and one year of extreme drought. In the period 2021-2050 it is estimated that Limassol will be characterized by 10 years of mild drought, 7 years of moderate drought, 1 year of severe drought and 1 year of extreme drought.

During the period 1960-1990 the area of Nicosia which is a continental lowland area of Cyprus was characterized by 5 years of mild drought, 1 year of moderate drought and one year of severe drought. In the period 2021-2050 it is estimated that Nicosia will be characterized by 14 years of mild drought, 2 years of moderate drought and 1 year of severe drought.

During the control period (1960-1990) the area of Larnaca which is located at the southeastern coast of Cyprus was characterized by 7 years of mild drought, 2 years of severe drought and one year of extreme drought. In the period 2021-2050 it is estimated that Larnaca will be characterized by 10 years of mild drought 1 year of moderate drought.

Finally, during the period 1960-1990 the area of Panagia, which is a high elevation area located at the district of Pafos, was characterized by 5 years of mild drought and one year of severe drought. In the period 2021-2050 it is estimated that Panagia will be characterized by 11 years of mild drought, 3 years of moderate drought and 1 year of extreme drought.

Taking into consideration the abovementioned indicators, it can be concluded that the future exposure of Cyprus to droughts is **very high**.

2.4.4.2 Assessment of adaptive capacity

Drought management is an essential element of water resources policy and strategies in EU but especially in drought prone areas, such as Cyprus. Following up the recent drought management of 2008 in Cyprus, it was found that adaptive strategies were limited. Dealing with the shortfall of water resources consisted of corrective and emergency measures with the implementation of drought mitigation plans. Decision makers have reacted to drought episodes mainly through a crisis-management approach by declaring a national or regional drought emergency programme to alleviate drought impacts. Nevertheless, nothing can be done to reduce the recurrence of drought events in a region. Therefore, drought management should not be regarded as managing a temporary crisis. Rather, focus must be given on developing comprehensive, long-term drought preparedness policies and plans of actions that place emphasis on monitoring and managing emerging stress conditions and other hazards associated with climate variability in order to significantly reduce the risks and vulnerabilities to extreme weather events (WDD, 2011a – Annex VIII).

According to the European Commission (EC, 2008) Drought Management Plans (DMP) should be prepared in advance before they are needed, based on relevant country specific legislation and after careful studies are carried out concerning the characterization of the drought in the basin, its effect and the mitigation measures. The main objective of drought management plans is to minimize the adverse impacts on the economy, social life and environment when drought appears. This general objective can be developed through a series of specific objectives that might include:

- Guarantee water availability in sufficient quantities to meet essential human needs to ensure population's health and life.
- Avoid or minimize negative drought impacts on the status of water bodies, especially on ecological flows and quantitative status for groundwater and in particular, in case of prolonged drought, as stated in article 4.6. of the WFD.
- Minimize negative effects on economic activities, according to the priority given to established uses in the River Basin Management Plans, in the linked plans and strategies (e.g. land use planning).

The Water Development Department of Cyprus has elaborated a Drought Management Plan in 2010 (WDD, 2011a – Annex VIII) in order to address these issues. The DMP of Cyprus structures upon the EU policy on drought management and is closely linked with the Government Water Policy which is based on the Framework Directive (WFD) criteria and objectives. The main elements of the Cyprus DMP are:

- An early warning system based on hydrological indicators
- A correlation of indicators with thresholds for different drought stages to trigger action
- A set of phase-specific measures to achieve objectives[6]

The main index for each hydrologic region is selected to be the corresponding 12 month SPI based on which the alert status is decided. The 12 month runoff index is used as a check on the SPI, since there is no past implementation of this system in Cyprus. In a case when the runoff index is more adverse than the SPI, a decision shall be taken by the responsible authorities. The alert level status for the River Basin Area (whole of Cyprus) is given by the worst alert level status of the different Hydrologic Regions. However, the drought management measures will apply only in the hydrologic regions it is required. As for the other indices, the wet period runoff index provides an early warning tool for the operators, since its calculation can provide an indication of drought earlier than the 12 month SPI. Finally, the storage capacity index concerns the alert level in relation to the Southern Conveyor and Paphos water projects and is directly related to the permissible abstractions (WDD, 2011a – Annex VIII).

The actions against drought according to the level of alert may include the notification of responsible operators, raising awareness for sustainable water use, notification of users for consumption reduction, increase in desalinated water production, intensive controls of abstractions and leakages, limits to the abstractions from dams, releases from dams only for river ecosystem protection.

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[6] This action will be elaborated in the Strategic Plan to be developed in the framework of the CYPADAPT project (Action 5)

According to the EU policy on drought (EC, 2008), a DMP should provide a dynamic framework for an ongoing set of actions to prepare for, and effectively respond to drought, including periodic reviews of the achievements and priorities, readjustment of goals, means and resources, as well as strengthening institutional arrangements, planning, and policy-making mechanisms for drought mitigation. Effective information, early warning systems and drought risk maps are the foundation for effective drought policies and plans, as well as effective networking and coordination between competent authorities in water management at different levels. In addition to an effective early warning system, the drought management strategy should include sufficient capacity for contingency planning before the onset of drought, and appropriate policies to reduce vulnerability and increase resilience to drought. When working towards a long-term drought management strategy, it is necessary to establish the institutional capacity to assess the frequency, severity and localisation of droughts and their various effects and impacts on crops, livestock, the environment and specific drought impacts on populations. This is rather a complex process that requires increased capacity, strong institutional structure as well as active administrative and public involvement.

Cyprus has considerably increased its adaptive capacity in coping with drought by adopting the EU guidelines on water and drought management. However, the Cyprus DMP and its Water Policy have recently implemented and have yet to be tested to prove their efficiency in achieving the abovementioned goals. For these reasons, Cyprus future adaptive capacity to droughts is considered **moderate**.

The enhancement of the Drought Management Plan is also recommended in order to further enhance adaptive capacity towards this impact. Nevertheless, its assessment and final selection for implementation will be made through the use of the Multicriteria Analysis (MCA) tool which will be developed and implemented in the framework of Actions 4 and 5 of the CYPADAPT project.

2.4.5 Assessment of overall future vulnerability

The principal aim of this chapter is to identify the key vulnerabilities of water resources to future climate changes, as well as to assess the magnitude of these vulnerabilities. However, it must be noted that, as there were no sufficient data to evaluate all indicators further research is required.

In order to quantify the future vulnerability potential of water resources against a climatic change impact, the values of sensitivity, exposure, adaptive capacity and vulnerability are quantified as follows:

Degree of sensitivity, exposure & adaptive capacity		Degree of vulnerability		Legend
None	0	None	V≤0	
Limited	1	Limited	0<V≤1	🟩
Limited to Moderate	2	Limited to Moderate	1<V≤2	🟨
Moderate	3	Moderate	2<V≤3	🟨
Moderate to High	4	Moderate to High	3<V≤4	🟧
High	5	High	4<V≤5	🟧
High to Very high	6	High to Very high	5<V≤6	🟥
Very high	7	Very high	6<V≤7	🟥
Not evaluated	-	Not evaluated	-	⬜

Since vulnerability is defined by the following formula:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity * \ Exposure$$

“Impacts” and “Adaptive capacity” should be evaluated on the same scale (1-7). For this to be achieved, the square root of “Sensitivity x Exposure” is used. The results of the future vulnerability assessment for the water sector in Cyprus are summarized in Table 2-16.

Table 2-16: Overall future vulnerability assessment of the water resources in Cyprus to climate changes

Impact		Sensitivity	Exposure	Adaptive Capacity	Vulnerability
Water availability for domestic water supply	in urban areas	Very high (7)	Very high (7)	High to Very high (6)	Limited (1)
	in mountain areas	Very high (7)	Very high (7)	Limited to Moderate (2)	High (5)
Water availability for irrigation	in plain & coastal areas	Very high (7)	Very high (7)	Moderate (3)	Moderate to High (4)
	in mountain areas	Very high (7)	Very high (7)	Limited to Moderate (2)	High (5)
Water quality	of surface water bodies	Moderate to High (4)	Limited to Moderate (2)	Moderate (3)	None (-0.2)
	of groundwater bodies	High to Very high (6)	High to Very high (6)	Limited to Moderate (2)	Moderate to High (4)
Floods	in urban areas	Moderate to High (4)	Limited (1)	Moderate (3)	None (-1)
	in mountain areas	Limited (1)	Moderate (3)	High (5)	None (-3.3)
Droughts		Very high (7)	Very high (7)	Moderate (3)	Moderate to High (4)

As it can be seen from the table above, the 'first priority' vulnerabilities for the water sector in Cyprus, are related to the water availability for domestic water supply and irrigation in mountain areas. Water supply in Cyprus is characterized by very high sensitivity and exposure to climate changes while mountain areas have low adaptive capacity to cope with these changes mainly due to the insufficiency of government water works attributed to techno-economical reasons.

The 'second priority' vulnerabilities of the sector are related to the water availability for irrigation in plain and coastal areas, groundwater quality and droughts. Although water availability in plain and coastal areas is enhanced by government water works and the competition for water between the domestic and the agricultural sector is not so intense, it does not always meet actual water demand for irrigation (especially during drought periods). Groundwater quality is considered a crucial issue in light of climate changes since the majority of groundwater bodies are already in a bad qualitative situation while their rehabilitation is very slow. Droughts present an equally important vulnerability for the water sector, since droughts are a common phenomenon in Cyprus and are expected to be more frequent in the future, while the measures that are being taken, manage only to avoid the worst effects but not to eliminate all adverse consequences.

Water availability for domestic water supply was estimated to present limited vulnerability to climate changes since although freshwater resources most of the times are not sufficient for satisfying demand for drinking water, the Government of Cyprus has undertaken a series of drastic measures, thus relieving the island from such a pressure.

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3 SOIL RESOURCES

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Abbreviations and Acronyms

CIAM	Centre for Integrated Assessment Modelling
CLIMSOIL	Climate Change Soil Carbon
DOA	Department of Agriculture
DoE	Department of Environment
DoF	Department of Forests
FWI	Fire Weather Index
EEA	European Environment Agency
EMEP	European Monitoring and Evaluation Programme
FAO	Food and Agriculture Organization
ies	Institute for Environment and Sustainability
JRC	Joint Research Centre
MANRE	Ministry of Agriculture, Natural Resources and Environment, Republic of Cyprus
MCA	Multi Criteria Analysis
NRCS	Natural Resource Conservation Service
PRECIS	Providing Regional Climates for Impact Studies
PWP	Permanent Wilting Point
RCM	Regional Climate Change
RDP	Rural Development Programme
SSSA	Soil Science Society of America
SOC	Soil Organic Carbon
SOM	Soil Organic Matter
UNEP	United Nations Environment Programme
USDA	United States Department of Agriculture
NRCS	Natural Resources Conservation Service
WDD	Water Development Department
WHO	World Health Organization

The thin layer of soil covering the earth's surface represents the difference between survival and extinction for most terrestrial life.

(Doran & Parkin, 1994)

3.1 Climate change and soil resources

Soil is, certainly, one of the most important variables, as it is necessary for the comprehension of the landscape evolution, erosion and sedimentation, environmental change, natural hazards and in general subsurface geology (World Resources Institute, 1990). Climate change could change or endanger ecosystems and the many goods and services they provide, mainly due to the strong influence over dryland vegetation type, biomass and diversity (WMO, 2005). Many soil properties and processes will be influenced by alteration of spatial and temporal patterns in temperature, rainfall, solar radiation and winds enhancing the existing problem of soil degradation. However despite the significance of the problem, there is still no concerted effort at global level for the systematic monitoring of the impacts of different climatic factors on land degradation in different regions and for different classes of land degradation (WMO, 2005).

The soil sector is highly dependent on climate. Direct impacts of climate change on Cyprus soil sector, arise mainly from decreased rainfall, increased temperature, droughts, fluctuations in intense precipitation events, sea level rise, increased atmospheric CO_2 and wind speed. Those climatic parameters can cause changes in soils through complicated physical procedures (directly and indirectly).

The impact, vulnerability and adaptive measures for the soils sector in Cyprus regarding climatic changes was assessed in Deliverable 1.2. The main vulnerability priorities for the soil sector of Cyprus are the extensive desertification and the soil erosion by rain water and soil salinzation. In specific, the first priority of Cyprus on soils seems to be the phenomenon of desertification, as 57% of the island is characterized as “Critical”, 42,3% as “Fragile” and only 0.7% as “Potential” to desertification. Soil erosion, which is actually one of the factors causing desertification, constitutes also key vulnerability for the soils resources of Cyprus mainly due to the intensive agricultural activities taking place and the increasing percentage of abandoned rural land. Soil salinization is the third vulnerability priority caused by the salinization of coastal aquifers and the irrigation with low quality (saline) water.

Future climate change impact, vulnerability and adaptation measures in the sector of soil resources will be reassessed for the case of Cyprus, in the framework of this study, in order for the future vulnerability potential of soils to be quantified. Future vulnerability priorities will be identified and appropriate adaptation measures to be implemented.

Each climatic parameter (rainfall, temperature, atmospheric emissions, wind) was analyzed for the future situation with the use of the PRECIS regional climate model through comparison between a control period (1961–1990) and a future period (2021–2050). Regional Climate Models of the ENSEMBLES project have also been used. The results of models were used as an ensemble mean for testing and comparing the respective results of PRECIS. Detailed information is available in Deliverable 3.2 while the main model used in this report is the PRECIS (Providing Regional Climates for Impact Studies) regional climate model. The reason is that while, in the other simulations models, Cyprus is placed in the south-eastern part of the domain in PRECIS simulations, Cyprus lies at the center of the study domain. The future period 2021-2050 has been chosen specifically for the needs of stakeholders and policy makers to assist their planning in the near future, instead of the end of the twenty-first century as frequently used in other climate impact studies.

3.2 Baseline situation

Soil provides a variety of requirements for plants -such as shelter, moisture storage and a supply of nutrients- and thus for animal life too. The common denominator of all soil problems is soil degradation. This issue has affected many countries of the world, as more than 1.2 billion hectares in 1990 were areas of severe concern for soil degradation (World Resources Institute, 1990).

Cyprus due to its geographical position in the eastern part of the Mediterranean Sea, bears all the characteristics of a semi-arid climate and some of the deficits of the global climate change. During the latest decades, remarkably low precipitation has been recorded, rating the island in the second most threatened zone in terms of land degradation (Figure 3-1).

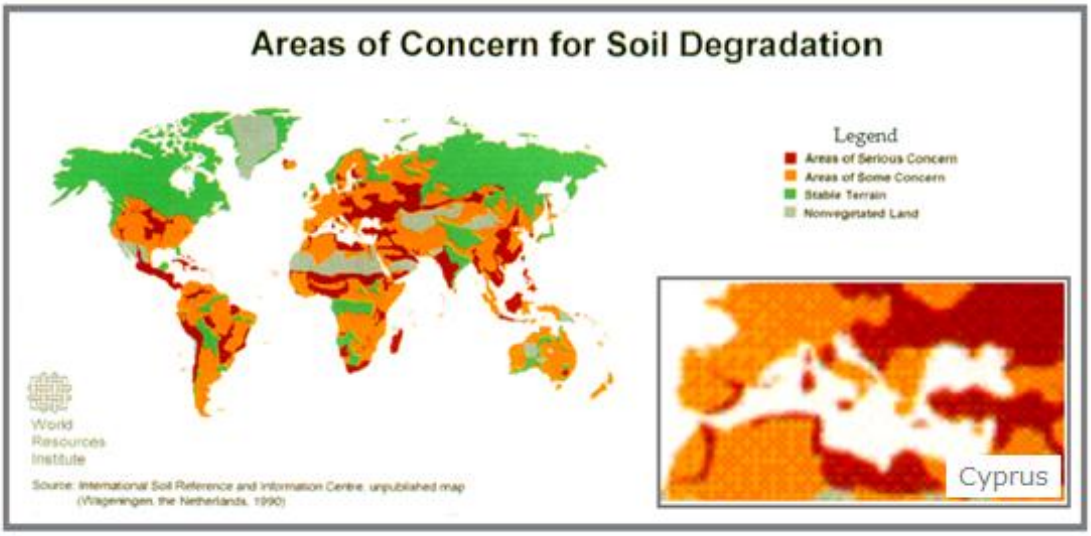


Figure 3-1: Areas of concern for soil degradation

Source:World Resources Institute, 1990

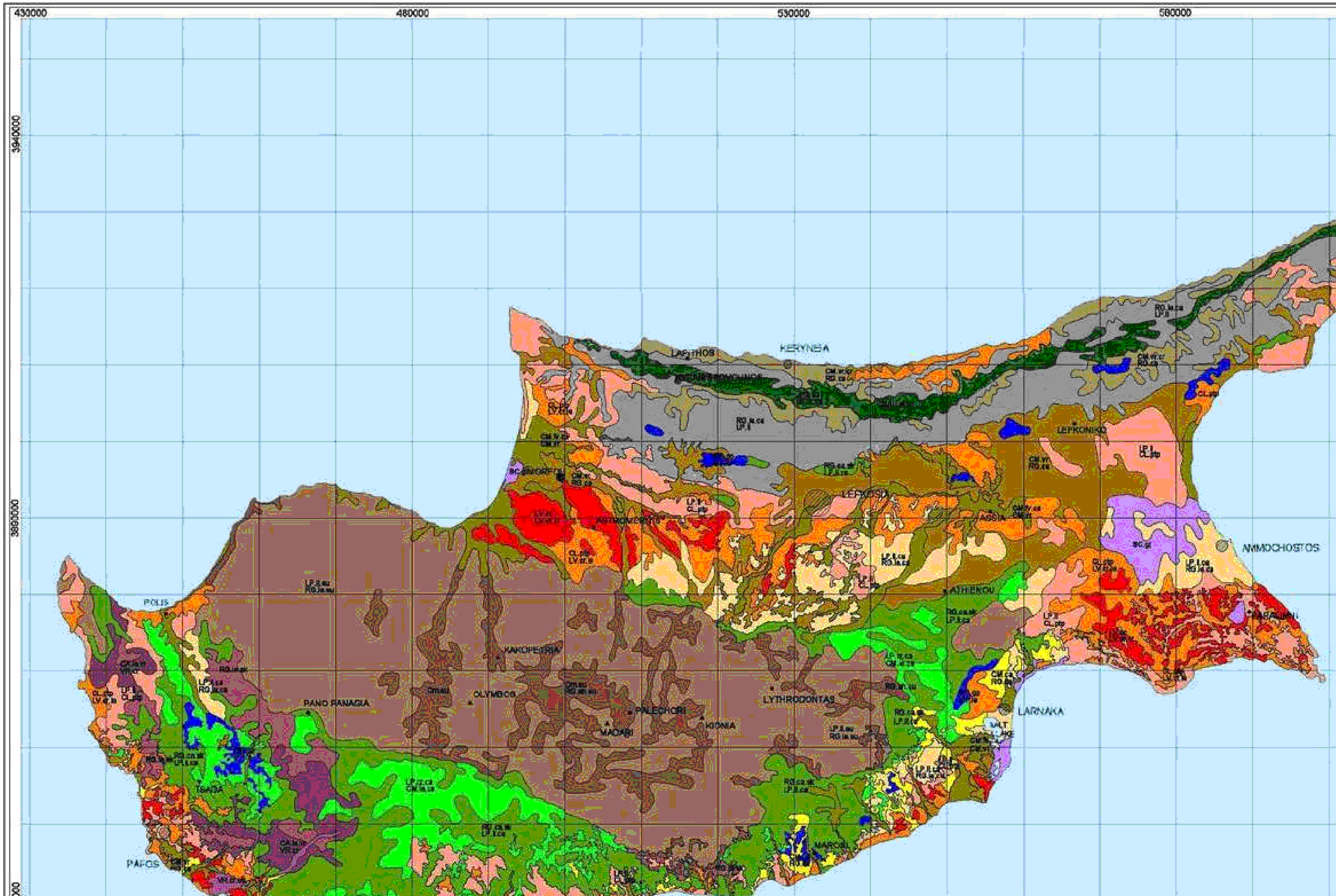
The island of Cyprus is characterized by two mountains regions (the limestone range of Kyrenia and the Troodos range), a central plain of Mesaoria and the coastal plains. Slopes in excess of 18% and 12% cover 10% and 22% of the island. The geological background of the island of Cyprus is formed by three geological zones: a) the ophiolithic complex of the Troodos Mountain range and its extension under the Mesaoria, b) the Mamonia zone and c) the Kyrenia Mountain range consisting mainly of allocthonous formations. In between these lie the autochtonous sedimentary rocks (Republic of Cyprus, Geological Survey Department; I.A.CO Ltd, 2007).

There have been extensive researches for the identification-determination of the physical and chemical soil properties and the classification of the various soil types for the island of Cyprus since 1957 (Hadjiparaskevas). According to the latest system for soil mapping, the dominant soil types in Cyprus are leptosols, regosols, cambisols and associated soil groups, as shown in Table 3-1 and Figure 3-2.

Table 3-1: Main soil groups in Cyprus based on the FAO (1998) classification. Data from Hadjiparaskevas(2008).

Soil order	Sub-order	Characteristics
Lithosols	Calcaric Eutric	Limited in depth by continuous coherent and hard rock within 10 cm of the surface.
Fluvisols	Calcaric Eutric	Recent alluvial deposits, having no diagnostic horizons other than an Ochric A or a histic H horizon.
Regosols	Calcaric Eutric	Uncosolidated material, having no diagnostic horizons other than an ochric A horizon.
Rendzinas		Mollic horizon immediately overlying extremely calcareous material.
Solonchaks	Gleyic Orthic	High salinity within 125 cm of the surface (EC > 15 mmhos).
Solonetz		Natric B-horizon.
Ventisols		40% or more clay in all horizons, developing wide cracks from the soil surface downwards.
Cambisols	Ventic Calcaric Calcic Eutric Chromic	Cambic B-horizon and no diagnostic horizon other than an ochric or an umbric A horizon, a calcic or a gypsic horizon.
Luvisols	Vertic Calcic Chromic	Argillic B-horizon.

Source: Biochemical atlas of Cyprus (Cohen & Rutherford, 2011)


430000
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LAPITHOS
KERYNEIA
LEFKONIKO
MORFOU
LEFKOSIA
ASSIA
AMMOCHOSTOS
ATHIENOU
POLIS
KAKOPETRIA
PANO PANAGIA
OLYMBOS
PALECHORI
MADARI
KIONIA
LYTHRODONTAS
LARNAKA
TSADA
PAFOS

Several factors of climate change deteriorate some environmental phenomena or create new more complicated conditions for the soils of Cyprus. Considering the above as well as the study conducted by I.A.CO. (2007), the additional pressures on soil resources of Cyprus as a result of several activities are listed below:

- Eutrophication due to contaminated waters.
- Degradation of soil productivity due to desertification (I.A.CO Ltd, 2007).
- Changes in plant species distribution due overexploitation and contamination of surface and ground water (DoE, 2000), affecting soil biodiversity.
- Changes in forest plant species distribution in the abandoned parts of the unprotected state forests, affecting soil organic matter.
- Soil retrogression and changes in soil biodiversity due to overgrazing.
- Increased carbon sequestration due to the reforestation of croplands.
- Loss of organic carbon because of the tilling of the land.
- Soil changes due to changes of the land use.
- Degradation of soils near the seashore due to tourism development.
- Land degradation of cities due to urbanization.
- Increased erosion of soils due to the the aging of the rural population, and the abandonment of the rural areas and the traditional agricultural activities.
- Soil salinization from the water from the overexploited aquifers which experience salinization as the result of sea intrusion (increased water need in the center and south of the island after the forced movement of people in 1974 that Turkish invasion took place).

Additional pressure on soil resources may have a severe impact on natural ecosystem (climate, ecology) and human social system (society, culture and technology) as well (World Meteorological Organization, 2005).

3.3 Future impact assessment

Alterations in the mean and extreme (maximum, minimum) values of factors of climate (rainfall, temperature, atmospheric emissions, wind) cause changes in soils through complicated physical procedures (directly and indirectly). The general correlations between the observed climate changes in Cyprus and the impacts on soil resources of temperate climates[1] are listed in the following table (Table 3-2).

The impacts of climate change on Cyprus's soil sector are considered to be the similar to the areas identified in Deliverable 1.2 with the observed ones, however as climate change factors are expected to change, the magnitude of the impacts is expected to change. According to PRECIS projections for the future period 2021-2050, the average annual temperature in Cyprus is expected to increase by 1-2°C with respect to the control period 1960-1990, while precipitation is expected to decrease in seasonal level and in minor degree in annual level. Concerning future changes of annual max total rainfall over 1 day, PRECIS projections show that a slight increase of about 1-4 mm is anticipated. Finally, regarding annual mean wind speed changes in the near future, PRECIS projections show that in western, southeastern and inland regions a slight decrease of about 0.20 m/s is anticipated while in southern and mountain regions a lower decrease of about 0.1 m/s is expected. PRECIS projections for extreme wind events, show a decrease of about 5-12 days for the number of days with mean wind speed greater than 5 m/s.

In this section the climate change impacts on the soil resources sector, as these have been identified in Deliverable 1.2 will be reviewed in light of the climate projections for the future (2021-2050). Table 3-2 shows the potential future climate-induced impacts on the soil resources sector in general, and for the case of Cyprus in particular are recorded. In the context of the future impact assessment the indicators presented in Table 3-2 summarize the potential impacts of climate change on Cyprus' soil resources.

Table 3-2: Relationship between potential climate changes and impacts on the soil resources sector

Potential climate change in Cyprus	Future impacts on soil resources in temperate climates
Decreased rainfall & increased temperature	– Some small chemical effects on soils, due to the increased evapotranspiration (Brinkman & Sombroek, 1996). – Negative effect on soil organic matter due to temperature rise (Brinkman & Sombroek, 1996). – Greater organic matter supply from vegetation or crops growing more vigorously because of the combined phenomena of the higher photosynthesis, the greater potential evapotranspiration and the higher water-use efficiency in a high-CO_2 atmosphere (Brinkman & Sombroek, 1996). – Mineralogical change of the stability of iron oxide haematite over the dominant goethite, leading to a decrease of the intensity and amount of

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[1] The table presents all the possible dimensions of the observed climate changes. The reason for presenting impacts on soil resources from other regions of the Mediterranean (similar to the climatic conditions of Cyprus) is to assist to the identification of components which have not yet been examined by the competent bodies.

Potential climate change in Cyprus	Future impacts on soil resources in temperate climates
	phosphate fixation and finally to the reddening of presently brown soils (Brinkman & Sombroek, 1996; Buol et al., 1990).
Droughts	– Decrease of soil moisture due to the decreased rates of groundwater recharge. – Reduction of crop yields (soil fertility) (Moore, 2005). – Removal of certain nutrients from soil (Moore, 2005). – Increased soil erosion. – Decrease in soil respiration (Vallejo et al., 2005). – Reduction of soil organic carbon (Vallejo et al., 2005). – Reduction of litter inputs with the uncertainty associated with this process (Vallejo et al., 2005). – Soil salinization (Vallejo et al., 2005).
Heavy and/or intense precipitation events	– Flooding and water logging of soil. – Landslides (Paul & Kimble). – Flooded upland soils cause oxygen depletion or reducing conditions, which may in turn affect the chemistry of the soil-water system and, consequently, soil aggregation (SSSA, 2009). – Deterioration of soil quality by making it more prone to erosion due to the raindrop impact (Proffitt et al., 1993). – Increased soil erosion due to poor vegetation.
Sea level rise	– Salinization of coastal soils (minor effect). – Changes in the geomorphology of the seashore.
Increased atmospheric CO_2	– Increase of growth rates and water use efficiency of natural vegetation, leading to increased night time respiration and shorter growth cycles which can cause unproductive periods in the soils of agro-ecosystems (Brinkman & Sombroek, 1996). – Increased productivity is accompanied by more litter, greater root activity and increased microbial activity. Microbial activity combined with higher concentrations of CO_2 lead to accelerated rates of plant nutrient release and inevitably to the increase of the quantity of plant nutrients cycling through soil organisms (Brinkman & Sombroek, 1996). – Greater microbial activity in combination with higher soil temperatures produce greater amounts of polysaccharides and other stabilizers leading to the increase of the “stable” soil organic matter content and stimulates further the microbial activity (macrofauna, earthworms), improving infiltration rate and bypass flow by the greater number of stable biopores. These phenomena increase the resilience of soil against water erosion and loss of soil fertility. In addition, the increased proportion of bypass flow also decreases the nutrient loss by leaching during periods with excess rainfall. – Despite the positive effects for the soil plant system, temporarily problems can be caused by the competition of plants for nutrients. This temporary effect is responsible for the impact of plant response to elevated CO_2 (Brinkman & Sombroek, 1996).
Changes in fire regimes (increased number of wildfires)	Burnt areas are more prone to erosion. An untouched area by fire near a burnt one is more prone to soil particle displacement by landslides. Soil hydrophobicity (Moss & Green, 1987). Degradation of soil biodiversity. Loss of organic matter.

The complexity of the impacts of climate change on soil resources is obvious, and as a result there are several indicators which can be used in order to present the soil condition of an area. In order to assess, the impacts of climate change are grouped in the following impact categories:

- Soil erosion (by wind and/or rain water
- Water retention capacity (reduction of available soil moisture) of soils
- Landslides
- Soil organic carbon content
- Loss of soil organic matter
- Soil biodiversity
- Soil Contamination (heavy metals, nitrates, phosphates, al saturation)
- Soil salinization - Sodification
- Desertification

3.3.1 Soil erosion (by wind and/or rain water)

The processes of soil erosion involve detachment of material by two processes, raindrop impact and flow traction; and transported either by saltation through the air or by overland water flow (JRC, 2012). Changes in the variables of climate (e.g. fading of wind speed, increase of mean precipitation) are highly connected with the wind and rain water erosion and furthermore the natural rate of soil erosion can be accelerated by human activity. Long dry periods along with regular strong seasonal winds are the main causes for wind erosion, while the force of raindrops, surface and subsurface runoff and river flooding are the main causes for rain water erosion (WMO, 2005). The impacts of these phenomena on soils are more obvious in lands with sparse vegetation cover, erodible soils of semi-arid zone with excess slope greater than 12% (Kosmas, 1999).

Situation in Cyprus: Wind speed, heavy rain or in the contrary long periods of drought in connection with poor vegetation, geology and the topography can have an erosive effect. Geology of the area in combination with the sparse vegetation and the increased frequency of heavy rainfall events are the main causes for the observed erosion in the plain areas of Cyprus. In order to have future estimations wind speed has been calculated for the future period (2021-2050).

Wind erosion

Wind erosion is not very common in Cyprus, but can take place in areas with low vegetation cover (I.A.CO Ltd, 2007), erodible or pulverized soils and hilly areas with slope greater than 12% (Kosmas, 1999).

In specific, soils with shallow rock contact (Leptosols, Lithosols, Lithic Xerorthents) -especially those formed on limestone of the semi-arid and arid zones, and soils of dry hilly areas have a reduced resistance to erosion. Such erodible soils are located in the central mass of Troodos range, due to their shallow, rocky with steep slopes features (slope of 18% and 12% cover the

10% and 22% of the island respectively). In those areas PRECIS projections for the future period (2021-2050) show that a slight decrease is anticipated in annual mean wind speed of about 0.1 m/s. Concerning future changes of extreme wind events, the number of days with mean wind speeds greater than 5 m/s is anticipated to decrease in mountain areas from 5 days to 10 days depending on the elevation. However soils of mountain areas due to vegetation cover are not prone to soil erosion. In other areas of Cyprus, not mountainous, were soil protection is lower, a decrease of about 12 days is anticipated in western, southeastern and inland areas while southern areas present a slight decrease of about 5 days. As a conclusion wind erosion in Cyprus will be a rare and very slow procedure.

Rain water erosion

Rain water can have an erosive result in soil horizons. For example, rain water erosion has already damaged the horizon A (topsoil consisting the first 0-25cm of ground) of many areas of the island of Cyprus, such as Aradippou-Koshi (I.A.CO Ltd, 2007). Soil erosion has obvious future impacts such as reduced soil fertility of the area, especially in areas where soils are shallow or have subsurface of low fertility.

Both heavy rainfall and ordinary rainfall can have an impact on soil erosion while in spring, when soils are most vulnerable because of degraded crop residue cover, soil preparation by tillage and no crop canopy, rains are coming hard and fast causing substantial soil erosion. Further research is essential to connect degree of soil erosion with intensity and amount of rain. In this frame, forecasting of rainfall intensity and frequency in the various seasons is of critical importance.

Heavy rain in Cyprus the future period (2021-2050) is anticipated to have an increase, in terms of annual max total rainfall over 1 day. In specific PRECIS projections show that a slight increase of about 2-4 mm is anticipated in annual max total rainfall over 1 day in western, inland and mountain regions. Additionally, southern and southeastern areas present an increase of about 1 mm in annual max total rainfall over 1 day. In this frame rain water erosion is not anticipated to be deteriorated due to heavy rainfall significantly.

Concerning ordinary rainfall, no change is anticipated in the future period (2021-2050) both for spring and summer total precipitation. However, a decrease of about 0-20 mm is anticipated in winter total rainfall for all the domain of study. As a result, for western and mountain regions were soil protection is high a precipitation of about 210 mm is anticipated, while for southern regions precipitation of 150mm respectively is forecasted. For southeastern district, that soil protection is low; precipitation will be about 70 mm in comparison with present-day climate where precipitation is 90 mm.

A similar pattern to winter is evident for autumn precipitation where a decrease of about 10-15 mm is anticipated for the whole study domain. More specifically future amounts of autumn rainfall will reach 55 mm in southeastern and southern district, that are low soil protection areas, 95 mm for mountain region and 135 mm for western regions, that are high soil protection areas compared with current amounts which are 70 mm, 110 mm and 150mm.

As a conclusion the minor future period (2021-2050) changes in precipitation are anticipated to have a major impact on soil erosion.

3.3.2 Water retention capacity (reduction of available soil moisture) of soils

Losses of water from soil is determined by soil texture, soil structure, porosity, consistence, bulk density, aeration and temperature, determine the rate at which water is lost from the soil (Danoff-Burg J. A., 2002). Furthermore, maintaining or even enhancing the water retention capacity of soils can play a positive role in mitigating the impacts of more extreme rainfall intensity and more frequent and severe droughts (EEA, JRC, WHO, 2008).

Situation in Cyprus: The soil composition, which is one of the most important factors for the water retention capacity of soils, varies across regions in Cyprus. The drainage conditions are excellent in the valley and coastal areas, the Chrysochou valley, the narrow valleys of GIalias, Pediaeos, Akaki and Peristerona, Troodos Igneous Massif and the areas of Episkopy-Akrotiri-Garyllis-Yermasoyia. In addition, the drainage conditions are satisfactory in Kokkinochoria and the area of Pissouri-Paralimni while less favourable in the area of Paphos (MANRE).

In order to extract safe conclusions regarding the future impact of climate changes on water retention capacity of soils, the following are considered necessary:

- Correlation with climatic conditions with clear distinction of the effect from human activities
- Determination of the water retention capacity of soils in Cyprus
- Data records of long-term series

3.3.3 Landslides

Landslides are caused by various factors which influence the terrain and the geo-environment, among which is climate. The following table (Table 3-3) presents the interrelations between the potential climate change factors and the associated potential impacts on soil structure, for the case of Cyprus.

Table 3-3: Potential slope stability responses to potential climate change factors in Cyprus

Potential climate change	Condition/process affected	Slope stability response
Increase in rainfall intensity	Infiltration more likely to exceed subsurface drainage rates. Rapid build-up of perched water tables.	Landslide triggering by reduction in effective normal stress leading to reduction in shear strength. Increase in cleft water pressures.
	Increased throughflow.	Increase in seepage and drag forces, particle detachment and piping. Piping removes underlying structural support. Enhances drainage unless blockage occurs.

Increased variability in precipitation and temperature	More frequent wetting and drying cycles.	Increase fissuring, widening of joint systems. Reduction in cohesion and rock mass joint friction.
Increased temperature	Reduction in antecedent water conditions through evapotranspiration.	Lower antecedent water status-more rain required to trigger slides.
	Rapid snow melt-runoff and infiltration.	Build-up of porewater pressure and strength reduction.
	Increased sea level.	Enhanced basal erosion on coasts, increase in groundwater levels on coastal slopes.

Source: Deciphering the effect of climate change on landslide activity: A review (Crozier, 2009)

Situation in Cyprus: Anticipated increase in temperature and number of heat wave days can cause reduction in antecedent water conditions through evapotranspiration, a rapid snow melt-runoff and infiltration and increased sea level. This could lead to lower antecedent water status-more rain required to trigger slides, build-up of pore water pressure and strength reduction and enhanced basal erosion on coasts, increase in groundwater levels on coastal slopes respectively. Furthermore the increase of frequency of heavy rain and the increase of flood events may provoke soil slippage events. The reason is that soil slippage is intensified by soil composition and excessive slope in certain areas of the Cyprus' mountains, especially near Paphos.

Although further research is required to correlate possibility of landslide events in Cyprus with anticipated changes in temperature and heavy rain events, climatic predictions are presented as a baseline for a future study. No projections have been made concerning future flood events. Further research is required.

Cyprus will experience, in the near future, a warming of about 1 –2°C. Seasonal changes in temperature are also anticipated. Average winter minimum and average autumn minimum temperature is anticipated to have an increase of 0.8 -1°C and 1.6-2°C respectively. Summer maximum temperature in the current period is 27-33°C while in the future period (2021-2050) it is anticipated to be increased about 1.7-2.7 °C, while spring maximum temperature will increased 1.5-1.8°C.

Concerning heat wave days an increase of about 10 days is expected in western regions, 20-30 days in mountain regions, and 30 days inland, southern and southeastern regions. Thus future heat wave days will be around 20 days, 40-60 days and 60 days respectively.

As far as heavy rainfall is concerned, future changes of annual max total rainfall over 1 day, PRECIS projections show that a slight increase of about 2-4 mm is anticipated in western, inland and mountain regions. Additionally, southern and southeastern areas present an increase of about 1 mm in annual max total rainfall over 1 day. In this frame rain water erosion is not anticipated to be deteriorated due to heavy rainfall significantly.

In order to extract safe conclusions regarding the impact of climate changes on landslides in a future study, the following are considered also as necessary:

- Correlation with climatic conditions and clear distinction of the effect from human activities
- Risk mapping of landslides in Cyprus
- GIS Landslide hazard mapping of Cyprus
- Data records of long-term series

3.3.4 Soil organic carbon content

Changes in climatic variables, such as the increase of temperature, can affect soil organic carbon. Some of the impacts of low organic carbon levels include the reduction in soil fertility, land degradation and depletion of biodiversity. In addition, the organic soils which act as carbon sinks will become a CO_2 and methane source due to the temperature rise, increasing greenhouse gases and subsequently climate change.

Situation in Cyprus: In Cyprus, the greatest carbon pool is soil, with an estimated amount of SOC around 3.884 thousand tons (DoF, 2006). It must be noted that the soil organic carbon content in soil material is in general low and sequestrated in the surface organic layer. Nevertheless, this percentage of SOC is typical for areas around the Mediterranean Sea.

There is no data available for the response of low level SOC to anticipated increase in temperature for Cyprus. Further research is required. However, in order to find correlation between temperature change and SOC level, prediction of temperature increase in Cyprus are presented as a baseline for a future study.

In specific, Cyprus will experience, in the near future, a warming of about 1 – 2°C. Winter minimum and summer maximum changes in temperature are presented as the seasonal cases with the most significant future changes. Winter minimum temperature is anticipated to have an increase of 1°C in western regions, mountain regions, inland and southern regions and an increase of 0.8°C in southeastern regions. Thus future temperatures will be around 9-13°C in western regions, 6°C in mountain regions, 6°C in inland regions,6°C in southern regions and 7°C respectively. Summer maximum temperature in the current period is 27-29°C for western regions, 30-32 °C for mountain regions, 33 °C for inland regions, 32 °C for southern regions and 33 °C for southeastern regions. In the future period it is anticipated to increase about 1.7-2 °C for western regions, 2-2.7 °C for mountain regions, 2.4 °C for inland regions, 2.3 °C for southern regions and 2.3 °C for southeastern regions. Concerning heat wave days an increase of about 10 days is expected in western regions, 20-30 days in mountain regions, and 30 days inland, southern and southeastern regions. Thus future heat wave days will be around 20 days, 40-60 days and 60 days respectively.

In order to extract safe conclusions regarding the anticipated increase in temperature and decrease in precipitation on soil organic carbon, the following are considered necessary:

- Data availability for a long period
- Correlation with climatic conditions and clear distinction of the effect from human activities

3.3.5 Loss of soil organic matter

Soil organic matter (*SOM*), as a major component of global carbon cycle (Schlesinger, 1997), can act both as a sink and a source of carbon in response to climate, land use changes and rising atmospheric levels of CO_2 (Jobbagy & Jackson, 2000; Kirschbaum, 2000). The parameters which influence the indicators of SOM are climate (Alvarez & Lavado, 1998; Ganuza & Almendros, 2003), topography (Burke, 1999; Raghubanshi, 1992), vegetation (Finzi et al., 1998), parent material (Spain, 1990), chronosequence (Schlesinger, 1990) and management (Yang & Wander, 1999). **The most important climatic factors though seems to be temperature and precipitation** (Dai & Huang, 2005; Jenny, 1980; Sims & Nielsen, 1986; Homman et al., 1995; Alvarez & Lavado, 1998).

Situation in Cyprus: The mean value of organic matter into the cultivated soils is less than 1% (Hadjiparaskevas). According to the Cypriot Ministry of Agriculture (MANRE), the organic matter content in surface soil in the valley and coastal areas is 1.5%, the narrow valleys of Gialias and Pediaeos 1.5-2.0%, the Morphou alluvial plain 1-2% and the south eastern Mesaoria (Kokkinochoria) less than 1%. The organic matter accumulates in the top 10cm of soil reaching 3-4% in areas of the Troodos Igneous Massif with permanent vegetation on surface, whereas in areas with no permanent vegetation the organic matter content of the surface soil is much lower. The areas of Episkopi-Akrotiri-Garyllis-Yermasoyia have SOM around 1-2%, the areas of Pissouri-Paralimni 1.0-1.5%, Paphos 1.5-2%, the area near Moni-Pareklishia 1% and the surface soil of hilly areas 1.5-2%.

There is no scientific information available for the loss of organic matter due to climate change for Cyprus. However, in order to find correlation between temperature and precipitation change and loss of organic matter, climatic predictions for temperature increase and precipitation decrease in Cyprus are presented as a baseline for a future study.

In specific, Cyprus will experience, in the near future, a warming of about 1 – 2 °C. Winter minimum temperature is anticipated to have an increase of 1°C in western regions, mountain regions, inland and southern regions and an increase of 0,8 °C in southeastern regions. Thus future temperatures will be around 9-13°C, 6°C, 6°C,6°C and 7°C respectively. Summer maximum temperature in the current period is 27-29°C for western regions, 30-32 °C for mountain regions, 33 °C for inland regions, 32 °C for southern regions and 33 °C for southeastern regions. In the future period it is anticipated to increase about 1.7-2 °C for western regions, 2-2.7 °C for mountain regions, 2.4 °C for inland regions, 2.3 °C for southern regions and 2.3 °C for southeastern regions. However there is no data available for the response for the loss of organic matter due to anticipated increase in temperature. Further research is required.

Concerning heavy rain in Cyprus the future period (2021-2050) PRECIS projections show that annual max total rainfall over 1 day will have a slight increase of about 2-4 mm in western, inland and mountain regions. Additionally, southern and southeastern areas present an increase of about 1 mm in annual max total rainfall over 1 day. In this frame rain water erosion is not anticipated to be deteriorated due to heavy rainfall significantly.

Concerning ordinary rainfall, no change is anticipated in the future period (2021-2050) both for spring and summer total precipitation. However, a decrease of about 0-20 mm is anticipated in winter total rainfall for all the domain of study. As a result, for western and mountain regions were soil protection is high a precipitation of about 210 mm is anticipated, while for southern regions precipitation of 150mm respectively is forecasted. For southeastern district, precipitation will be about 70 mm in comparison with present-day climate where precipitation is 90 mm.

A similar pattern to winter is evident for autumn precipitation where a decrease of about 10-15 mm is anticipated for the whole study domain. More specifically future amounts of autumn rainfall will reach 55 mm in southeastern and southern district, that are low soil protection areas, 95 mm for mountain region and 135 mm for western regions, that are high soil protection areas compared with current amounts which are 70 mm, 110 mm and 150mm.

In order to extract safe conclusions regarding the impact of climate changes on soil organic matter, the following are considered necessary:

- Data availability from a long monitoring period
- Correlation with climatic conditions and clear distinction of the effect from human activities
- Determination of soil organic matter values for Cyprus

3.3.6 Soil biodiversity

Climate change (i.e. temperature rise, decreased precipitation and changes in CO_2) affects soil directly -with the alterations on soil temperature and soil moisture, and indirectly through the changes in vegetation communities, productivity and rate of the organic matter decomposition (EEA, JRC, WHO, 2008). However, the alteration of soil biodiversity patterns due to global climate change is currently beyond scientific knowledge[1] (JRC & ies, 2010). Finally another parameter of climate change affecting soil biodiversity is the changes in the interrelations of carbon cycle. Soil biota regulates the decomposition process in substrates, affecting carbon level in soils.

Situation in Cyprus: Increase in temperature and decrease in precipitation will affect soil moisture. If soil moisture is low soil biodiversity is expected to be poor, as only the most resilient species survive in dry conditions. Further investigation is required to this respect, as there is no data available for the response of limited soil biodiversity to climate change not only for Cyprus but worldwide too. However, in order to find correlation between temperature and precipitation change and soil moisture, climatic predictions for Cyprus for the future period (2021-2050) are presented as a baseline for a future study.

Cyprus will experience, in the near future, a warming of about 1 – 2 °C. Winter minimum and summer maximum temperatures forecasted for the future period (2021-2050) are presented as the most extreme cases.

More specifically winter minimum temperature is anticipated to have an increase of 1°C in western regions, mountain regions, inland and southern regions and an increase of 0.8°C in southeastern regions. Thus future temperatures will be around 9-13°C, 6°C, 6°C,6°C and 7°C respectively. Summer maximum temperature in the current period is 27-29°C for western regions, 30-32 °C for mountain regions, 33 °C for inland regions, 32 °C for southern regions and 33 °C for southeastern regions. In the future period it is anticipated to increase about 1,7-2 °C for western regions, 2-2.7 °C for mountain regions, 2.4 °C for inland regions, 2.3 °C for southern regions and 2.3 °C for southeastern regions. However there is no data available for the response of soil biodiversity due to anticipated increase in temperature. Further research is required.

Generally, annual total precipitation appears to have minor decreases or no changes at all. The only region with an increase in total annual precipitation, minor though (up to 5mm), is the area around Orites Forest, east from Paphos. Concerning winter total rainfall, a decrease of about 0-20mm is anticipated in for all the domain of study. As a result, for western and mountain regions and southern regions a precipitation of about 210 mm and 150mm respectively is anticipated. For southeastern district precipitation will be about 70 mm in comparison with present-day climate where precipitation is 230 mm and 90 mm respectively. A similar pattern to winter is evident for autumn precipitation where a decrease of about 10-15 mm is anticipated for the whole study domain. More specifically future amounts of autumn rainfall will reach 55 mm in southeastern and southern district, that are low soil protection areas, 95 mm for mountain region and 135 mm for western regions compared with current amounts which are 70 mm, 110 mm and 150mm. However there is no data available for the response of soil biodiversity due to decrease in precipitation for Cyprus. Further research is required.

In order to extract safe conclusions regarding the future impact of climate changes on soil biodiversity, the following are considered necessary:

- Data availability from a long monitoring period about the response of soil biota to climate change
- Mapping of soil biota for Cyprus
- Correlation of soil biodiversity with climatic conditions and clear distinction of the effect from human activities

[1] Only some experimental results from extreme environments are available, which demonstrate that an increase in mean temperature usually leads to an increase in bacteria, fungi and nematode numbers but an overall reduction in biodiversity (JRC; ies, 2010).

3.3.7 Soil Contamination (heavy metals, nitrates, phosphates, al saturation)

Some processes of chemical degradation of soils are related to climate change and contribute to desertification. The most common types of soil contamination are chemical pollution (heavy metals), acidification and loss of nutrients (nitrogen, phosphate).

Situation in Cyprus: Chemical pollution in Cyprus may only be located in industrial areas, without posing a serious threat for more distant areas (I.A.CO. Ltd, 2007). However, it must be noted that Industrial activity in Cyprus is limited and it is not anticipated to be increased significantly in the future period (2021-2050). As far as acidification is concerned, serious incidents of acid rain in Cyprus have not been recorded (I.A.CO Ltd, 2007) since Cyprus is not an industrialized country and industrial activity is not anticipated to be increased significantly in the future period (2021-2050). Furthermore, soil buffering capacity to acidification in Cyprus is high, due to the high levels of calcium carbonate content of soils. Finally, in Cyprus, critical loads of nutrients may be located in areas with husbandry waste, irrigated agriculture and uncontrolled landfills, without posing a serious threat for the more distant areas (I.A.CO Ltd, 2007).

3.3.8 Soil Salinization – Sodification

Soil salinization is mainly an arid zone problem leading to land desertification. An increase will further reduce soil quality, further limit the growing of crops, further constrain agricultural productivity and, in severe cases, will lead to the abandonment of agricultural soils (Martínez-Sánchez et al., 2010). Such conditions can be exacerbated by the anticipated increased temperature and reduced precipitation. Furthermore, climate change will increase flood incidence and salinity along coastal regions through the influence of sea-level rise (UNEP, 2001). Sodification is the excessive accumulation of sodium (Na^+) in solid (crystallized Na_2CO_3 and/or $NaCCO_3$ salts on the soil surface or on the surface of soil's structural elements; exchangeable ions in the soil absorption complex) and liquid phase (ions in the highly alkaline soil solution) (Varallyay, 2006).

Situation in Cyprus: The accumulations of salts in soils of Cyprus are the results of the soil composition, the use of treated irrigation water with high percentage of salts and the use of saline water for irrigation from boreholes. Those factors can be affected by changes in temperature and precipitation.

Decrease in precipitation may increase water demand which may lead to increased overpumping. This could lead to further pressure on already saline aquifiers. However, there is no information available for soil salinization due to climate change for Cyprus. In order to find correlation between precipitation changes and soil salinization, climatic predictions for Cyprus for the future period (2021-2050) are presented as a baseline for a future study.

Annual total precipitation appears to have minor decreases or no changes at all. The only region with an increase in total annual precipitation, minor though (up to 5mm), is the area around Orites Forest, east from Paphos. Concerning winter total rainfall, a decrease of about 10%-20% is anticipated in for all the domain of study. As a result, for western and mountain regions and southern regions a precipitation of about 210 mm and 150mm respectively is anticipated. For southeastern district precipitation will be about 70 mm in comparison with present-day climate where precipitation is 230 mm and 90 mm respectively. A similar pattern to winter is evident for autumn precipitation where a decrease of about 10%-20% is anticipated for the whole study domain. More specifically future amounts of autumn rainfall will reach 55 mm in southeastern and southern district, that are low soil protection areas, 95 mm for mountain region and 135 mm for western regions compared with current amounts which are 70 mm, 110 mm and 150mm. However there is no data available for the response of soil biodiversity due to decrease in precipitation for Cyprus. Further research is required.

Generally decrease in precipitation, with the more frequent drought periods, in combination with the increased water demand can deteriorate the water quality and quantity and as a result the soil quality and productivity.

3.3.9 Desertification

Desertification is an increasing threat for the soil resources of southern Europe and the Mediterranean. More specifically, the phenomenon in arid semiarid and arid sub-humid areas is responsible for the loss of production yield, reduction of water availability, reduction of hydropower potential and land degradation, affecting relevant dimensions such as the ecology, income and quality of life (I.A.CO Ltd, 2007).

Situation in Cyprus: Desertification is a serious problem for Cyprus, since the 57% of the island is characterized as “Critical”, the 42.3% as “Fragile” and only the 0.7% as “Potential” to desertification (I.A.CO Ltd, 2007). Climate change and in specific reduction of precipitation and temperature rise, can deteriorate the phenomenon. The factors contributing to desertification in Cyprus -as identified in the study conducted by I.A.CO. (I.A.CO Ltd, 2007)- are climate, topography, geology, soil composition, hydrology and human factors such as urban development and reduction of rural population.

There is no information available for future response of desertification phenomenon due to climate change for Cyprus. However, in order to find correlation between temperature and precipitation change and soil desertification, climatic predictions for Cyprus for the future period (2021-2050) are presented as a baseline for a future study.

Cyprus will experience, in the near future, a warming of about 1 – 2 °C. Winter minimum and summer maximum temperatures forecasted for the future period (2021-2050) are presented as the most extreme cases.

Winter minimum temperature is anticipated to have an increase of 1°C in western regions, mountain regions, inland and southern regions and an increase of 0.8°C in southeastern regions. Thus future temperatures will be around 9-13°C, 6°C, 6°C,6°C and 7°C respectively. Summer maximum temperature in the current period is 27-29°C for western regions, 30-32 °C for mountain regions, 33 °C for inland regions, 32 °C for southern regions and 33 °C for southeastern regions. In the future period it is anticipated to increase about 1.7-2 °C for western regions, 2-2.7 °C for mountain regions, 2.4 °C for inland regions, 2.3 °C for southern regions and 2.3 °C for southeastern regions. However there is no data available for the response of soil desertification to anticipated increase in temperature. Further research is required.

Generally, annual total precipitation appears to have minor decreases or no changes at all. The only region with an increase in total annual precipitation, minor though (up to 5mm), is the area around Orites Forest, east from Paphos. In seasonal projections of precipitation winter and autumn rainfall show the most important changes. Concerning winter total rainfall, a decrease of about 0-20 mm is anticipated in for all the domain of study. As a result, for western and mountain regions and southern regions a precipitation of about 210 mm and 150mm respectively is anticipated. For southeastern district precipitation will be about 70 mm in comparison with present-day climate where precipitation is 230 mm and 90 mm respectively. A similar pattern to winter is evident for autumn precipitation where a decrease of about 10-15 mm is anticipated for the whole study domain. More specifically future amounts of autumn rainfall will reach 55 mm in southeastern and southern district, that are low soil protection areas, 95 mm for mountain region and 135 mm for western regions compared with current amounts which are 70 mm, 110 mm and 150mm. However there is no data available for the response of soil desertification due to decrease in precipitation for Cyprus. Further research is required.

3.4 Future vulnerability assessement

In this section, the future vulnerability of soil resources to climate change impacts is assessed in terms of their sensitivity, exposure and adaptive capacity based on the available quantitative and qualitative data for Cyprus and the climate projections for the period 2021-2050. In particular, sensitivity is defined as the degree to which soils will be affected by climate changes, exposure is the degree to which soils will be exposed to climate changes and their impacts while the adaptive capacity is defined by the ability of soil resources to adapt to changing environmental conditions which is also enhanced by the measures implemented in Cyprus in order to mitigate the adverse impacts of climate change on the sector.

It has been attempted to use the same the indicators used for the assessment of sensitivity, exposure and adaptive capacity of Cyprus soil resources to climate change impacts with those used for the assessment of current vulnerability of soil resources sector wherever similar data for the future were available in order for the results to be comparable. Indicators used for the future vulnerability assessment of climate change impacts on soil resources are summarized in Table 3-4.

Table 3-4: Indicators used for the future vulnerability assessment of climate change impacts on the soil resources of Cyprus

Vulnerability Variable	Selected indicators
Soil erosion (by wind and/or rain water)	
Sensitivity	For wind erosion – Wind velocity – Changes in precipitation
	For water rain erosion – Soil composition – Decrease in precipitation associated with strong seasonal winds
Exposure	– Wind velocity – Areas of sparse vegetation – Areas of soil surface roughness – Areas with erodible soils – Areas of limited soil fertility – Land uses (maps) – Areas where slopes have slope greater than 12% – Sparse vegetation cover – Intensity of rain – Changes in precipitation

Adaptive capacity	– Terracing – Natura 2000 – Measures for the protection of the coastal areas from erosion – National Forest Strategy – Rural Development Program 2007-2013 (Measures 2.1 and 2.3.6.)
Landslides	
Sensitivity	– Slope stability* – Soil composition – Increase in rainfall intensity – Change of climatic parameters
Exposure	– Areas of recorded soil slippage events
Adaptive capacity	– Technical structures – Terracing (with grants from the E.U.) – Research project entitled 'Study of landslides in areas of Paphos District'
Soil contamination	
Sensitivity	– Surface percentage of areas of calcic soils (for the acidification of soils)
Exposure	– Acidification of soils – Nitrogen and phosphorus content of soils – Precipitation changes
Adaptive capacity	– Nitrate Directive – Good Agricultural Practices – Enforcement of the European legislation – Water Pollution Law
Soil salinization-sodification	
Sensitivity	– Soil composition – Treated irrigation water with high percentage of salts – Saline water from aquifer boreholes for irrigation
Exposure	– Areas of salinized soils – Crop areas using inferior quality water
Adaptive capacity	– Enforcement of Water Framework Directive – Salt Infiltration capacity of rain

Desertification	
Sensitivity	– Overexploitation of water and soil resources – Growing water demand – Economic growth and development of the urban and coastal areas – Aging of the rural population – Abandonment of the traditional agricultural activities – Reduction of rainfall – Topography – Poor on desertification and erodible soils
Exposure	– Areas of soil sealing and soil compaction – Areas of increased groundwater use and demand – Abandoned areas – Areas of excessive slopes – Area (surface percentage) of prone to desertification and erodible soils – Changes in temperature – Changes in precipitation
Adaptive capacity	– Surface percentage of vegetation cover – Measures for combating desertification applied on the agricultural sector, the forest sector, the animal husbandry sector, the water resources sector, the coastal areas, the societal and economic sector – Measures for the elimination of SO_x, NO_x, VOCs and NH_4 emissions.

* No date available for this indicator

The relationship between sensitivity, exposure and adaptive capacity is based on the following qualitative equation:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity * Exposure$$

Sensitivity, exposure and adaptive capacity are evaluated on a 7-degree qualitative scale ranging from “none” to “very high”.

The vulnerability of soil resources in Cyprus is assessed for the following impact categories presented in Section 4.3:

1. Soil erosion (by wing and/or rain water)
2. Landslides
3. Contamination (heavy metals, nitrates, phosphates, al saturation)
4. Soil salinization-sodification
5. Desertification

The future vulnerability assessment of “*Water retention capacity (reduction of available soil moisture) of soils*”, “*Loss of soil organic matter*”, “*Soil organic carbon content*” and “Soil *biodiversity*” was not assessed for the case of Cyprus due to lack of sufficient research data.

Nevertheless the future vulnerability of soils will vary substantially as it is related to the different rate and magnitude of climate change in different parts of Cyprus. The variability of the air pollution levels, altitude, temperature and rainfall variations, meteorological conditions (e.g. wind, moisture), local geomorphology and soil characteristics will have an impact on soil resources which in order to be assessed a systematic research is essential to be carried out.

It must be noted that, there are no sufficient scientific evidence and data to evaluate or correlate all future impacts and indicators to climate changes. Consequently, further research is required in order to provide concrete information for a more detailed and descriptive assessment of the future vulnerability of the sector. Nevertheless, an attempt was made to provide a preliminary assessment of the future vulnerability. In case additional data are provided by the competent authorities of Cyprus, the future vulnerability of the sector could be re-assessed.

3.4.1 Soil Erosion (by wind and/or rain water)

3.4.1.1 Assessment of sensitivity and exposure

Sensitivity

The process of soil erosion involves detachment of material by two processes: raindrop impact and flow traction. This material is transported either by saltation through the air or by overland water flow (JRC, 2012). Sensitivity of soil erosion is affected by wind velocity, and precipitation changes.

Wind erosion (movement of very small particles on the surface) occurs when wind speed exceeds 4,5m/s. It is increased by wind speed and reduced by soil surface roughness. In Cyprus, a statistical analysis on winds indicates that at coastal areas the mean annual wind velocity ranges between 4 and 6 m/s, and reduced further inland (Pasiardes, 1995). Particularly high velocities in certain high points of Mesaoria plain are due to strengthening of westerly winds by the funneling effect between the Troodos and the Kyrenia mountains (I.A.CO Ltd, 2007).

Soil erosion is affected by precipitation as well. A change in the intensity and pattern of precipitation can affect plains significantly due to the soil composition and the sparse vegetation cover. Nevertheless, sensitivity of soil erosion due to changes in precipitation is not going to be affected in the future period (2021-2050) since both seasonal and annual precipitations are not expected to change significantly. Additionally heavy rain events are expected to increase about 1-4 mm.

Considering the above, the sensitivity of soil erosion in Cyprus for the future period (2021-2050) can be characterized as **moderate to high.**

Exposure

Wind erosion is not very common in Cyprus, but can take place in areas with low vegetation cover (I.A.CO Ltd, 2007), erodible or pulverized soils and hilly areas with slope greater than 12% (Kosmas, 1999).

In specific, soils with shallow rock contact (Leptosols, Lithosols, Lithic Xerorthents) - especially those formed on limestone of the semi-arid and arid zones, and soils of dry hilly areas have a reduced resistance to erosion. Such erodible soils are located in the central mass of Troodos range, due to their shallow, rocky with steep slopes features (slope of 18% and 12% cover the 10% and 22% of the island respectively).

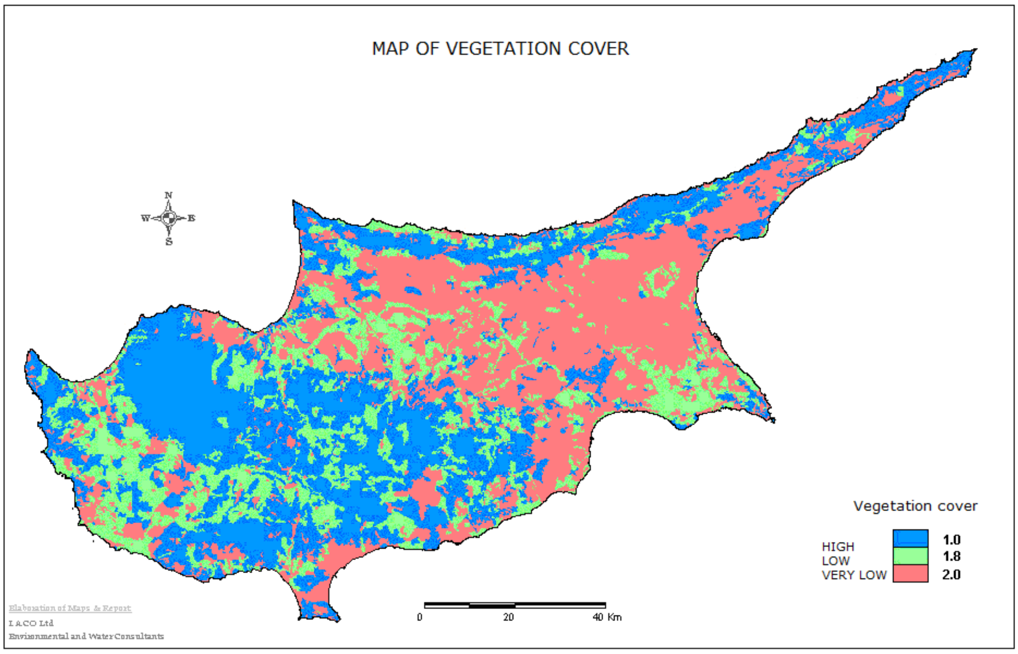

Figure 3-3: Map of vegetation cover

For Troodos range, as PRECIS projections show, is anticipated a decrease of about 0.1 m/s in wind speed. However soils of mountain areas due to vegetation cover are not prone to soil erosion (Figure 3-3) so exposure degree may not be affected**.** In low level areas of Cyprus were soil protection and vegetation cover is low (Figure 3-3,Figure 3-5), wind speed is anticipated to decrease about 0.1-0.2 m/sec. Those wind speeds are not expected to affect soil erosion exposure degree.

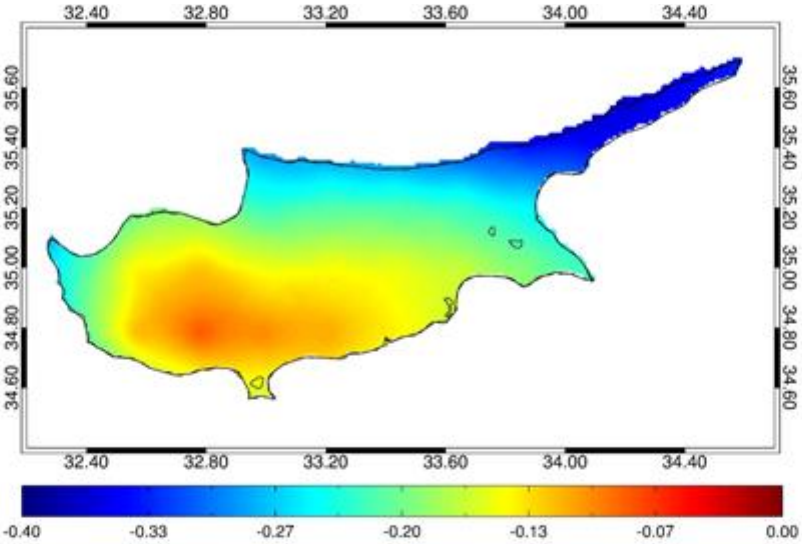

Figure 3-4: Changes in annual mean wind speed between the future (2021-2050) and the control period (1961-1990).

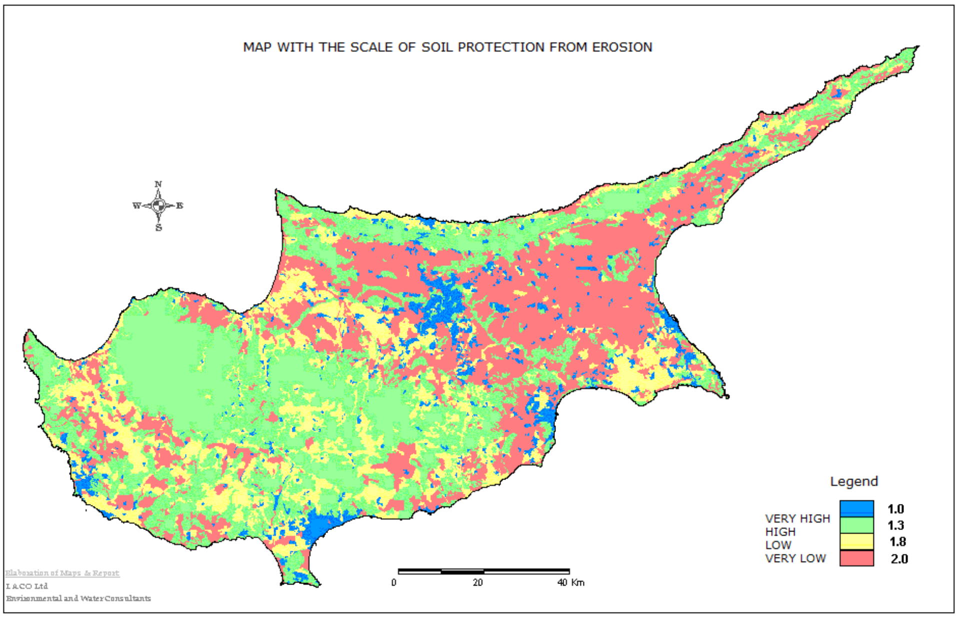

Figure 3-5: Map with the scale of soil protection from erosion

Source: I.A.CO Ltd, 2007

Maps presented in Figure 3-3, Figure 3-4 and Figure 3-5 can lead to the conclusion that very low soil protected areas, with low vegetation cover, anticipate the higher decrease in wind speed. As a result degree of exposure to soil erosion may be decreased. However the decrease in speed is not significant so further research is required to estimate exposure.

Another fact that enhances the belief that exposure to soil erosion due to wind will not be increased in the future period (2021-2050) is that the number of days with mean wind speed greater than 5 m/s are going to decrease. In western, southeastern and inland areas with the lowest vegetation cover and soil protection a decrease of about 12 days is anticipated while in mountain areas that are supposed to be more protected from wind erosion the decrease varies from 5 days to 10 days depending on the elevation. Also southern areas present a slight decrease of about 5 days.

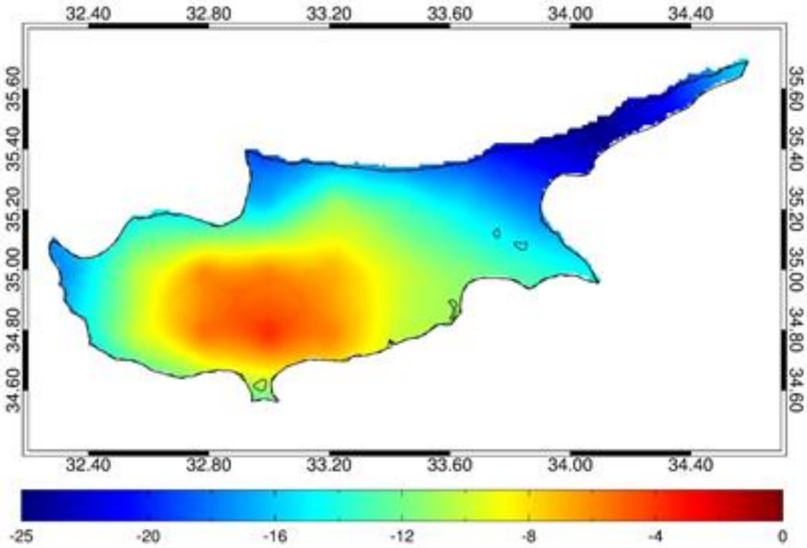

Figure 3-6: Changes in the number of days with mean wind speed > 5m/s between the future (2021-2050) and the control period (1961-1990).

Maps presented in Figure 3-3, Figure 3-4 and Figure 3-6 can lead to the conclusion that very low soil protected areas, with low vegetation cover, anticipate the higher decrease in the number of days with mean wind speed greater than 5 m/s for the future period. Thus the degree of exposure to soil erosion may be decreased.

Another parameter affecting exposure to soil erosion is rain water. Rain water erosion has already damaged the horizon A (topsoil consisting the first 0-25cm of ground) of many areas of the island of Cyprus, such as Aradippou-Koshi (I.A.CO Ltd, 2007). This leads to reduced soil fertility especially in areas where soils are shallow or have subsurface of low fertility.

Both heavy rainfall and ordinary rainfall can have an impact on soil erosion while in spring, when soils are most vulnerable because of degraded crop residue cover, soil preparation by tillage and no crop canopy, rains are coming hard and fast causing substantial soil erosion. Further research is essential to connect degree of exposure to soil erosion with rain intensity and amount. In this frame, forecasting of rainfall intensity and frequency are presented as a baseline for a future study.

In specific, PRECIS projections show that a slight increase of about 2-4 mm in annual max total rainfall over 1 day is anticipated in western, inland and mountain regions. Additionally, southern and southeastern areas present an increase of about 1 mm in annual max total rainfall over 1 day. A comparison between maps presented in Figure 3-3, Figure 3-4 and Figure 3-7 can lead to the conclusion that very low soil protected areas, with low vegetation cover, anticipate the higher decrease in heavy rain events (in terms of annual maximum total precipitation over 1 day) for the future period. Thus the degree of exposure to soil erosion may be decreased.

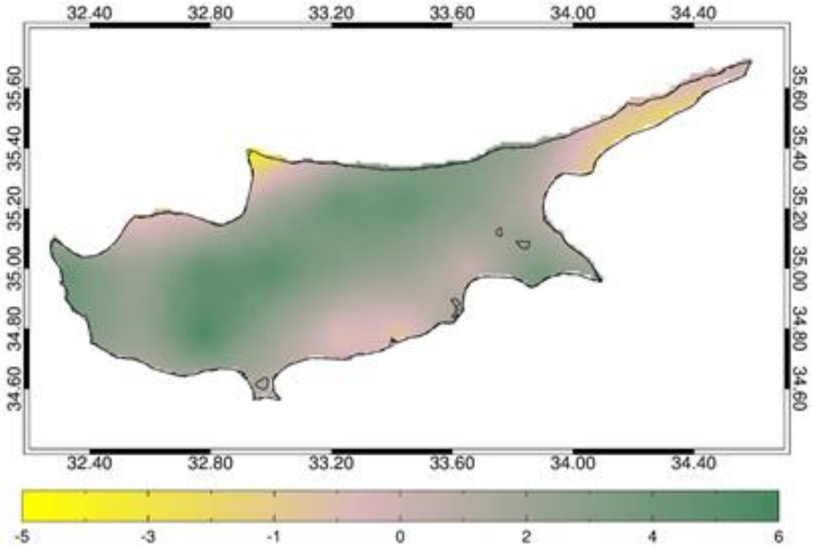

Figure 3-7: Changes in annual maximum total precipitation over 1 day between the future (2021-2050) and the control period (1961-1990).

Concerning ordinary rainfall, no change is anticipated in the future period (2021-2050) both for spring and summer total precipitation. However for winter and autumn are remarkable changes. For western and mountain regions were soil protection is high a precipitation of about 210 mm is anticipated, while for southern regions precipitation of 150mm is forecasted respectively. For southeastern district, that soil protection is low, precipitation will be about 70 mm. That depicts a change of about 20 mm in comparison with the current period. A comparison among maps presented in Figure 3-3, Figure 3-4 and Figure 3-8 can lead to the conclusion that decreased winter precipitation may not affect degree of exposure to soil erosion.

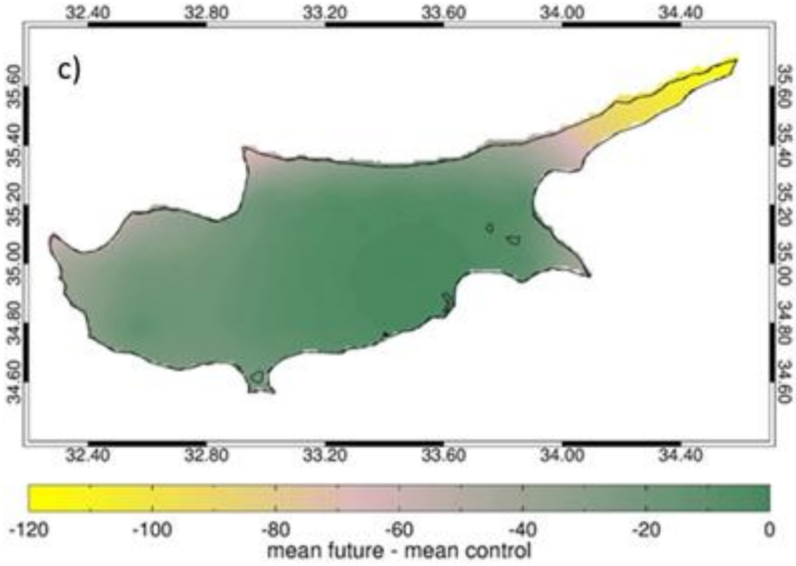

Figure 3-8: Changes in winter total precipitation in the near future (Future – Control period) using PRECIS RCM model

A similar pattern to winter is evident for autumn precipitation where a decrease of about 10-15 mm is anticipated for the whole study domain. More specifically future amounts of autumn rainfall will reach 55 mm in southeastern and southern district, that are low soil protection areas, 95 mm for mountain region and 135 mm for western regions, that are high soil protection areas**.** A comparison among maps presented in Figure 3-3, Figure 3-4 and Figure 3-9 can lead to the conclusion that decreased autumn precipitation may affect degree of exposure of very low soil protected areas with low vegetation cover. This conclusion is enhanced by the fact that autumn follows summer period that soil moisture may decrease.

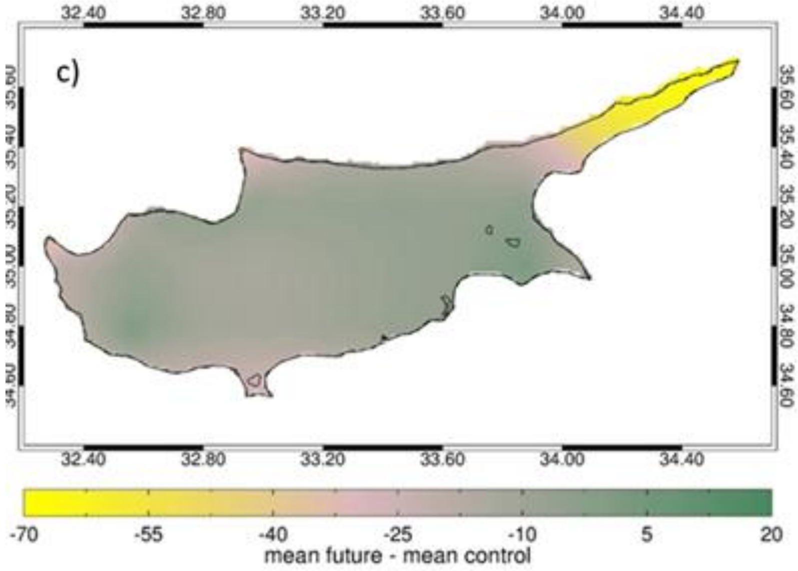

Figure 3-9: Changes in autumn total precipitation in the near future (Future – Control period) using PRECIS RCM model

To sum up, taking into account the current exposure to soil erosion as well as the relative future climate changes the exposure of soils to soil erosion for the future period (2021-2050) can be characterized as **high**. However further review on correlation of soil erosion and precipitation is required.

3.4.1.2 Assessment of adaptive capacity

The measures applied in Cyprus which enhance soil protection from erosion are presented next:

i) The Good Agricultural and Environmental Conditions,

ii) Provision of subsidies to farmers through the Rural Development Programme (RDP) for increasing vegetation cover and reducing run-off, especially in mountain areas.

iii) Farm-level measures protect soil from erosion by reducing run-off from agricultural land, especially when livestock manures have been applied. Nevertheless, farm-level restricted application depends on the private initiative of farmers.

iv) The protection of forests from fires also contributes to the reduction of soil erosion and run-off, as trees have the capacity to retrain water through their deep routes.

v) Control grazing is another measure for preventing soil erosion and thus run-off.

vi) The application of Advanced Irrigation Systems

vii) Measures undertaken for the protection of the coastal areas

viii) The preservation of animal and plant species

ix) Restoration of natural features such as hedgerows, floodplains and woodlands improve water retention in soils, absorption and run-off, and buffer agricultural land from extreme weather events. Since the majority of adaptation measures regarding this issue require action at the farm level, the government measures to assist adaptation mainly refer to the provision of economic incentives to farmers.

x) Sustainable agricultural practices protect soil from erosion.

Although there is a rich set of indigenous strategies and policy processes, they are not sufficient to reduce negative impacts of climate change. The multiple stressors of soil erosion are difficult to be addressed in semi-arid climate types such as Cyprus.

Following, additional recommended adaptation measures that are considered to further enhance adaptive capacity towards this impact are presented indicatively. Nevertheless, their assessment and final selection for implementation will be made through the use of the Multicriteria Analysis (MCA) tool which will be developed and implemented in the framework of Actions 4 and 5 of the CYPADAPT project.

- Mandatory implementation of the Code of Good Agricultural Practice

- Continuation and increase agri-environmental measures within the RDP with emphasis on erosion control
- Grants and incentives for maintenance of terracing, and protection walls in sloping lands even in areas where farming has been abandoned
- Control of abandonment of farming and support of traditional agricultural practices
- Incentives for terracing in burnt areas and intervention for prevention of increased erosion
- Implementation of a plan for the sustainable use of land (on the basis of slope and type, structure, depth and resilience of soil to erosion)
- Extension of the Goats Law to cover all the areas in Cyprus. The objective is the control of grazing by license on the basis of the carrying capacity of each area.
- Studies and research for the definition of number of animals that could be accepted by each area without detrimental impact on its ecosystem. For each area the productive capacity, the time and intensity of grazing should be evaluated for securing sustainability
- Reinstatement of the institution of the Rural Constable for the control of illegal and free grazing
- Proper soil cultivation
- Enhancement of land surface cover

As a result, the adaptive capacity of soils to erosion in the future in Cyprus is characterized as **limited to moderate** for the future period (2021-2050)**.**

3.4.2 Landslides

Although data records of long-term series are necessary for the evaluation of the impact of “Landslides” for Cyprus, an attempt was made to present the future susceptibility of Cyprus to landslides and its probable vulnerability of landslides to climate.

3.4.2.1 Assessment of sensitivity and exposure

Sensitivity

Soil composition, tectonics and topography are factors which increase susceptibility to soil slippage. Due to lack of relevant information estimated for the future period further research is required.

Cyprus is well-known for its interesting and often complex geology, particularly in the south-west part of the island. The reason for the increased susceptibility of this area to landslides is the remains of former sea-floor deposits and massive submarine slides, which tend to be heavily deformed and are rich in the types of clay minerals that are prone to land sliding. This tendency is exacerbated by the steep terrain and the long history of powerful earthquakes in the region (British Geological Survey). In addition**,** climate change increases the likelihood for land displacements. More specifically changes in temperature and precipitation could be relevant for more landslides. Further research is required in order to provide concrete information for the future.

Considering the above, the sensitivity of Cyprus to landslides for the future period (2021-2050) can be characterised as **moderate.**

Exposure

Landslides are common in certain areas of Cyprus, but it was not until recently that the Ministry of Agriculture and Natural Resources and Environment undertook a relevant research project entitled 'Study of landslides in areas of Paphos District' for recording the landslide events. The project used aerial photography and QuickBird satellite imagery, supported by field verification and Terrain Classification mapping in order to identify and map 1842 landslides, cataloguing them within a GIS-based landslide inventory. This has shown that landslides cover approximately 24% of the 546km^2 project study area, with the largest (compound) landslides reaching almost 3km width and 4,5 km length, comprising spreads of calcareous cap-rock, block slides and substantial earth flows (Hart et al., 2010).

The recent project 'Study of landslides in areas of Paphos District'showed that landslides cover approximately 24% of the 546km^2 project study area, with the largest (compound) landslides reaching almost 3km width and 4.5 km length, comprising spreads of calcareous cap-rock, block slides and substantial earth flows (Hart et al., 2010). In addition, another study for the evaluation of landslide risk in Europe show that in some places of Cyprus (in specific areas near Paphos and the mountains of Troodos), the landslide risk varies from moderate to high with respect to their landscape susceptibility.

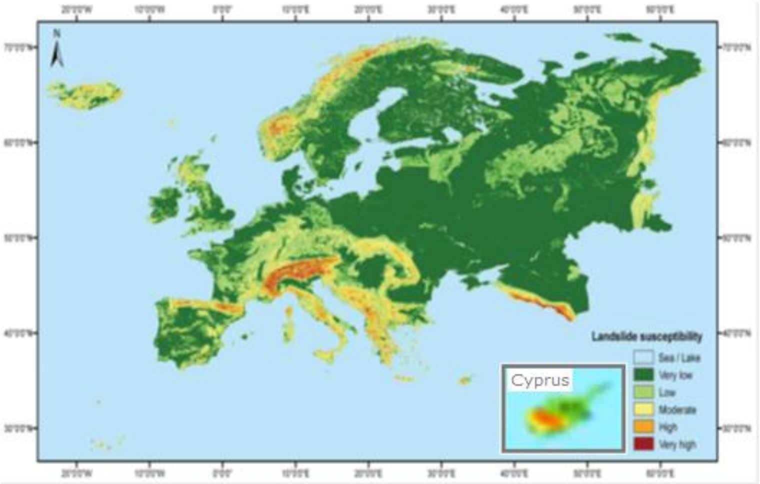

Figure 3-10: Classified landslide susceptibility map of Europe

Source: Van Den Eeckhaut et al., 2010

Temperature and precipitation changes can have an impact on lanslide occurance (Crozier, 2009). An increase in temperature can cause reduction in antecedent water conditions through evapotranspiration, a rapid snow melt-runoff and infiltration and increased sea level. This could lead to lower antecedent water status-more rain required to trigger slides, build-up of porewater pressure and strength reduction and enhanced basal erosion on coasts, increase in groundwater levels on coastal slopes respectively. The anticipated increase in temperature works to the above mentioned direction.

Although further research is required to correlate possibility of landslide events and temperature increase in Cyprus climatic predictions are presented as a baseline for a future study.

In specific, Cyprus will experience, in the near future, a warming of about 1 – 2 °C. Winter minimum and summer maximum temperatures forecasted for the future period (2021-2050) are presented in the following as the most extreme cases.

Southeastern regions, well-known for its interesting and often complex geology, are anticipated to have an increase about 2.3°C in summer maximum temperature and about 0.8°C in winter maximum temperature. In Pafos district and Troodos mountain, where landslide risk is high, temperature is anticipated to reach 6.1°C and 6°C on average in winter respectively and 34 °C and 32°C on average in summer.

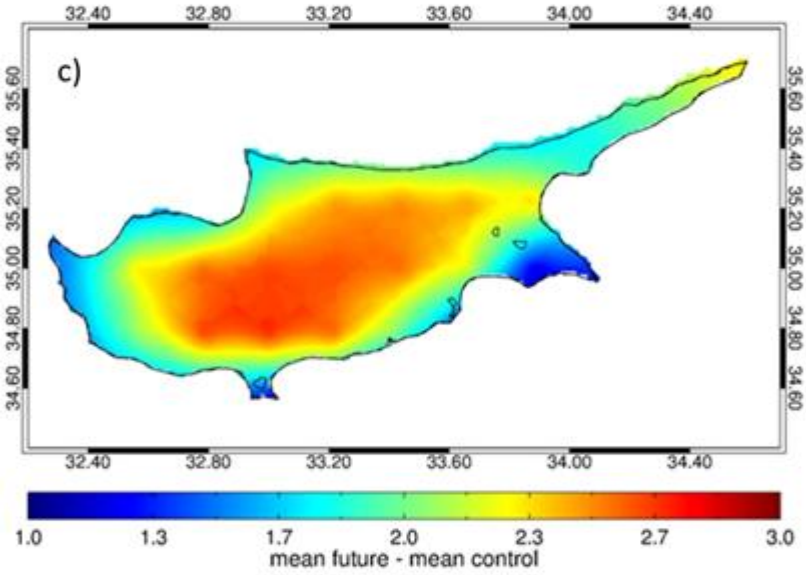

Figure 3-11: Changes in average summer maximum temperature in the near future (Future – Control period) using PRECIS RCM model

Maps presented in Figure 3-10 and Figure 3-11 can lead to the conclusion that in areas with high landslide risk is anticipated the higher increase in average summer maximum temperature. As a result degree of exposure to landslides may be increased.

Furthermore winter minimum temperature is anticipated to have an increase of 1°C in western regions, mountain regions, inland and southern regions and an increase of 0.8°C in southeastern regions.

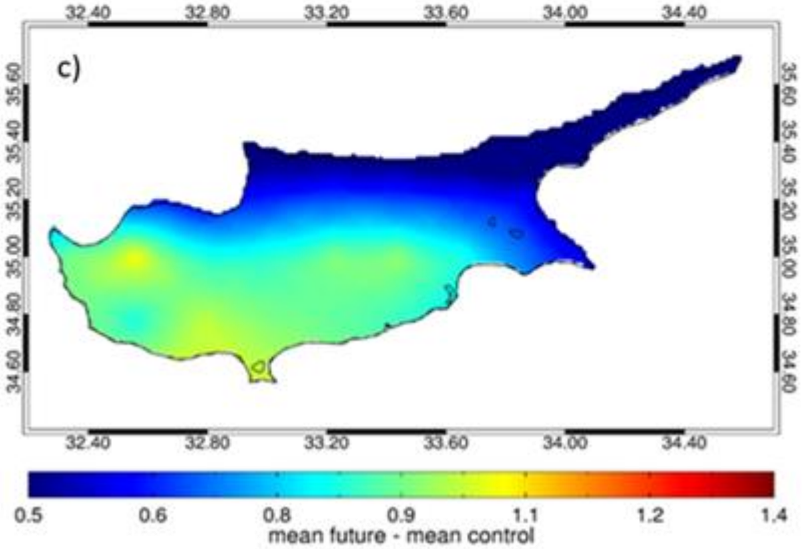

Figure 3-12: Changes in average winter minimum temperature in the near future (Future – Control period) using PRECIS RCM model

Maps presented in Figure 3-10 and Figure 3-12 can lead to the conclusion that areas with high landslide risk anticipate an increase in average winter maximum temperature that may not affect the degree of exposure.

Another climatic change that may affect exposure to landslides is change in anticipated heat wave days. PRECIS predicts an increase of about 10 days in western regions, 20-30 days in mountain regions where landslide risk is high, and 30 days in inland, southern and southeastern regions that have a complex morphology. Thus future heat wave days will be around 20 days, 40-60 days and 60 days respectively.

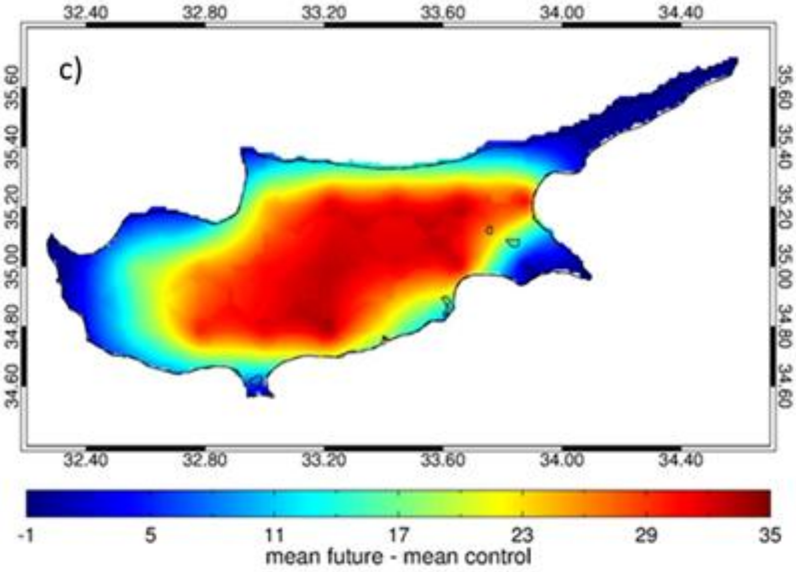

Figure 3-13: Number of heatwaves days in the near future (Future – Control period) using PRECIS RCM model

Maps presented in Figure 3-10 and Figure 3-13 can lead to the conclusion that areas with high landslide risk anticipate a significant increase in heat wave days that may increase the degree of exposure. Further research is required.

Increase in precipitation can lead to landslide triggering by reduction in effective normal stress leading to reduction in shear strength and increase in cleft water pressures. Furthermore increase in intensity of precipitation can cause increase in throughflow and finally increase in seepage and drag forces, particle detachment and piping. Thus future changes of annual max total rainfall over 1 day should be encountered. PRECIS projections show that a slight increase of about 2-4 mm is anticipated in western, inland and mountain regions. Additionally, southern and southeastern areas present an increase of about 1 mm in annual max total rainfall over 1 day.

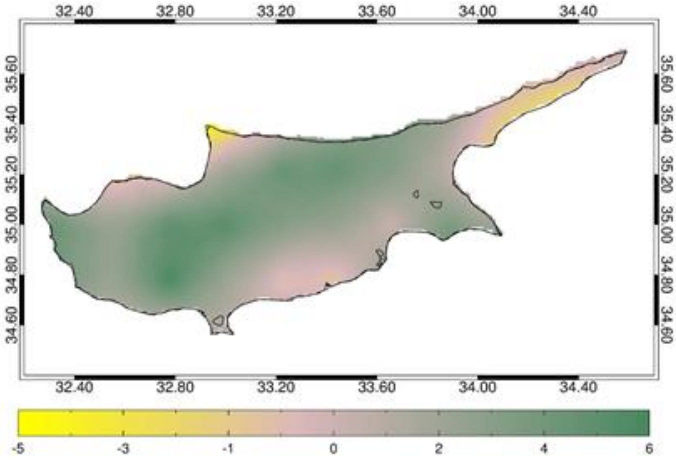

Figure 3-14: Changes in annual maximum total precipitation over 1 day between the future (2021-2050) and the control period (1961-1990).

Increase in heavy rainfall is more important in mountain regions that the risk of landslide is high, deteriorating the situation even more. Maps presented in Figure 3-10 and Figure 3-14 can lead to the conclusion that areas with high landslide risk anticipate a significant increase in heat wave days that may increase the degree of exposure. Further research is required.

Variability in precipitation and temperature can cause more frequent wetting and drying cycles that increase fissuring and widening of joint systems and reduction in cohesion and rock mass joint friction and can result landslide events. Further research is required concerning future variability in precipitation and temperature in order to assess degree of exposure.

To sum up, taking into account the current exposure to landslides as well as the relative future climate changes the exposure of soils to landslides for the future period (2021-2050) can be characterized as **limited to moderate**. Further research has to be conducted.

Examples from other countries

In Greece for example surveys have made possible to calculate the probability of exceeding the limits of rainfall ("thresholds") beyond which it becomes probable a landslide event (Caine, 1980), and the possible change. This change was used as a measure of the change of expression on the likelihood of landslides and therefore the status of risk. This procedure used the limits of Caine (1980) (global threshold - global threshold) and Calcaterra et al. (2000) (limit in the Mediterranean region - local threshold).

In Spain the influence of rainfall on the erosivlity of soils was estimated by using factor R of the USLE model, or with the use of more simple relationships that base the estimate on monthly or annual rainfall values (Renard *et al*. 1994). Nearing, *et al*. (2004), applying the WEEP model to soils characteristic of the USA, determined that for each 1% increase in annual rainfall, there is a 2% increase in surface runoff and that erosion increases by 1.7%. The lower sensitivity of erosion than runoff to change is due to the fact that the soil is protected by the increase in aboveground biomass, resulting from increased rainfall. Rainfall intensity is also expected to increase in accordance with the intensification of the hydrological cycle which is expected to cause global warming. In the case of Andalucia, making use of the Raizal model (MicroLEIS DSS; de la Rosa *et al*. 2004) and assuming a foreseeable climatic disturbance for the year 2050, it was found that the risk of water erosion increases in 47% of soils, although it decreases in 18% of the soils in other areas. The USLE was developed from erosion plot and rainfall simulator experiments. The USLE is composed of six factors to predict the long-term average annual soil loss (A). The equation includes the rainfall erosivity factor (R), the soil erodibility factor (K), the topographic factors (L and S) and the cropping management factors (C and P) (Renard K.G. and Freidmund J.R, 1994).

3.4.2.2 *Assessment of adaptive capacity*

The localized landslides have been encountered with some technical structures and terracing with grants from the European Union in order to prevent the soil loss. In addition, a two-year research program of the Geological Survey Department of Cyprus in collaboration with the British Geological Survey and more recently as part of Scott Wilson's was carried out in order to map landslides of Paphos, including mapping and analysis of digital satellite images (British Geological Survey)**.** Last, one of the most drastic measures taken was the relocation of of certain mountainous settlements to safer places.

A) In addition, a number of measures undertaken either separately or in conjunction with one another to face the problem of slope failures and landslides. Such measures include:

- The decrease of the dip of the slope
- The unloading of the land-slit mass
- The construction of berms and terraces
- The controlled pumping of ground water to maintain a stable water table
- The construction of drainage system and retaining walls

B) Depending on the characteristics of each case or rock fall, different measures can be taken to resolve the problem. The most frequently used method for facing the problem is the installation of anchors and rock bolts.

C) Remedial measures are often very difficult and include filling up the sinkhole with grout.

Following, additional recommended adaptation measures that are considered to further enhance adaptive capacity towards this impact are presented indicatively. Nevertheless, their assessment and final selection for implementation will be made through the use of the Multicriteria Analysis (MCA) tool which will be developed and implemented in the framework of Actions 4 and 5 of the CYPADAPT project.

- Continuation and increase agri-environmental measures within the RDP with emphasis on erosion control
- Grants and incentives for maintenance of terracing, and protection walls in sloping lands even in areas where farming has been abandoned
- Enhancement of land surface cover
- Implementation of a special plan for incentives and support to farmers for the installation of improved irrigation systems in the mountainous and semi-mountainous areas that fall under the sensitive areas to desertification

Consequently the adaptive capacity of landslides to climate changes for the future period (2021-2050) can be characterized as **moderate,** due to the fact that landslide is a physical phenomenon not easily controlled as it depends mainly on geology and soil composition.

3.4.3 Soil Contamination (heavy metals, nitrates, phosphates, al saturation)

3.4.3.1 Assessment of sensitivity and exposure

Sensitivity

The risk of soil acidification in Cyprus is **limited** because most of the soils have well-developed carbonate accumulations (calcic soils) (I.A.CO Ltd, 2007) as shown in the following table (Table 3-5). The calcic soils, due to their high concentrations of calcium carbonate (including limestone and dolomite), are more resistant to acid rain [1].

Table 3-5: The calcium carbonate content of soils in Cyprus

Areas of Cyprus	Calcium carbonate content of soils
Valley and coastal areas	45–55%
Chrysochou valley	30-40%,
Narrow valleys of Gialias, Pediaeos	10-20%,
Morphou alluvial plain	50%,
South eastern Mesaoria (Kokkinochoria)	0-3%,
Troodos igneous massif	do not contain free calcium carbonate
Areas of Episkopi-Akrotiri-Garyllis-Yermasoyia range	from 10-30% to 60-70%,
The areas of Pissouri-Paralimni	50-60%,
Soils on the “Nicosia” geological formation	40-60%,
Paphos	10-30%,
Area near Kalavasos	60-70%,
Area near Moni-Pareklishia	free from calcium carbonate
Hilly areas except those on the “Mamonia” geological formation	50-70%.

Source: MANRE

Exposure

Soil contamination in Cyprus is mainly located in areas with extensive use of fertilizers, urbanization, wastes from husbandry, or uncontrolled landfills. Areas with nitrogen pollution in groundwater bodies such as the areas Kokkinohoria, Kiti-Pervolia, Akrotiri, Paphos, Poli Chrysohous, and Orounta which were identified as Vulnerable Nitrate Zones according to the Directive 91/676/EC (MANRE, 2008), are also possibly exposed to soil pollution too.

The European Environment Agency classified Cyprus, among the 32 EEA member countries and EEA cooperating countries in 2000 for current legislation (CLE) in 2010 (EEA, 2012), in

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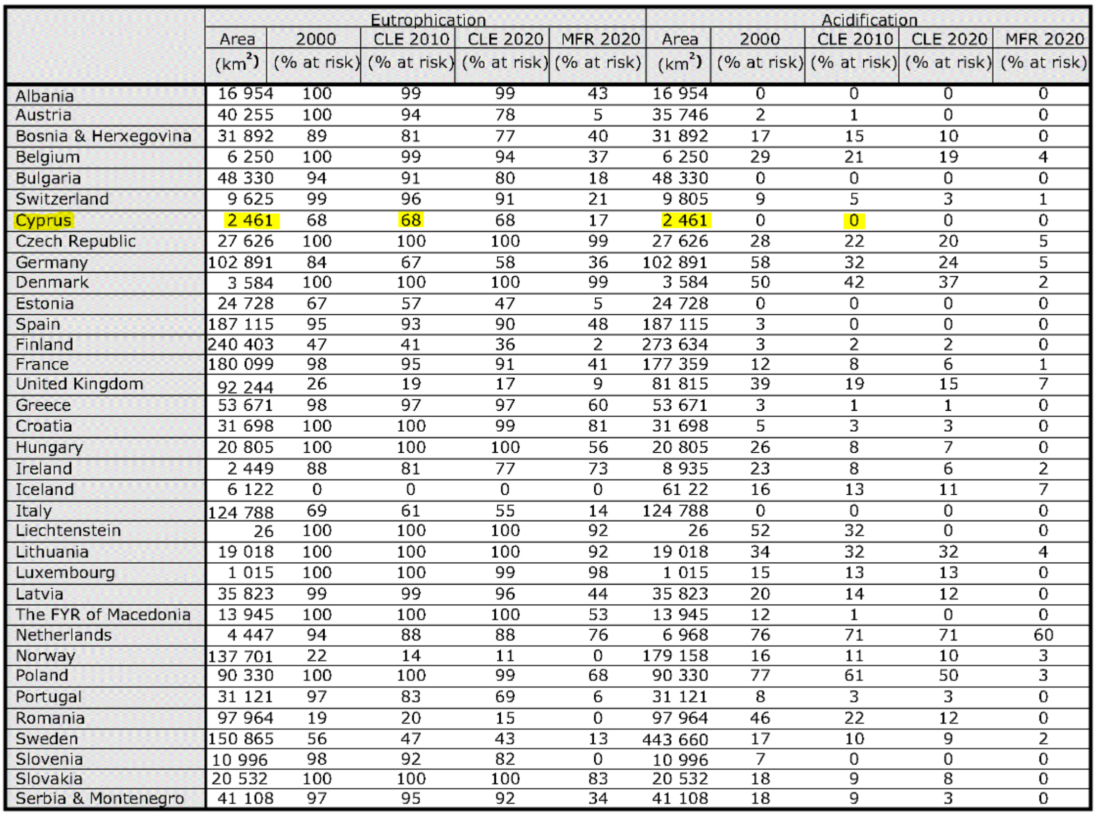
[1] The calcium carbonate (chemically) neutralizes acids, and this is why “liming” is used as an ecological restoration method to adjust the pH of lakes affected by acid rain (Ghosh, 2002).

the countries with the lowest percentage of ecosystem area at risk of acidification and eutrophication as shown in Table 3-6, Figure 3-15 and Figure 3-16.

Table 3-6: Percentage of natural ecosystem area at risk of acidification (left) and of eutrophication for the 32 EEA member countries and EEA cooperating countries in 2000 and for two emission scenarios: current legislation (CLE) in 2010 and 2020, maximum feasible reduction scenario [1]



	Eutrophication					Acidification				
	Area (km^2)	2000 (% at risk)	CLE 2010 (% at risk)	CLE 2020 (% at risk)	MFR 2020 (% at risk)	Area (km^2)	2000 (% at risk)	CLE 2010 (% at risk)	CLE 2020 (% at risk)	MFR 2020 (% at risk)
Albania	16 954	100	99	99	43	16 954	0	0	0	0
Austria	40 255	100	94	78	5	35 746	2	1	0	0
Bosnia & Herxegovina	31 892	89	81	77	40	31 892	17	15	10	0
Belgium	6 250	100	99	94	37	6 250	29	21	19	4
Bulgaria	48 330	94	91	80	18	48 330	0	0	0	0
Switzerland	9 625	99	96	91	21	9 805	9	5	3	1
Cyprus	2 461	68	68	68	17	2 461	0	0	0	0
Czech Republic	27 626	100	100	100	99	27 626	28	22	20	5
Germany	102 891	84	67	58	36	102 891	58	32	24	5
Denmark	3 584	100	100	100	99	3 584	50	42	37	2
Estonia	24 728	67	57	47	5	24 728	0	0	0	0
Spain	187 115	95	93	90	48	187 115	3	0	0	0
Finland	240 403	47	41	36	2	273 634	3	2	2	0
France	180 099	98	95	91	41	177 359	12	8	6	1
United Kingdom	92 244	26	19	17	9	81 815	39	19	15	7
Greece	53 671	98	97	97	60	53 671	3	1	1	0
Croatia	31 698	100	100	99	81	31 698	5	3	3	0
Hungary	20 805	100	100	100	56	20 805	26	8	7	0
Ireland	2 449	88	81	77	73	8 935	23	8	6	2
Iceland	6 122	0	0	0	0	61 22	16	13	11	7
Italy	124 788	69	61	55	14	124 788	0	0	0	0
Liechtenstein	26	100	100	100	92	26	52	32	0	0
Lithuania	19 018	100	100	100	92	19 018	34	32	32	4
Luxembourg	1 015	100	100	99	98	1 015	15	13	13	0
Latvia	35 823	99	99	96	44	35 823	20	14	12	0
The FYR of Macedonia	13 945	100	100	100	53	13 945	12	1	0	0
Netherlands	4 447	94	88	88	76	6 968	76	71	71	60
Norway	137 701	22	14	11	0	179 158	16	11	10	3
Poland	90 330	100	100	99	68	90 330	77	61	50	3
Portugal	31 121	97	83	69	6	31 121	8	3	3	0
Romania	97 964	19	20	15	0	97 964	46	22	12	0
Sweden	150 865	56	47	43	13	443 660	17	10	9	2
Slovenia	10 996	98	92	82	0	10 996	7	0	0	0
Slovakia	20 532	100	100	100	83	20 532	18	9	8	0
Serbia & Montenegro	41 108	97	95	92	34	41 108	18	9	3	0

Source: EEA, 2012

The percentage of sensitive ecosystems at risk of chemical changes with negative effects on ecosystem function and structure caused by acidification has been calculated by the EEA as the share of sensitive ecosystems for which critical loads for acidification are exceeded by deposition of acidifying nitrogen sulphur compounds.

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[1] Hettelingh J-P, Posch M, Slootweg J (eds.) (2008) Critical load, dynamic modelling and impact assessment in Europa: CCE Status Report 2008, Netherlands Environmental Assessment Agency.

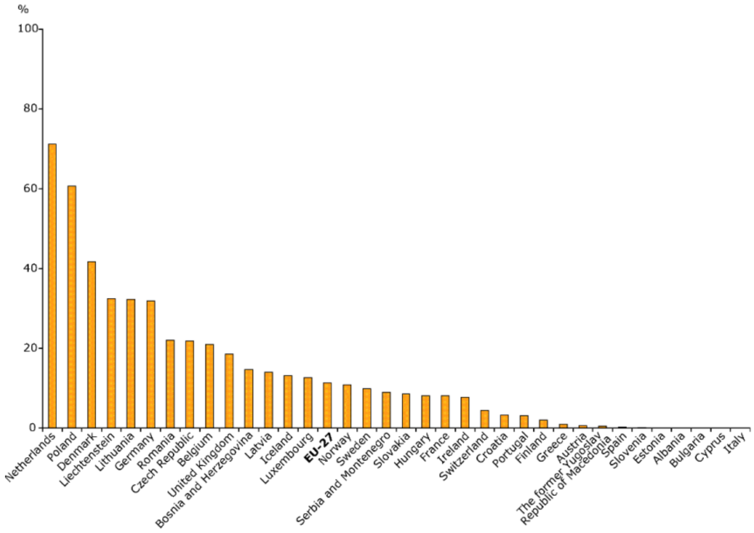

Figure 3-15: Percentage of ecosystem area at risk of acidification for EEA Member Countries and EEA Cooperating Countries in 2010 for a current legislation (CLE) scenario[1]

Source: European Environment Agency, 2012

The percentage of ecosystem at risk of eutrophication and negative changes in nutrient balances is presented in Figure 3-16. This percentage has been calculated by the EEA as the share of sensitive ecosystems for which decomposition of oxidized and reduced nitrogen compounds exceeds the critical loads.

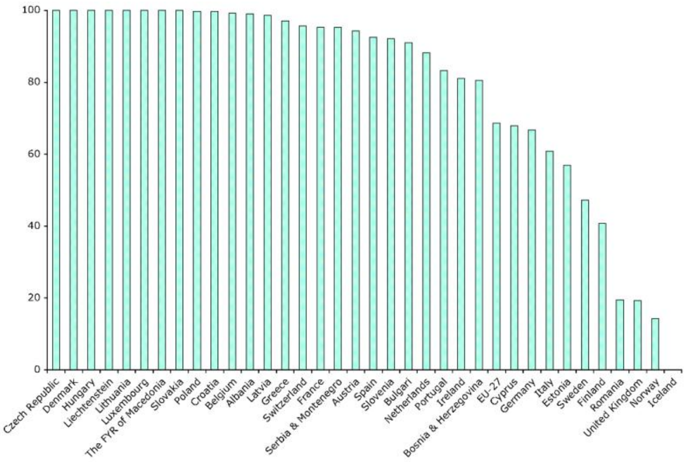

Figure 3-16: Percentage of ecosystem area at risk of eutrophication for EEA Member Countries in 2010 for a current legislation (CLE) scenario[2]

Source: European Environment Agency, 2012

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[1] The results were computed using the 2008 Critical Loads database. Deposition data was made available by the LRTAP Convention EMEP Centre for Integrated Assessment Modeling (CIAM) at the International Institute for Applied Systems Analysis (IIASA) in autumn 2007.

[2] The results were computed using the 2008 Critical Loads database. Deposition data was made available by the LRTAP Convention EMEP Centre for Integrated Assessment Modeling (CIAM) at the International Institute for Applied Systems Analysis (IIASA) in autumn 2007.

More specifically for the forest ecosystems of Cyprus, a research survey was carried out calculating the critical loads of acidity and nutrient nitrogen for Cyprus forest ecosystems in order to identify sites where deposition levels have reached a critical state and ecosystems could be at risk. Calculation of critical loads is based on a mass balance approach that takes into account atmospheric deposition, stand structure, bedrock and soil chemistry. Deposition scenarios compiled by the Centre for Integrated Assessment Modelling (CIAM) of the European Monitoring and Evaluation Programme (EMEP) were provided by the ICP Modelling and Mapping programme. A comparison between deposition rates and critical loads allowed to compute the so-called exceedance. For Cyprus at that time only the EMEP yearly deposition dataset of acidifying sulphur and nitrogen pollution (50 by 50 km grid cells, EMEP 2003) was available, allowing for a very rough estimation on exceedances. The comparison between the deposition values in 2000 with the critical loads showed that nowhere are exceedances in Cyprus (Nagel, 2003; LRTAP/IWF, 2011).

The reason is the relatively high acid neutralisation capacity of the mostly calcareous soils in Cyprus resulting in high critical loads. As depositions are actually underestimated, local sources were also taken into account. As a result it was estimated that about 17 % of the natural ecosystems area is stressed by acid depositions near the critical loads. The area is located at the lowlands between Pentadactylos and Troodos mountains. In these areas the main vegetation types are maquis and garique which are characterized by low critical loads. The comparison between the deposition values of nitrogen compounds in 2000 (EMEP 2003) with the critical loads shows exceedances in about 60 % of the Cyprian ecosystems. The critical loads of halophytic vegetation in salt lakes and lagoons near Ammochostos, Lemesos and Morfou are exceeded more than twice, but also at the Pentadactylos mountains the actual depositions are higher than critical loads. Also at the circum Troodos sedimentary succession area exceedance of critical loads is observed. Only critical loads at the Troodos forests are not exceeded at all (Nagel, 2003).

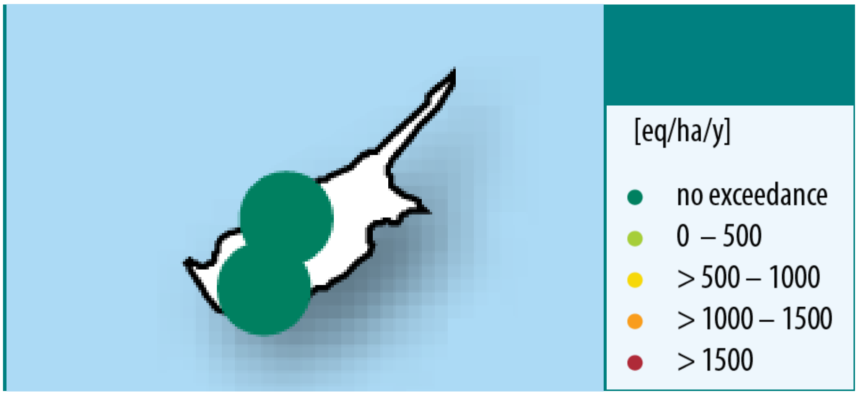


Figure 3-17: Exceedance of critical loads for nutrient nitrogen in 2000

Source: LRTAP/IWF, 2011

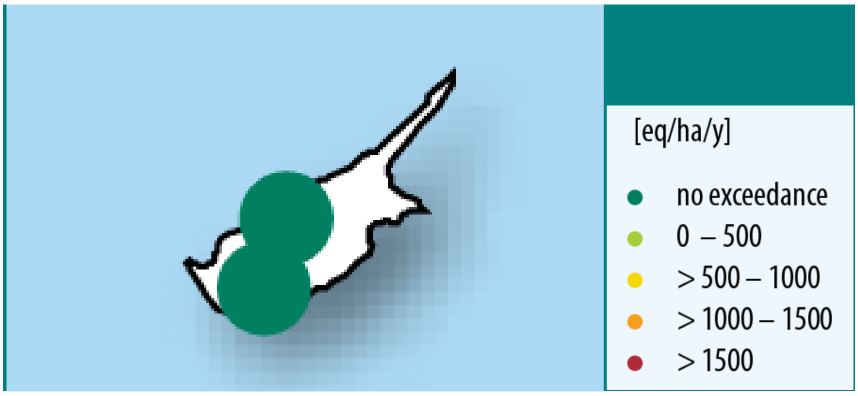


Figure 3-18: Exceedance of critical loads for acidity in 2000

Source: LRTAP/IWF, 2011

Soil contamination due to acidity and nitrogen pollution of groundwater bodies can be affected by changes in precipitation. Further research is required in order to estimate the anticipated response of soil contamination due to changes in precipitation. Climatic predictions are presented as a baseline for a future study.

Annual total precipitation and seasonal precipitation will have a decrease of about 0-20 mm for the whole domain of study with a minimum value of about -120mm in the peninsula of Karpasia. This decrease in precipitation may have negative impact on water availability and thus in freshwater quality, affecting in this way freshwater biodiversity. However further research is required to estimate response of soil contamination in precipitation changes.

In western regions chemical and ecological status of river and lake bodies is estimated as good affecting positively soil quality. Although in annual total rainfall the decrease is minor the anticipated decrease of about 0-20mm in winter total precipitation may affect this status characterization. The same decrease is anticipated in mountain, southern and southeastern regions that the most vulnerable nitrate zones are situated and ecological and chemical status of lakes and rivers is estimated as moderate. More specifically future precipitation (2021-2050) is expected to be around 210 mm in western and mountain regions, 70mm in inland and southeastern regions and 150mm in southern regions.

A similar pattern to winter is evident for autumn precipitation where a decrease of about 10-15mm is anticipated for the whole study domain. More specifically future amounts of autumn rainfall will reach 55 mm in southeastern and southern district that the most vulnerable nitrate zones are situated, 95 mm for mountain region and 135 mm for western regions compared with current amounts which are 70 mm, 110 mm and 150mm. As already mentioned western regions depict a good ecological status of river and lake bodies that affect soil quality while in rest of the areas the status is considered moderate.

Further research is required on impact of future changes in annual and seasonal precipitation on acidification, eutrophication and ozone contamination of soils in order to estimate the anticipated response of soil contamination.

To sum up, taking into account the current exposure to soil contamination as well as the relative future climate changes the exposure of soils to soil contamination for the future period (2021-2050) can be characterized as **moderate**.

3.4.3.2 Assessment of adaptive capacity

The Pollution Control Division of the Ministry of Agriculture, Natural Resources and Environment of Cyprus has the responsibility for the protection, control and prevention of pollution of water and soil from the operation of industrial and farming activities as well as any other human activity that may or tends to pollute the waters and the ground. The legislation named "The Control of Water Pollution Laws of 2002 to 2009" include the law 106(I)/2002 and its amendments (160(I)/2005, 76(I)/2006, 22(I)/2007, 11(I)/2008, 53(I)/2008, 68(I)/2009, 78(I)/2009) is relevant to the protection of water and ground form pollution.

Furthermore the Directive 91/676/EEC on the protection of waters against pollution caused by nitrates has been harmonized in the legislation of Cyprus with the Law on Water Pollution Control No. 106(I)/2002. For its implementation, the Department of Agriculture has established a (i) Code of Good Agricultural Practice as well as an (ii) Action Plan to prevent or reduce water pollution from nitrates.

i) <u>Code of Good Agricultural Practice</u>

The Code of Good Agricultural Practice which has been enacted by the Presidential Decree No. 263/2007 aims to reduce nitrate pollution from fertilizer use and livestock waste and the introduction of acceptable practices for the use of recycled water in irrigation and municipal sludge in agriculture that protect public health and the environment. However, the compliance with the guidelines of the code is prescriptive.

For certain types of facilities with significant potential 'polluting' activities implemented additionally "on the Integrated Prevention and Pollution Control Laws of 2003 - 2008" (Law 56 (I) / 2003, Law 15 (I) / 2006 and Law 12 (I) / 2008). These laws aim to prevent emissions to air and discharges to water and land-based weather and take the necessary measures, notably the introduction of Best Available Techniques (BAT) in order to achieve the highest level of environmental protection.

The protection of waters and soil, under the above laws are related to the granting discharge authorizations under the Ministry of Agriculture, Natural Resources and Environment. Permissions define environmental terms, depending on the type of each facility, for the rational management of liquid and solid wastes and their disposal in a controlled environment.

The implementation of the abovementioned measures has resulted in a significant reduction of soil contaminating activities in Cyprus. However, the natural remediation of the soils requires several years to take place while there are several techniques which are applied for the decontamination of soils.

Following, additional recommended adaptation measures that are considered to further enhance adaptive capacity towards this impact are presented indicatively. Nevertheless, their assessment and final selection for implementation will be made through the use of the Multicriteria Analysis (MCA) tool which will be developed and implemented in the framework of Actions 4 and 5 of the CYPADAPT project.

- Control the use of marginal quality water and proper advising on the impact of soils
- Provision of good quality irrigation water for leaching purposes where possible
- Ensuring drainage of irrigated soils
- Further reduction of water losses
- Implementation of a special plan for incentives and support to farmers for the installation of improved irrigation systems in the mountainous and semi-mountainous areas that fall under the sensitive areas to desertification

Consequently adaptive capacity for the future period (2021-2050) to soil contamination in Cyprus is considered to be **moderate**.

3.4.4 Soil Salinization – Sodification

3.4.4.1 *Assessment of sensitivity and exposure*

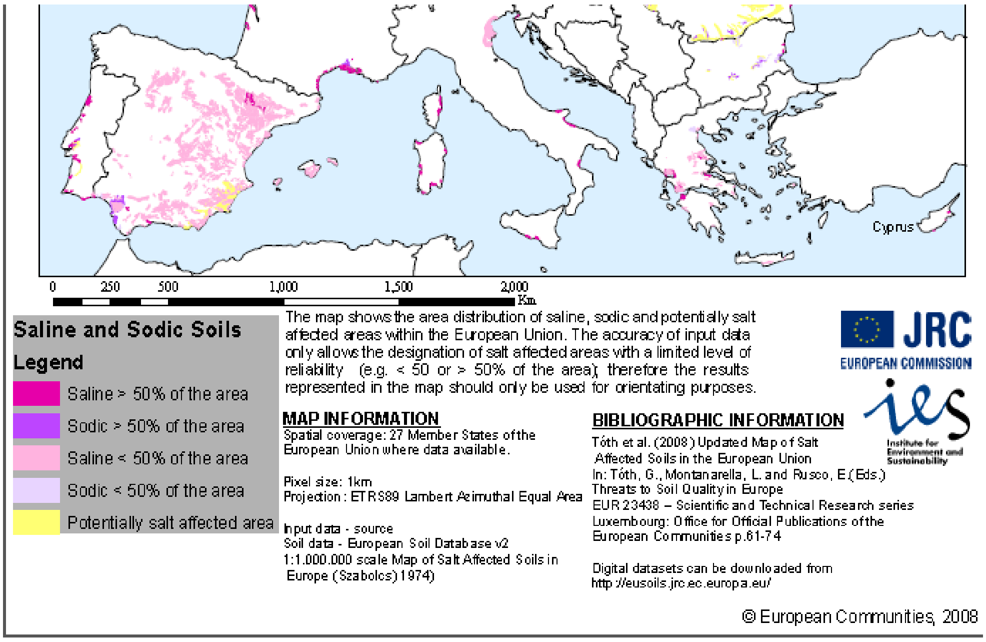
Sensitivity

Soil salinization in Cyprus is a combination of natural soil salinization and man-made soil salinization or secondary salinization. In Cyprus almost the soils are characterized as alkaline (Koudounas, 2001; I.A.CO Ltd, 2007). In addition, certain areas are affected by soil salinization due to the use of treated waste water with high salt content and the use of inferior quality water from aquifer boreholes for irrigation in combination with the more frequent consecutive years of droughts and the increased water demand. As a result, the sensitivity of soil salinization for the future period (2021-2050) for Cyprus can be characterized **moderate to high**.

Exposure

Cyprus exposure to salinization is evaluated according to indicators such as areas of salinized soils and crop areas using inferior quality water. Further research is required concerning the second indicator.

Cyprus has moderate exposure to soil salinization. Soils of the affected areas on the eastern part of the island are saline more than 50%, as shown in the following map (Figure 3-19). Certain areas of Larnaca are affected by the use of treated waste water with high salt content, and others (such as Akrotiri, Syrianochori, Livadia–Oroklini, Acheritou–Egkomi and on the west of Larnaca) by the use of inferior quality water (I.A.CO Ltd, 2007).



The map shows the area distribution of saline, sodic and potentially salt affected areas within the European Union. The accuracy of input data only allows the designation of salt affected areas with a limited level of reliability (e.g. < 50 or > 50% of the area); therefore the results represented in the map should only be used for orientating purposes.

MAP INFORMATION
Spatial coverage: 27 Member States of the European Union where data available.

Pixel size: 1km
Projection: ETRS89 Lambert Azimuthal Equal Area

Input data - source
Soil data - European Soil Database v2
1:1.000.000 scale Map of Salt Affected Soils in Europe (Szabolcs) 1974)

BIBLIOGRAPHIC INFORMATION
Tóth et al. (2008) Updated Map of Salt Affected Soils in the European Union
In: Tóth, G., Montanarella, L. and Rusco, E.(Eds.)
Threats to Soil Quality in Europe
EUR 23438 – Scientific and Technical Research series
Luxembourg: Office for Official Publications of the European Communities p.61-74

Digital datasets can be downloaded from
http://eusoils.jrc.ec.europa.eu/

© European Communities, 2008

Figure 3-19: Saline and sodic soils in European Union

Source: JRC, 2012

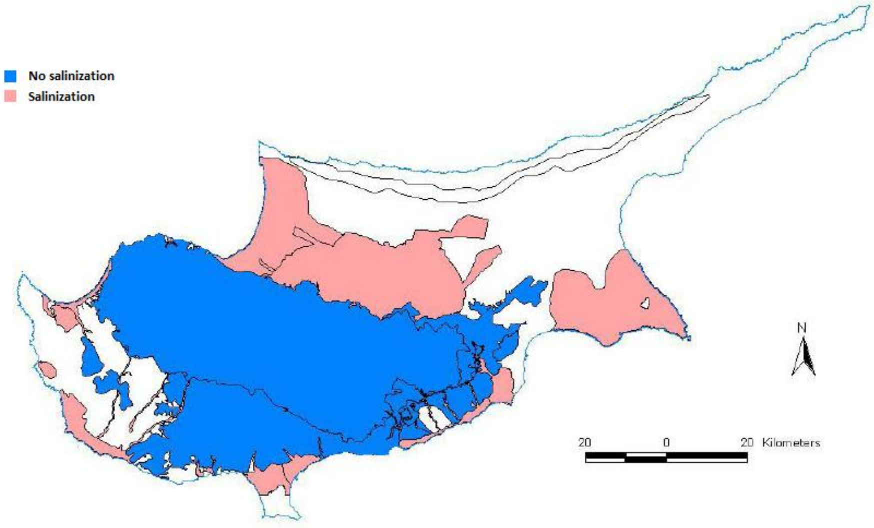


Figure 3-20: Salinization in the groundwater bodies of Cyprus

Source: WDD, 2008

There is no information available for salinization of ground water bodies and soil salinization due to climate change for Cyprus. However such conditions can be affected by increases in temperature and reduced precipitation. Although further research is required to correlate temperature -precipitation change and soil salinization, climatic predictions for the future period (2021-2050) are presented as a baseline for a future study.

More specifically Cyprus will experience, in the near future, a warming of about 1 – 2°C. Winter minimum and summer maximum temperatures are presented in the following as the most extreme cases.

Winter minimum temperature is anticipated to have an increase of 0.8-0.9°C in western, southern and eastern coastal areas that most of the saline ground water bodies are located. In mountain areas that no salinization in soils exists winter minimum temperature increase is about 0.9°C. Summer maximum temperature in western, southern and eastern coastal areas that most of the saline soils are located is anticipated to increase about 1.8-2.2°C. In mountain areas that no salinization in ground water bodies exists summer minimum temperature increase is about 2.3-2.7°C. However there is no data available for the response of salinization of ground water bodies to anticipated increase in temperature. Further research is required.

Generally, annual total precipitation appears to have minor decreases or no changes at all. However for seasonal total rainfall changes are forecasted for the future period (2021-2050) Concerning winter total rainfall, a decrease of about 0-20 mm is anticipated in for all the domain of study. As a result, for western, southern and eastern coastal areas that most of the saline ground water bodies are located precipitation is anticipated to decrease about 0-20 mm. In mountain areas that no salinization exists in ground water bodies winter total rainfall decrease is about 10mm. A similar pattern to winter is evident for autumn precipitation where a decrease of about 10-15 mm is anticipated for the whole study domain. More specifically future amounts of autumn rainfall for western, southern and eastern coastal areas will decrease about 10-15 mm and in mountain areas that no salinization exists in ground water bodies, autumn total rainfall will decrease about 10mm.

There is no data available for the response of salinization of ground water bodies and soil salinization due to decrease in precipitation for Cyprus. Further research is required. However, considering that the future climate changes affecting soil salinization are minor, they are not expected to significantly increase future exposure.

To sum up, taking into account the current exposure to salinization as well as the relative future climate changes, it is expected that the future exposure of soils to the risk of soil salinization is **moderate**.

3.4.4.2 Assessment of adaptive capacity

Studies have shown that the accumulations of salt are washed out to the sea with precipitation. Furthermore the law on the control of groundwater abstractions to reduce overexploitation and salinization “Integrated Water Management 79(I)/2010” which has been enforced in Cyprus since 2010, sets strict requirements on the granting of permissions for the drilling of boreholes and the pumping of groundwater. Furthermore, the Law foresees the installation and monitoring of water meters in boreholes, in order for the quantities of water pumped not to exceed the limits set. It is expected that with the new

Law a considerable number of violations, that have been made in the past, will be eliminated. What is more, the salinity of the water used for irrigation and recharge is monitored in order to avoid further deterioration of the groundwater bodies.

Following, additional recommended adaptation measures that are considered to further enhance adaptive capacity towards this impact are presented indicatively. Nevertheless, their assessment and final selection for implementation will be made through the use of the Multicriteria Analysis (MCA) tool which will be developed and implemented in the framework of Actions 4 and 5 of the CYPADAPT project.

- Provision of good quality irrigation water for leaching purposes where possible
- Regular monitoring of the salinity and salinization of soils and of the quality of irrigation water
- The irrigation should cover leaching requirements in addition to the plant's needs especially where the water has an increased salinity
- Further reduction of water losses
- Implementation of a special plan for incentives and support to farmers for the installation of improved irrigation systems in the mountainous and semi-mountainous areas that fall under the sensitive areas to desertification

Considering the above the adaptive capacity of soil resources in Cyprus is **limited to moderate**.

3.4.5 Desertification

3.4.5.1 Assessment of sensitivity and exposure

Sensitivity

Overexploitation of water and soil resources, growing water demand, economic growth and development of the urban and coastal areas, aging of the rural population, abandonment of the traditional agricultural activities, reduction of rainfall, topography and poor and erodible soils_are responsible for the naturally increased sensitivity of the island towards desertification. The only areas which are less prone to desertification are the mountain areas of Troodos due to the dense vegetation cover (Figure 3-21).

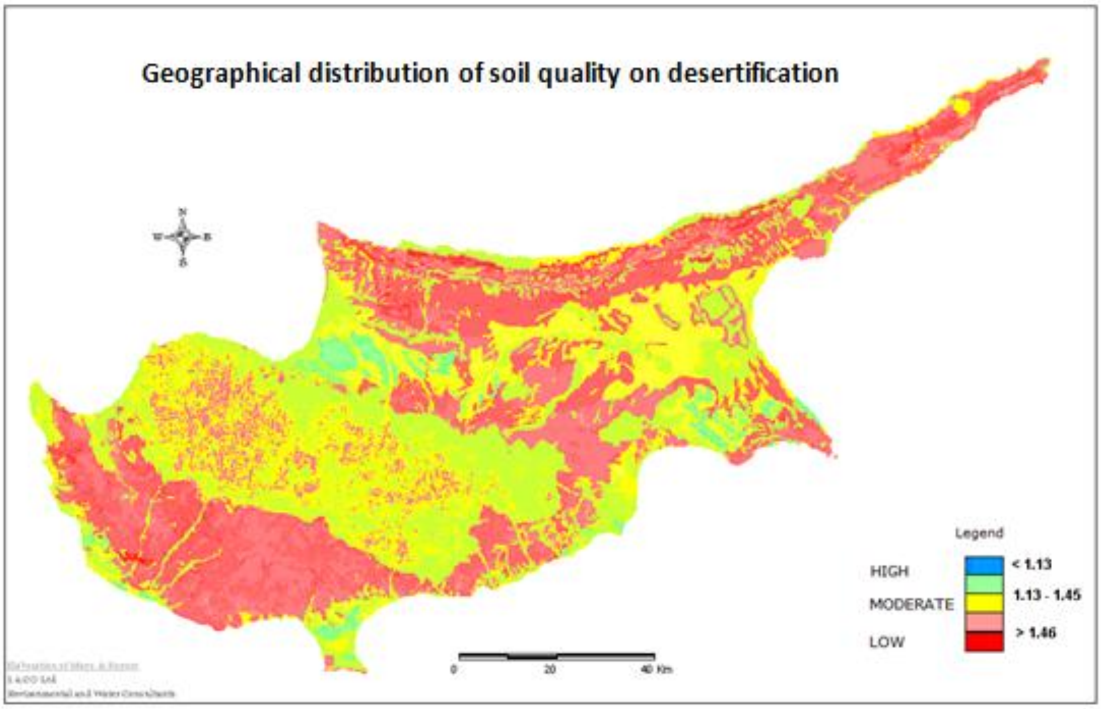


Figure 3-21: Geographical distribution of soil quality on desertification

In addition, some social aspects of Cyprus in combination with these physical characteristics of the island (topography, reduction of rainfall and poor on desertification and erodible soils) contribute to the deterioration of the phenomenon of desertification. One of the most important indicators for desertification is the overexploitation of water resources over the last 50-60 years with the reduction of water levels and water quality (various recorded levels of sea intrusion) due to the growing water demand and the increased groundwater use. Another parameter is the effects of the economic growth and development of the urban and coastal areas with the abandonment of the traditional agricultural activities and the aging of the rural population leading to the overexploitation of soil resources of the urban and coastal areas and the abandonment of the rural areas.

Considering the above, the sensitivity of Cyprus for the future period (2021-2050) to desertification can be characterized **very high.**

Exposure

Seriously eroded soils in semi-arid zones are found at sloping areas with excess higher than 12%. Hilly areas in Cyprus with slope excess of 12%, cover the 22% of the island. A large surface percentage of these hilly areas are covered by permanent vegetation (Figure 3-22) and are less affected by desertification. The most sensitive areas seem to be the plains, which are mostly covered by seasonal crops.

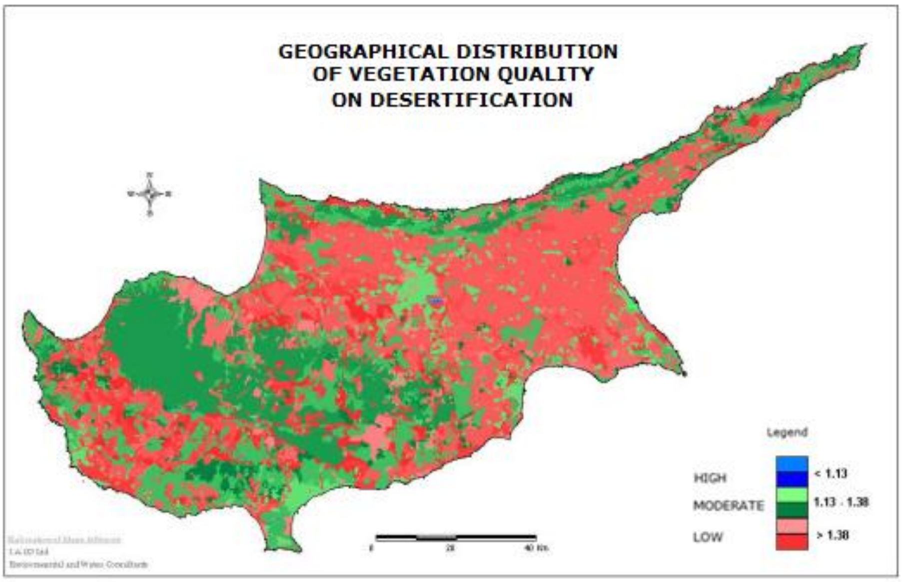


Figure 3-22: Geographical distribution of vegetation quality on desertification

Source: I.A.CO Ltd, 2007

Furthermore, the areas which are considered more prone to desertification are the urban and coastal areas due to the increased groundwater use and demand, soil sealing (and soil compaction, and the abandoned rural areas due to the economic growth and development of the urban and coastal areas are more prone to desertification (Figure 3-23).

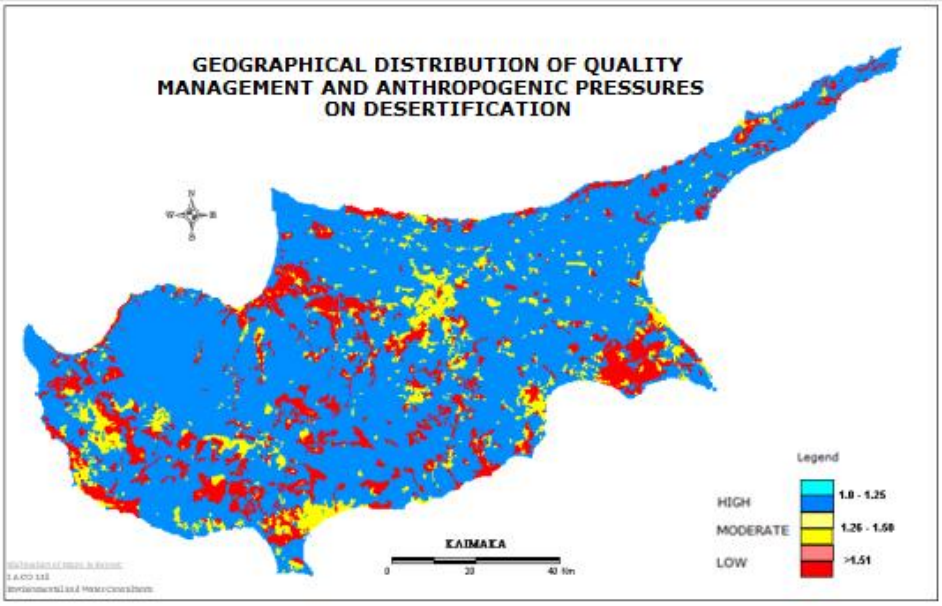


Figure 3-23: Geographical distribution of quality management and anthropogenic pressures on desertification

Source: I.A.CO Ltd, 2007

As shown in Figure 3-24 and Figure 3-25, desertification is characterised by high sensitivity for the current period. A surface area of 57% is characterized as "Critical", 42.3% as "Fragile" and only 0.7% as "Potential" to desertification (I.A.CO Ltd, 2007).

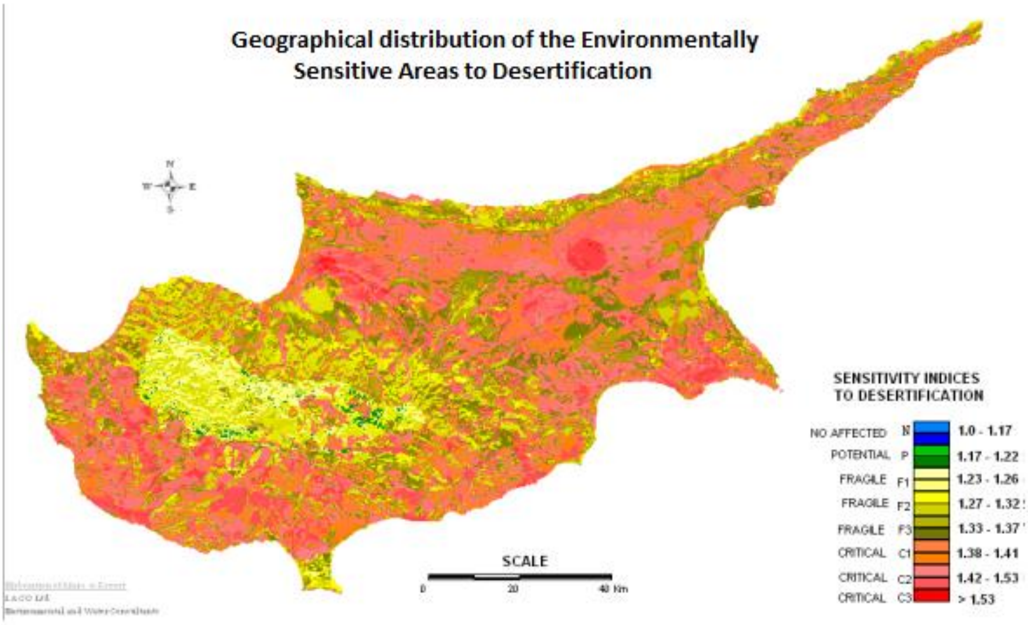


Figure 3-24: Geographical distribution of the Environmentally Sensitive Areas to Desertification

Source: I.A.CO Ltd, 2007

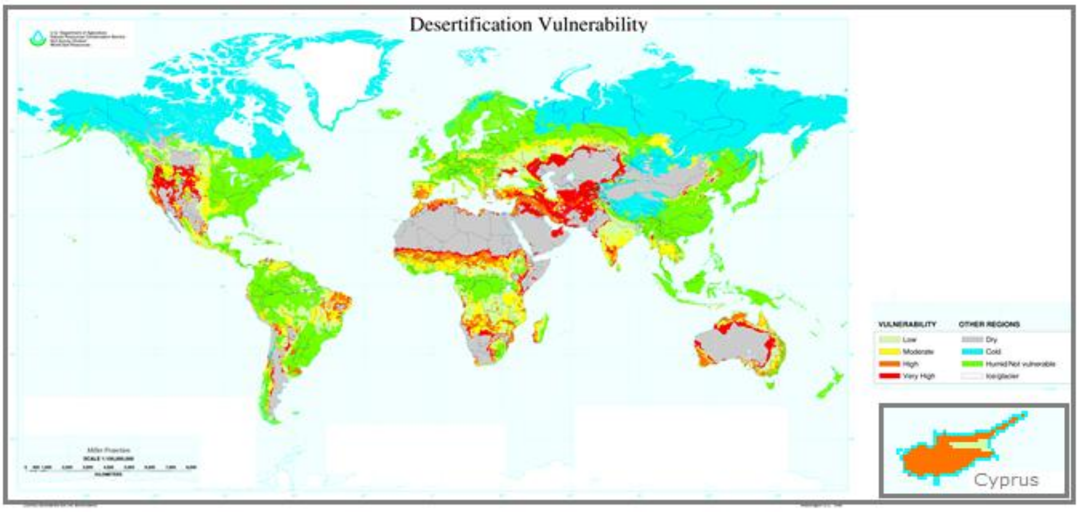


Figure 3-25: Map of global desertification vulnerability

Source: NRCS, 1998

Climate change and in specific reduction of precipitation and temperature rise, can deteriorate the phenomenon of desertification. Further research is required to correlate future desertification with changes in temperature and precipitation. Nevertheless, climatic predictions are presented as a baseline for a future study.

According to the previous maps areas that are sensitive to desertification are the areas with lower soil quality that are mainly coastal areas and low elevation areas. Anticipated changes in winter minimum and summer maximum temperatures are presented in Figure 3-26 and Figure 3-27 as the most significant cases for all areas.

In regions less prone to desertification, which are mainly mountain areas, temperature is anticipated to increase about 1°C on average in winter and 2-2.7°C on average in summer. In the rest areas were sensitivity to desertification is more critical winter minimum temperature is anticipated to have an increase of about 0.8- 1°C. Summer maximum in the future period is anticipated to increase about 1.7-2 °C for western regions, 2.4 °C for inland regions, 2.3 °C for southern regions and 2.3 °C for southeastern regions. As a result average summer maximum temperature and winter minimum temperature is anticipated to increase less in areas more prone to desertification than mountain areas. However effect of this increase in exposure degree to desertification requires further research.

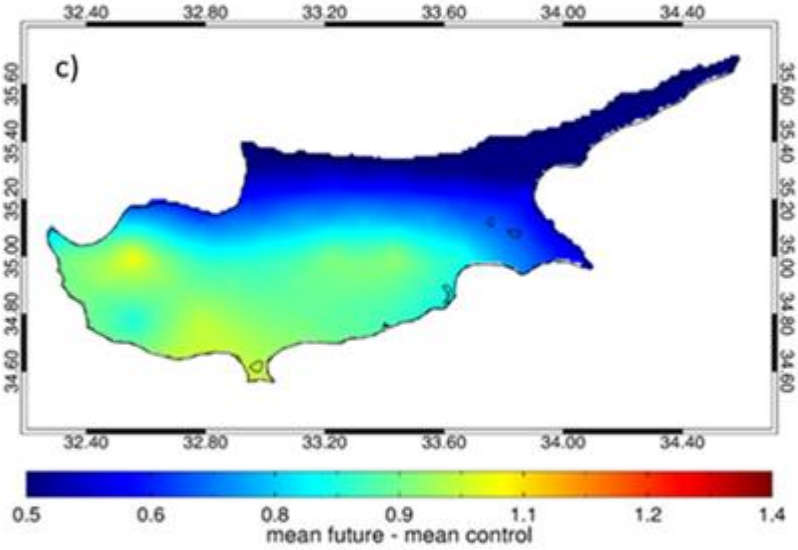


Figure 3-26: **Changes in average winter minimum temperature in the near future (Future – Control period) using PRECIS RCM model**

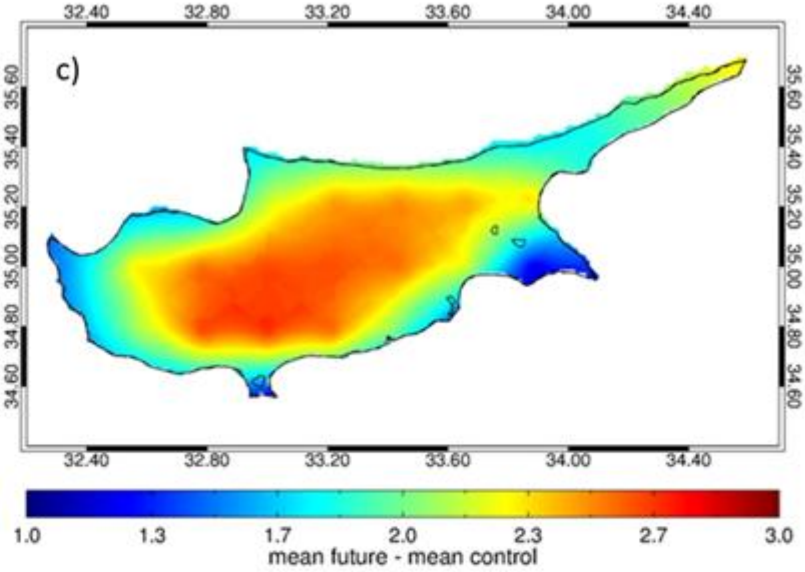


Figure 3-27: Changes in average summer maximum temperature in the near future (Future – Control period) using PRECIS RCM model

Impact of anticipated changes in precipitation in degree of exposure to desertification may not be significant since changes in precipitation are predicted as mild for all areas. In winter and autumn rainfall the decrease in precipitation is anticipate to be 20mm and up to 15mm respectively

More specifically for mountain regions that are less prone to desertification a precipitation of about 210mm is anticipated for winter and 95 mm for autumn total rainfall. For western, southern and inland regions, more prone to desertification and of lower soil quality, winter total rainfall will be about 210 mm, 70mm and 150mm respectively. For southeastern district that is covered by prone to desertification regions especially in the coastal areas precipitation will be about 70 mm. A similar pattern to winter is evident for autumn precipitation where autumn rainfall will reach 55 mm in southeastern and southern district and 135 mm for western regions**.**

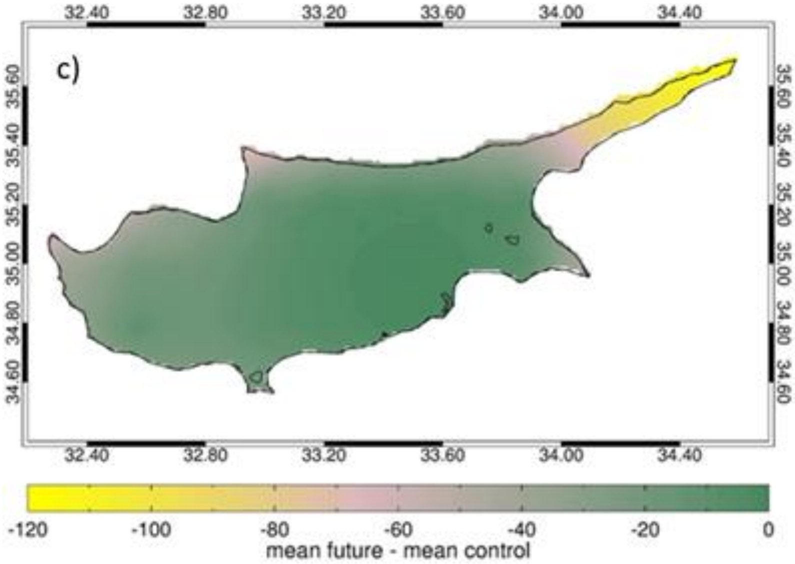


Figure 3-28: Changes in winter total precipitation in the near future (Future – Control period) using PRECIS RCM model

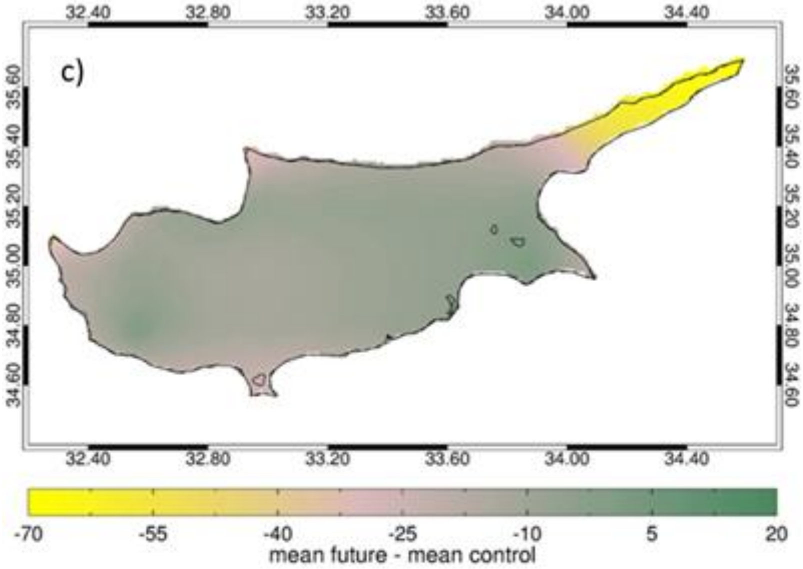


Figure 3-29: Changes in autumn total precipitation in the near future (Future – Control period) using PRECIS RCM model

To sum up, taking into account the current exposure to desertification as well as the relative future climate changes, the exposure of soils to desertification for the future period (2021-2050) can be characterized as **very high**.

3.4.5.2 Assessment of adaptive capacity

The resilience of soils against desertification includes parameters such as good soil quality and vegetation cover. In Cyprus, there is poor soil quality on desertification while vegetation cover is restricted to the mountain areas. Provided that it requires the coordinated action from the majority of sectors (i.e. agriculture, forestry, water resources etc), there is a series of measures ranging from legislation, to government works and private initiatives for the reduction of the escalation of the phenomenon. However, the phenomenon of desertification cannot be easily addressed in semi-arid climate types similar to Cyprus.

Following, additional recommended adaptation measures that are considered to further enhance adaptive capacity towards this impact are presented indicatively. Nevertheless, their assessment and final selection for implementation will be made through the use of the Multicriteria Analysis (MCA) tool which will be developed and implemented in the framework of Actions 4 and 5 of the CYPADAPT project.

- Mandatory implementation of the Code of Good Agricultural Practice
- Continuation and increase agri-environmental measures within the RDP with emphasis on erosion control
- Grants and incentives for maintenance of terracing, and protection walls in sloping lands even in areas where farming has been abandoned
- Control of abandonment of farming and support of traditional agricultural practices
- Incentives for terracing in burnt areas and intervention for prevention of increased erosion
- Implementation of a plan for the sustainable use of land (on the basis of slope and type, structure, depth and resilience of soil to erosion)
- Extension of the Goats Law to cover all the areas in Cyprus. The objective is the control of grazing by license on the basis of the carrying capacity of each area.
- Studies and research for the definition of number of animals that could be accepted by each area without detrimental impact on its ecosystem. For each area the productive capacity, the time and intensity of grazing should be evaluated for securing sustainability
- Reinstatement of the institution of the Rural Constable for the control of illegal and free grazing
- Provision of good quality irrigation water for leaching purposes where possible
- Regular monitoring of the salinity and salinization of soils and of the quality of irrigation water
- Ensuring drainage of irrigated soils
- The irrigation should cover leaching requirements in addition to the plant’s needs especially where the water has an increased salinity
- Further reduction of water losses
- Proper soil cultivation
- Enhancement of land surface cover

- Implementation of a special plan for incentives and support to farmers for the installation of improved irrigation systems in the mountainous and semi-mountainous areas that fall under the sensitive areas to desertification

For these reasons, the adaptive capacity is characterized as **limited to moderate**.

3.4.6 Assessment of overall future vulnerability

The principal aim of this chapter is to identify the key future vulnerabilities of soil resources to climate changes, as well as to assess the magnitude of these future vulnerabilities. However, it must be noted that, as there were no sufficient data to evaluate all indicators further research is required.

In order to quantify the vulnerability potential of soil resources against a climatic change impact, the values of sensitivity, exposure, adaptive capacity and vulnerability are quantified as follows:

Degree of sensitivity, exposure & adaptive capacity		Degree of vulnerability		Legend
None	0	None	V≤0	
Limited	1	Limited	0<V≤1	🟩
Limited to Moderate	2	Limited to Moderate	1<V≤2	🟨
Moderate	3	Moderate	2<V≤3	🟨
Moderate to High	4	Moderate to High	3<V≤4	🟧
High	5	High	4<V≤5	🟧
High to Very high	6	High to Very high	5<V≤6	🟥
Very high	7	Very high	6<V≤7	🟥
Not evaluated	-	Not evaluated	-	⬜

Since vulnerability is defined by the following formula:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity * Exposure$$

“Impacts” and “Adaptive capacity” should be evaluated on the same scale (1-7). For this to be achieved, the square root of “Sensitivity x Exposure” is used. The results of the vulnerability assessment for the soil resources in Cyprus are summarized in Table 3-7.

Table 3-7: Overall vulnerability assessment of soil resources in Cyprus to climate changes

Impact	Sensitivity	Exposure	Adaptive Capacity	Vulnerability
Soil erosion (by wind and/or rain water)	Moderate to High (4)	High (5)	Limited to Moderate (2)	Moderate (2.5)
Landslides	Moderate (3)	Limited to Moderate (2)	Moderate (3)	None(-0.6)
Soil contamination	Limited (1)	Moderate (3)	Moderate (3)	None (-1.3)
Soil salinization - sodification	Moderate to High (4)	Moderate (3)	Limited to Moderate (2)	Limited to Moderate (1.5)
Desertification	Very high (7)	Very high (7)	Limited to Moderate (2)	High (5)

The most important impacts of climate changes on the soil resources of Cyprus are the extensive desertification and the soil erosion by rain water. In specific, the most important problem of Cyprus on soils in the future seems to remain the phenomenon of desertification. Soil erosion, which is actually one of the factors causing desertification, constitutes also key future vulnerability for the soils resources of Cyprus mainly due to the intensive agricultural activities taking place and the increasing percentage of abandoned rural land. Soil salinization is the third future vulnerability priority caused by the salinization of coastal aquifers and the irrigation with low quality (saline) water.

It must be mentioned that the characterizations used in this report are only qualitative and based on the available data for the soil resources of Cyprus in comparison with the rest of Europe. An important conclusion of this report, especially due to the extensive land degradation, is the necessity for further thorough research for the soil resources of the island.

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4 COASTAL ZONES

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Abbreviations and Acronyms

CAMP	Coastal Area Management Programme
DTPH	Department of Town Planning and Housing of the Ministry of Interior, Republic of Cyprus
EIA	Environmental Impact Assessment
ICZM	Integrated Coastal Zone Management
IPCC	Intergovernmental Panel on Climate Change
MAP	Mediterranean Action Plan
MCA	Multi-Criteria Analysis
NGO	Non Governmental Organization
PAP/RAC	Priority Actions Programme/Regional Activity Centre
PRECIS	Providing Regional Climates for Impact Studies
PWD	Public Works Department of the Ministry of Communications and Works, and Delft Hydraulics, Republic of Cyprus
RCM	Regional Climate Model
RR	Precipitation
TX	Maximum temperature
WDD	Water Development Department (WDD) of the Ministry of Agriculture, Natural Resources and Environment, Republic of Cyprus

4.1 Climate change and coastal zones

Coastal zones are amongst the most dynamic natural environments on earth, including natural ecosystems such as coral reefs, mangroves, beaches, dunes and wetlands, in addition to important managed ecosystems, economic sectors, and major urban centers. A large part of the global human population lives in coastal areas and a considerable portion of global economic wealth is generated in coastal zones (Klein, 2002).

Human-induced global climate change and associated sea-level rise can have major adverse consequences for coastal ecosystems and societies (Klein, 2002). Coastal environments, settlements, and infrastructure are exposed to land-sourced and marine hazards such as storms (including tropical cyclones), associated waves and storm surges, tsunamis, river flooding, shoreline erosion, and influx of biohazards such as algal blooms and pollutants. All of these factors need to be recognized in assessing climate-change impacts in the coastal zone (McLean et al., 2001). In the Second Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), Bijlsma *et al.* (1996) noted that climate-related change in coastal zones represents potential additional stress on systems that are already under intense and growing pressure.

The impact, vulnerability and adaptation assessment for the coastal zones regarding the climate changes that have occurred the recent years in Cyprus (CYPADAPT, 2012), concluded that the current vulnerability of the coastal zones in Cyprus to climate changes focuses mainly on coastal erosion, which already constitutes a pressure for Cyprus' coasts and although it is addressed in a quite satisfactory degree, it is expected that climate changes will accelerate the phenomenon. The impact of coastal storm flooding and inundation is considered to present limited vulnerability for Cyprus' coasts taking into consideration the fact that this is not such an extensive issue for Cyprus for the time being, while the impact of the degradation of coastal ecosystems was not evaluated due to absence of sufficient information on the subject.

In the sections that follow, an attempt is being made to assess the impacts of future climate changes on the coastal zones of Cyprus based on the climate projections output produced by the PRECIS (Providing Regional Climates for Impact Studies) regional climate model as well as on other socio-economic projections for the period 2021-2050. The reason why PRECIS was selected to be used in the present study is that, unlike in other regional climate models, in PRECIS Cyprus lies at the center of the domain of the study. The future period 2021-2050 has been chosen, instead of the end of the twenty-first century as frequently used in other climate impact studies, in order to assist stakeholders and policy makers to develop near future plans.

4.2 Baseline situation

Cyprus is the third largest island in the Mediterranean having a total shoreline of 772 km, of which 296 km (38%) are within the area on which the Government exercises effective control, 404km (52%) are in the occupied part and 72km (10%) are within the British Military Bases. Except for Nicosia, all other major towns are settled across the shoreline. In Cyprus there is no single legal or functional definition of the 'coastal zone' and/or 'coastal area'. There are three main widely used geographical definitions referring to 'coastal zone / area', each one related to the purposes of a different law and institutional context (Environmental Service, 2006):

- The Foreshore Protection Law defines the 'foreshore' as 'all lands within 100 yards (91.44 m) of the high water mark'. The foreshore area is public property falling under the jurisdiction of this Law.
- The New Tourism Policy (under the Hotel Accommodation Law and the Town and Country Planning Law – Countryside Policy, 1990) designates a 'coastal zone' with latitude of 3 km from the coastline for the purpose of regulating tourism development.
- The Coastal Protection Study of the Coastal Unit of the Ministry of Communications and Works has adopted a definition of the 'coastal strip' as the area of 2km from the coastline for the purposes of the survey of coastal erosion problems.

Based on the third of the aforementioned definitions, the coastal zone that extends 2 km inland from the coastline covers 23% of the country's total area, in which about 50% of the total population lives and works and 90% of the tourism industry is located. The 95% of all licensed tourism hotel accommodation capacity are within the coastal zones. Urban population in the Local Plan areas of the coastal towns (Limassol, Larnaca and Paphos) presented a much higher growth than in the Nicosia Local Plan area in the period 1981-2001 e.g. 55% and 35% respectively. A much stronger contrast is revealed by the disparity in the growth of coastal rural areas (45%) and the inland rural areas (8%) (Environment Service, 2006).

4.2.1 Physical environment

The Cyprus coastline varies at a large degree, ranging from steep inaccessible cliffs and ragged rocky shorelines with sea caves to gentle sloping sandy beaches fringed with sand dunes. The coastal zone is characterized by rich wildlife, long and small beaches, open areas, cliffs, capes, harbors, sand dunes, accumulations of pebbles and, in general, marine and shore areas of prime ecological and scientific value.

Along the 772 km of the Cyprus coastline, coasts are almost everywhere low and shelving. Sea cliffs of any magnitude are extremely rare. According to its substrate, the shoreline is rocky, mainly with pebble beaches (54%), sandy beaches and many small coves (46%). Sand dunes, salt flats, salt lakes, salt marshes as well as freshwater marshes occur in the Cyprus coastal belt although they are limited to few areas (DoE, 2010a).

Sandy beaches are predominant in the large bays of Cyprus, Famagusta, Larnaca, Limassol, Polis Chrysochou and Morphou. These long beaches often grade into shingle beaches at one end of the bay depending on the wave-generated littoral drift. There are also pocket beaches in many rocky shores, which can be extensive (Demetropoulos, 2002). Sandy beaches on the island have different properties. They vary not only in the chemical and physical (grain size, etc) characteristics of the sand, but also in their profile (height and width), depth and stability (Demetropoulos, 2002).

Shingle beaches are often the poorest of the shoreline habitats, as practically nothing survives the grinding action of such beaches during periods of rough weather. They are extensive in Episkopi Bay and in parts of Morphou Bay as well as in stretches of the south coast between Limassol and Larnaca and between Petra of Romiou and Paphos (Demetropoulos, 2002).

Rocky shores in Cyprus also present great variations. The hard limestone shores, which predominate, are the most notable and ecologically interesting ones. There are several areas with such coastline - much of the south-eastern part of the island, all the way from Cape Pyla to Paralimni, is of such rock (with several pocket beaches) - as it is part of Akamas - and most of the Kyrenia coastline from Cape Kormakiti to Cape Andreas (again with many sandy pocket beaches) (Demetropoulos, 2002).

Salt lakes, sand dune and sea cliff habitats are included in this broad habitat category. Salt lakes are distributed around the east and south coasts. Salt lakes are stands of vegetation consisting of a small number of specialist species that can tolerate the salt content of the substrate, occurring along sheltered coasts, mainly on sand or mud (DoE, 2010a).

Sand dunes are hills of wind blown sand that have become progressively stabilized by a cover of vegetation. Sand dunes are species-rich habitats and can be described as coastal hills formed at the back of a beach by deposits of materials, varying on their origin, amount, type and size (DoE, 2010a).

Sea cliffs are distributed in a limited extent in coastline. A number of sea cliffs are very important bird-of-prey colonies, as well as seabird colonies (DoE, 2010a). High cliffs with sea caves can be found in several areas in Akamas, Akrotiri and elsewhere (Dendrinos and Demetropoulos, 1998).

Figure 4-1: Map of Cyprus

4.2.2 Pressures

The coastal zone in Cyprus is densely populated and therefore environmentally vulnerable. It is subjected to increasing pressures from a number of sources (e.g. industrial development, urban sprawl, exploitation of marine resources, tourism, etc.). There is, thus, an urgent need to integrate the many uses of coastal resources so that they can be rationally developed in harmony with one another and with the environment. These uses along with the anthropogenic impacts include (Ramos-Esplá et al., 2007):

- Tourism and recreation/leisure areas. These uses are representing the principal activity in the Cyprus coastal area, with significant increasing trends during the past years. The respective infrastructure, activities and impacts include tourism accommodations and beaching (bathing, nautical sports). The major impacts from these uses are coastal overfrequentation and habitat destruction (sand replenishment).
- Nautical development (marinas, boating, mooring). The major impacts from these uses are hydrodynamic alterations and habitat destruction (marinas, dredging, mooring, silting); disturbance of turtle nesting.

- Buildings and roads. The respective uses are referring to land reclamation, littoral roads, promenades and villas very close to the coast, lights, littoral overfrequentation. The major impacts are related with destruction and degradation of sand dunes and other sensitive coastal and marine habitats.
- Industrial activities. The main industrial activities exercised near the coastline and their impacts are:
  - Aquaculture. The major impacts from aquaculture include organic (including nutrients) and antibiotic pollution (habitat degradation) and the invasion of undesired living species.
  - Desalination plants. The major impacts derive from the release of untreated brine into the sea (osmotic alterations, chemical pollution habitat and biodiversity degradation) and high energy consumption related to emissions.
  - Power generation plants. The respective uses are dealing with electricity generation using the seawater for cooling. The major impact is the increase of seawater temperature causing metabolism and biological alterations.
  - Waste and wastewater treatment. The major impacts from these activities involve organic, nitrogen and phosphate pollution of surface and ground waters, sea eutrofication, algae blooms and degradation of coastal ecosystems. In particular at Paralimni and Ayia Napa, high algae blooms are present during summer periods.

In Table 4-1 the main types of coastal zones in Cyprus and their respective length are presented.

Table 4-1: Development Profile of the Cyprus coastal zone

Type of Coastal Zone's Area	Length of Coastal Zone in km	Percentage of Coastal Zone Area in Total Coastal Zone's Length (%)
Urban coastal areas (urban tourism and infrastructure)	90	30
Tourism driven development areas (expanding tourism development in areas with designated tourism development zones with pockets of agricultural land)	45	15
Rural coastal areas (mainly agricultural area mixed with increasing holiday homes)	106	36
Protected coastal areas	55	19
Total length of coastal zone of the area under government control	**296**	**100**
Sovereign Base Areas	72	
Northern coastal area	404	
Total coastal length of Cyprus	**772**	

Source: Coccossis et al., 2008

The human pressures on the coastal environment are expected to increase due to the population increase. In addition, the following main population growth indicators for the period 1981-2001 sum up the coastal concentration pattern and the extent of coastal pressures for both urban and rural residents (Coccossis et al., 2008):

- Total population growth: 35%;
    - Total urban population growth: 46%;
        - Coastal urban growth: 55%;
        - Inland urban growth: 35%;
    - Total rural population growth: 15%;
        - Coastal rural growth: 45%;
        - Inland rural growth: 8%.

On the basis of all the aforementioned information, it is clearly indicated that anthropogenic pressures on Cyprus coastal zone are not only extensive, but they also have increasing trends.

4.3 Future impact assessment

In this section, the climate change impacts on the coastal zones as these have been identified in Deliverable 1.2 “Climate change impact, vulnerability and adaptation assessment for the case of Cyprus” will be reassessed in light of the climate projections for the future (2021-2050).

The most notable reported climatic changes affecting coastal zones are the sea level rise due to ice melting and thermal expansion, the increase in the intensity and frequency of extreme weather events and the rise of air temperature which is associated with the increase in sea surface temperature. Following, the changes in climate and their respective impacts on the coastal zones of Cyprus are presented in Table 4-2.

Table 4-2: **Relationship between climate changes and impacts on the coastal zones sector**

Potential climate changes	Impacts
Sea level rise	– Coastal Erosion, loss of beach area, increase of inundation canals – Decrease of the total coastline length – Inundation, flood and storm damage – Seawater Intrusion, altered water quality/salinity, soil Salinity, losses and/or changes of coastal ecosystems
Increase in the frequency and intensity of extreme weather events	– Damages on the coastal human environment, increased water levels and wave heights, risk of flooding, inundation, increase or decrease storm surge occurrence – Increased cross-shore erosion, removal of sediment supply, degradation of coastal ecosystems – Re-orientation of beach plan form, increase or decrease longshore transport
Sea surface temperature rise	– Increased stratification, algal blooms, degradation of coastal ecosystems, loss of natural attractions and species

In the following sections of this chapter, the future impacts of climate change on the coastal zones are further analyzed where relative data and information are available. The impacts are presented according to their initial categorization in the current impact assessment (Deliverable 1.2), namely:

- Coastal storm flooding and inundation
- Coastal erosion
- Degradation of coastal ecosystems

4.3.1 Coastal storm flooding and inundation

Scientists project an increase in the frequency of large storms in the coming century. In addition to wind damage, coastal storms cause storm surges which flood low-lying coastal areas and allow destructive wave action to penetrate inland (Nicholls & Hoozemans, 1996). At the same time, a potential sea-level rise would increase the area likely to be inundated by these coastal storms because storm flooding would reach higher inland elevations. The return period for heavy rainfall events may decrease in many parts of the world, due to global warming (Gordon et al., 1992), which would intensify flooding.

Inundation is the permanent submergence of low-lying land. The primary mechanism at any location depends on the geomorphology of the coast. Many other factors apart from sea-level rise can play a part in determining land loss (*e.g.*, vegetation, sediment supply) (Sterr et al., 2003). Low-lying coastal areas such as deltas, coastal wetlands and coral atolls may face inundation as a result of sea-level rise.

‘Coastal squeezing’ is another major problem presented by sea flooding. This term refers to coastal morphologies that would otherwise readjust to the rising sea by retreating landwards, but are currently obstructed by physical or anthropogenic barriers, such as coastal infrastructure. Sand dunes, or wetlands lying in front of built up areas are such examples. As a quite large percentage of Cyprus’ coastal zone is developed, coastal squeezing can become a real issue for certain areas (Parari, 2009).

Pluviometrical data from the meteorological station in Nicosia (1930-2007) show an increase in the intensity and quantity of precipitation of 37-49% for the period 1970-2007 in comparison with the period 1930-1970 for a duration of precipitation between 5 minutes and 6 hours (Pashiardis, 2009). However, Cyprus has not experienced any severe floods from the sea in the past.

As far as the future impact is concerned, the climate projection model used does not provide estimates for storms, waves and floods. Nevertheless, there is an indicator referring to the annual maximum total precipitation over one day (heavy rainfall index) which could also be associated with flood risk. However, the PRECIS model showed that there will be no significant changes to this indicator in the future period (2021-2050), apart from a minor increase of 2-5 mm per year on average. It must be noted though that this indicator alone is not sufficient for estimating flood risk since other factors play an important role as well.

Although Sea Level Rise (SLR) is expected to intensify the impact, it must be noted that the SLR is not estimated to be significant for the case of Cyprus as the annual rate is negligible.

As the frequency and intensity of storms, waves and floods in the future cannot be estimated, the impact cannot be assessed.

The impacts of sea flooding, storm surges and tidal waves on the built environment of coastal zones are analyzed in detail in Section 11: Infrastructure.

4.3.2 Coastal erosion

Coastal erosion is caused by the physical removal of sediment by wave and current action (Sterr et al., 2003). Many coasts are experiencing erosion and ecosystem losses, but few studies have unambiguously quantified the relationships between observed coastal land loss and the rate of sea-level rise (Zhang et al., 2004; Gibbons and Nicholls, 2006, Nicholls et al., 2007). Coastal erosion is observed on many shorelines around the world, but it usually remains unclear to what extent these losses are associated with relative sea-level rise due to subsidence, and other human drivers of land loss, and to what extent they result from global warming (Hansom, 2001; Jackson et al., 2002; Burkett et al., 2005; Wolters et al., 2005; Nicholls et al., 2007).

Bird (1993) argues that with global warming and sea-level rise there will be tendencies for currently eroding shorelines to erode further, stable shorelines to begin to erode, and accreting shorelines to wane or stabilize. Local changes in coastal conditions and particularly in sediment supply may modify these tendencies, although Nicholls (1998) has indicated that accelerated sea level rise in coming decades makes general erosion of sandy shores more likely (McLean et al., 2001).

Erosion constitutes a greater threat than flooding in Cyprus, especially for the sandy and gravel beaches of the island such as the coastlines of Larnaca and Limassol which have been suffering from severe erosion during the last 30 years. The phenomenon of coastal erosion in Cyprus is mainly attributed to human interventions which in some cases are triggered by natural causes associated with climate change. Examples of human activities causing coastal erosion in Cyprus are (Özhan, 2002):

- ○ Sand and gravel mining
- ○ Decreasing the sediment transport efficiency by lowering water discharges due to decreased water availability
- Cutting off the sediment transport by damming the rivers.
- Alteration of the usual pattern of coastal currents and the associated sediment transport along and across the shoreline, due to man-made coastal structures and urban development too close to the shoreline,
- Land subsidence due to anthropogenic effects.

Although no studies have accomplished yet to clarify whether coastal erosion in Cyprus is also attributed to climate change (Shoukri and Zachariadis, 2012), it is expected that future climate change impacts could exacerbate coastal erosion in Cyprus (EC, 2009). However, there are no climate projections regarding the future intensity and frequency of waves and storms in Cyprus.

In addition, although Sea Level Rise (SLR) is expected to intensify the impact, it must be noted that the SLR is not estimated to be significant for the case of Cyprus as the annual rate is considered moderate.

Last but not least, another factor that is closely related to climate changes is the cut off the sediment transport to coasts by damming the rivers and the lowering of water discharges due to reduced water availability. As the latter is projected to further decrease in the future due to climate changes in Cyprus, it is considered that this will intensify the impact of coastal erosion.

However, as the frequency and intensity of storms and waves in the future cannot be estimated, the impact cannot be assessed.

4.3.3 Degradation of coastal ecosystems

The impacts of climate change for coastal ecosystems and wetlands in Cyprus are expected to be long-term and mostly affected by temperature, sea level rise and the reduction of the available sediment and biomass for the growth of ecosystems.

Another important risk that may affect coastal ecosystems in the next years is the increase of soil salinity due to sea water intrusion, irrigation with low-quality (saline) water and inadequate field drainage (Avraamides, 2001). Excessive rates of groundwater withdrawal have resulted in a large drop in the water table in the coastal ecosystems of Cyprus. Consequently, seawater has intruded into the respective aquifers. With growing populations in coastal regions, saltwater intrusion is expected to occur more widely, and may enhance the rate of saltwater infiltration. Also, sea level rise is expected to exacerbate intrusion of saline water into the fresh groundwater aquifers of the coastal areas. Increasing temperature is also expected to enhance soil evaporation, increasing soil salinity and therefore, leading to alteration in biodiversity habitats.

In addition, coastal wetland ecosystems, such as saltmarshes and mangroves or saltcedars, are especially threatened where they are sediment starved or constrained on their landward margin (Nicholls et al., 2007). It must also be noted that, low water availability in Cyprus has led to the construction of numerous dams which have significantly reduced sediment transport to coasts.

Overall, the impact of climate change for coastal ecosystems and wetlands in Cyprus is not known yet, as the relevant research in this domain is still lacking (EC, 2009).

4.4 Future vulnerability assessment

In this section, the future vulnerability of coastal zones to climate change impacts is assessed in terms of their sensitivity, exposure and adaptive capacity, based on the available quantitative and qualitative data for Cyprus and the climate projection for the period 2021-2050. In particular, sensitivity is defined as the degree to which coastal zones will be affected by climate changes, exposure is the degree to which coastal zones will be exposed to climate changes and their impacts, while the adaptive capacity is defined by the ability of coastal zones as a natural system to adapt to changing environmental conditions as well as by the effectiveness of the relative existing and planned adaptation measures.

For the assessment of future vulnerability, the same indicators used in the current vulnerability assessment (CYPADAPT, 2012) were used, wherever the necessary data were available. These indicators are summarized in Table 4-3.

Table 4-3: Indicators used for the vulnerability assessment of climate change impacts on the coastal zones of Cyprus

Vulnerability variable	Selected indicators
Coastal storm flooding and inundation	
Sensitivity	– Elevation, low-lying areas, sea cliffs – Vegetation cover (i.e. sand dunes, salt lakes) – Sediment supply – Slope – Proportion of the coastline occupied by urban and tourist infrastructure
Exposure	– Sea level rise – Coastal floods – Frequency and intensity of rainfall, storms, wind and waves at the coastal zones*
Adaptive capacity	– Hard defense works (seawalls, revetments, breakwaters, groynes) – Fishing shelters – Artificial reefs – Foreshore Protection Law
Coastal Erosion	
Sensitivity	– Coastline length of low-lying areas and percentage of the total coastline – Proportion of sandy and gravel beaches
Exposure	– Sea level rise – Length of eroded coasts and percentage of the total coastline – Frequency and intensity of rainfall, storms and waves at the coastal zones*

Vulnerability variable	Selected indicators
Adaptive capacity	– Hard defense works (seawalls, revetments, breakwaters, groynes) – Fishing shelters – Artificial reefs – Beach nourishment – Prohibition of sand and graveling mining
Degradation of coastal ecosystems	
Sensitiviy	– Estuaries, coastal aquifers – Areas of high biodiversity value – Length of the coastline with important ecosystems (protected areas) and percentage of the total coastline
Exposure	– Degradation of coastal ecosystems* – Sea level rise – Salinization of coastal aquifers – Coastal erosion
Adaptive capacity	– Coastal defense structures – National list of habitats designated as ‘special areas of conservation’

*There were no data regarding this indicator

The relationship between sensitivity, exposure and adaptive capacity is based on the following qualitative equation:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity * Exposure$$

Sensitivity, exposure and adaptive capacity are evaluated on a 7-degree qualitative scale ranging from “none” to “very high”.

In the sections that follow, the vulnerability is assessed for each of the impact categories presented in Section 4.3:

1. Coastal storm flooding and inundation
2. Coastal erosion
3. Degradation of coastal ecosystems

It must be noted that, there are no sufficient scientific evidence and data to evaluate or correlate all impacts and indicators to future climate changes. Consequently, further research is required in order to provide concrete information for a more detailed and descriptive assessment of the future vulnerability of the sector. Nevertheless, an attempt was made to provide a preliminary assessment of the future vulnerability. In case additional data are provided by the competent authorities of Cyprus, the future vulnerability of the sector could be re-assessed.

4.4.1 Coastal storm flooding and inundation

1.2.3.1. Assessment of sensitivity and exposure

Sensitivity

The elevation of an area combined with a number of other factors, such as vegetation, sediment supply and slope, determine the risk of inundation. In general, the lower the slope, the greater the land loss (Sterr et al., 2003).

As far as the elevation of coasts in Cyprus is concerned, the majority of the coastline and especially the southern and southeastern coasts of Cyprus is low and shelving, while sea cliffs of any magnitude are extremely rare (Figure 4-2). It is estimated that, less than 5% of Cyprus coastline is comprised of low-lying areas[1] (EC, 2009). The main area in Cyprus identified as low-lying is located in Larnaca.

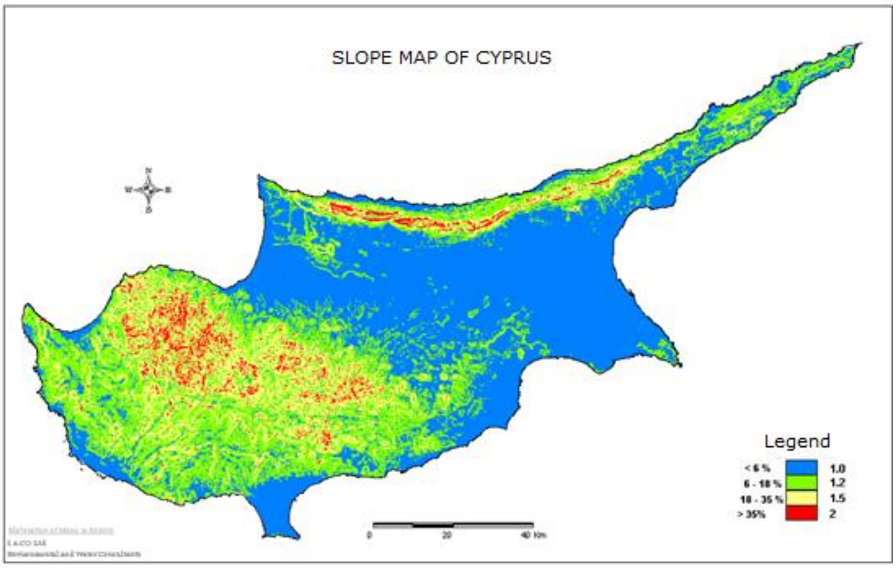

Figure 4-2: Slope map of Cyprus

Source: I.A.CO Ltd, 2008

Natural ecosystems with vegetation along the coastal belt, such as sand dunes and salt lakes are limited to few areas. In particular, salt lakes are distributed around the east and south coasts. As far as the sand dune ecosystems, these are confined to 22 sites (Hadjichambis et al., 2003). Dunes, at many places, are low and beaches narrow, mostly because of a restricted sediment supply which is the result of dam construction over the last 20 years, as well as of tourism activities and beach erosion (DoE, 2010a).

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[1] Low-lying areas are defined as 10 km of coastal zone below 5 metres elevation

Although a series of case studies have been carried out for many of the coasts in Cyprus providing some of the data required to assess risk of inundation, there is no clear picture for the whole island.

For accessing the risk of coastal squeezing, that is, the obstruction of coastal morphologies to retreat landwards due to physical or anthropogenic barriers, the proportion of the coastline occupied by urban and tourist infrastructure was used as an indicator. As it can be seen from Table 4-1, approximately 45% of the coastline is occupied by urban and tourist areas (30% and 15% respectively). However, it must be noted that their proximity to the coast varies from area to area. In general, it can be said that in urban areas the main barriers are constructions such as harbours or roads while for the case of tourist areas the anthropogenic barriers are mainly hotels, restaurants, etc.

Taking into account the available data on the above mentioned indicators, it can be said that the sensitivity of Cyprus coastal zone to sea flooding is **moderate to high**.

Exposure

For the assessment of the exposure of Cyprus' coastal zones to storm flooding and inundation in the future, a number of climatic factors, such as wind and wave characteristics (Sterr et al., 2003), storminess, heavy rainfall as well as other factors induced by climate change such as sea level rise can be used as indicators.

While changes in storminess may contribute to changes in extreme coastal high water levels, the limited geographical coverage of studies to date and the uncertainties associated with overall storminess changes mean that a general assessment of the effects of storminess changes on storm surge is not possible at this time (Field et al., 2012).

Results from embedded high-resolution models and global models show a likely increase of peak wind intensities and notably, increased near-storm precipitation in future tropical cyclones. Most recent published modelling studies investigating tropical storm frequency, simulate a decrease in the overall number of storms, though there is less confidence in these projections and in the projected decrease of relatively weak storms in most basins, with an increase in the numbers of the most intense tropical cyclones. Model projections show fewer mid-latitude storms averaged over each hemisphere, associated with the poleward shift of the storm tracks that is particularly notable in the southern hemisphere, with lower central pressures for these poleward-shifted storms. The increased wind speeds result in more extreme wave heights in those regions (Meehl et al., 2007).

However, according to the projections of the PRECIS climate model, the mean wind speed greater than 5 m/s in Cyprus during the future period 2021-2050 is not expected to present substantial changes, on the contrary, it presents minor decreases in general. With regard to the current exposure to high wind speeds of the coastal tourist areas, PRECIS shows that in western (Pafos, Chrysochou) and southeastern (Larnaca, Ayia Napa) areas the number of days with mean wind speed > 5 m/s is approximately 80 while southern (Limassol) regions present about 40-50 days with mean wind speed > 5 m/s. Figure 4-6 depicts PRECIS projections of the changes in the number of days with mean wind speed greater than 5 m/s. As it is shown, in western, and southeastern coastal areas a decrease of about 12 days is anticipated. Also southern areas present a slight decrease of about 5 days. Consequently, it is expected that the future exposure of coastal tourist areas to storm surges is limited.

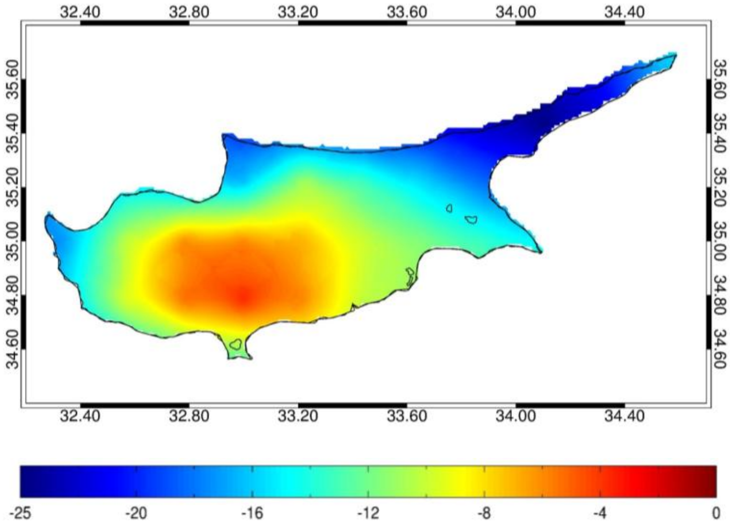

Figure 4-3: Changes in the number of days with mean wind speed > 5m/s between the future (2021-2050) and the control period (1961-1990)

The coasts mostly exposed to large waves are those located on the western part of the island (Demetropoulos, 2002).

The climate projection model used for the case of Cyprus does not provide estimates for the frequency and intensity of floods in the future. Nevertheless, there is an indicator referring to the annual maximum total precipitation over one day indicating heavy rainfall which could also be associated with flood risk. However, the PRECIS model showed that The climate projection model used for the case of Cyprus does not provide estimates for the frequency and intensity of floods in the future. Nevertheless, there is an indicator referring to the annual maximum total precipitation over one day indicating heavy rainfall which could also be associated with flood risk. However, the PRECIS model showed that a slight increase of about 2-5 mm is anticipated in western, inland and mountain regions. Additionally, southern and southeastern areas present an increase of about 1 mm in annual max total rainfall over 1 day (Figure 4-7). It must be noted though that this indicator alone is not sufficient for estimating flood risk since other factors play an important role as well.

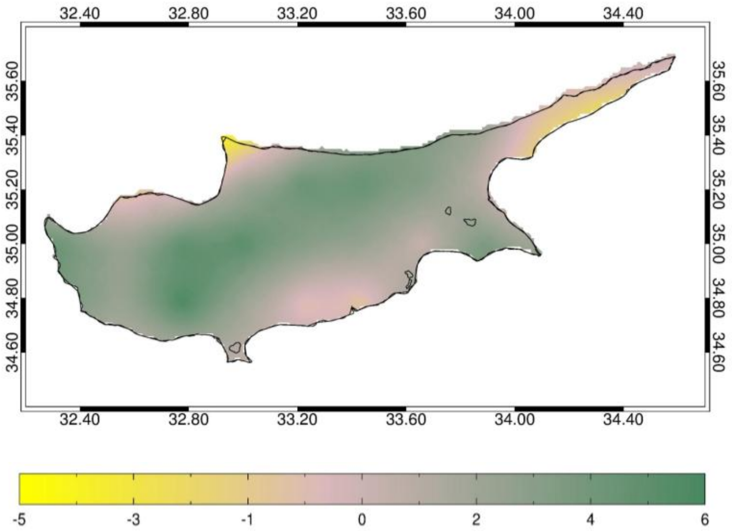

Figure 4-4: Changes in annual maximum total precipitation over 1 day between the future (2021-2050) and the control period (1961-1990)

Sea level rise in the Mediterranean Sea is not expected to be as high as in the oceans. Especially for the case of Cyprus, the sea level rise is expected to be moderate (EC, 2009). Furthermore it must be added that, based on archaeological data, Cyprus appears to be experiencing long-term uplift of between 0 and 1 mm per year. This uplift is expected to counteract sea-level rise and given a global rise in sea level of 0.5m by 2100, relative sea-level rise in Cyprus will be in the range 0.4-0.5m (Nicholls and Hoozemans, 1996). The sea level changes in Cyprus as observed during the period between 1993 and 2000 show an increase of 5-10 mm/year (Figure 4-5).

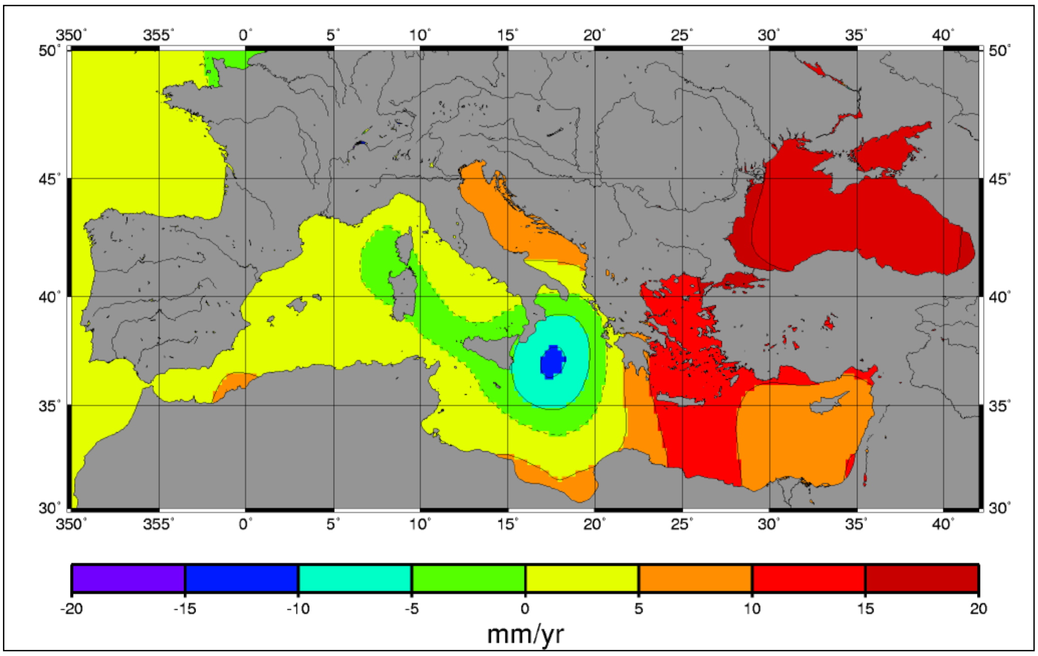

Figure 4-5: Mediterranean basin sea level changes between 1993 and 2000

Source: Ministry of Environment of Lebanon, 2011

Considering the above, the future exposure of the coastal zones of Cyprus to storm flooding and inundation is characterized as **limited to moderate**.

1.2.3.2. Assessment of adaptive capacity

The resilience of coastal zones to storm flooding and inundation depends on the presence of sand dunes, trees and shrubs as well as of wetlands as they provide significant protection against storm waves, through their buffering properties and their ability to attenuate wave energy. Furthermore, the ability of ecosystems to retreat landwards where it is safer, enhances their adaptive capacity.

As far as human interventions for the protection from flooding and inundation in Cyprus are concerned, these are mainly in the form of hard defense structures such as seawalls and coastal revetments. In addition, the measures applied in Cyprus for the protection from erosion, help prevent coastal flooding as well, by enhancing depositional processes along the coast. Structures such as groynes and breakwaters enhance the deposition of sediment on the beach thus helping to buffer against storm waves and surges, as the wave energy is spent on moving the sediments in the beach than on moving water inland (Short and Masselink, 1999). However, seawalls and revetments are not considered attractive for bathing beaches and thus breakwaters and groynes are the predominant defense works, although the latter are considered less drastic measures in case of a severe storm or flooding event.

After the Turkish invasion in 1974 there was an effort to restore the economy and tourist industry. Among the years 1974 and 1980 a number of hard defense structures were constructed along the Cyprus coast. The main type of works was hammer head groins which were constructed illegally by hotel owners in an attempt to create more attractive sandy beaches. In addition, a number of breakwaters were constructed by the government. The following years, Cyprus prepared and implemented a number of Master Plans for the protection of eroded coasts and intends to do the same for the rest of the coastal areas that is deemed necessary (Coccossis et al., 2008).

Fishing shelters, which are constructed for the protection of fishing boats against extreme events such as storm and large waves, also protect the coast. Currently in Cyprus there are 11 fishing shelters in operation. In addition, artificial reefs which are actually submerged breakwaters provide protection from flooding by absorbing part of the incident wave energy before it reaches the coast. The DMFR will create up to 4 artificial reefs in the marine areas of Famagusta, Limassol and Paphos (Source: Strategy for the creation of artificial reefs, Cyprus).

In addition, to prevent coastal squeezing and allow for landwards retreat, the Foreshore Protection Law of Cyprus prohibits building development except for light structures (sheds, footpaths, etc.) in the zone within 100 yards (91,44m) of the high water mark. The foreshore area in Cyprus is public property falling under the jurisdiction of this Law (Coccossis et al., 2008). However, the implementation of the Foreshore Protection Law is not adequately monitored, resulting in numerous violations and interventions in the foreshore zone.

Taking into account the abovementioned measures that are already applied in Cyprus as well as their effectiveness, the future adaptive capacity of Cyprus' coastal zones to storm flooding and inundation is considered to be **limited to moderate**.

Following, additional recommended adaptation measures (Shoukri & Zachariadis, 2012; DoE, 2010b) that are considered to further enhance adaptive capacity towards this impact are presented indicatively. Nevertheless, their assessment and final selection for implementation will be made through the use of the Multicriteria Analysis (MCA) tool which will be developed and implemented in the framework of Actions 4 and 5 of the CYPADAPT project.

- Sea level rise considerations in existing and new coastal developments/ infrastructure
- Research on sea level rise, increase monitoring sites and apply model simulations
- Enforcement of the framework strategy "Integrated Management of Coastal Areas"

4.4.2 Coastal Erosion

1.2.3.3. Assessment of sensitivity and exposure

Sensitivity

The areas that are most sensitive to coastal erosion are the low-lying areas and the sandy and gravel beaches. As also mentioned before, less than 5% of Cyprus coastline is comprised of low-lying areas[2] with the main low-lying area being Larnaca (EC, 2009).

Of the total beach length, sandy beaches occupy approximately 46% while pebble beaches the rest 54%. Sandy beaches are predominant in the large bays of Cyprus as for example in Famagusta, Larnaca, Limassol, Polis Chrysochou and Morphou where the majority of tourism concentrates.

On the other hand, there are several areas of the coastline which are not considered sensitive to erosion as they have mainly rocky shores, as for example an extended area of the south-eastern part of the island, all the way from Cape Pyla to Paralimni (with several pocket beaches) - as it is part of Akamas - and most of the Kyrenia coastline from Cape

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[2] Low-lying areas are defined as 10 km of coastal zone below 5 metres elevation

Kormakiti to Cape Andreas (again with many sandy pocket beaches) (Demetropoulos, 2002). However, the area of Kyrenia is not under the effective control of the Republic of Cyprus.

Considering the above, the sensitivity of Cyprus' coastal zones to erosion is characterized as **high**.

Exposure

According to Coccosis et al. (2008), 110km or 30% of the coastline which is under the control of the Republic of Cyprus is subject to erosion. According to another older source (Research Promotion Foundation, 2006), the percentage of erosion in Cyprus reaches 37.8%, fact that places the country among the countries in the European Union with the highest rates of coastal erosion.

For the assessment of the exposure of Cyprus' coastal zones to coastal erosion in the future, several climatic factors are used, such as heavy rainfall, wind and wave characteristics (Sterr et al., 2003), storminess as well as other factors induced by climate change such as sea level rise. Furthermore, the percentage of the coastline in Cyprus already exposed to erosion comprises a useful exposure indicator.

Results from embedded high-resolution models and global models show a likely increase of peak wind intensities and notably, increased near-storm precipitation in future tropical cyclones. Most recent published modelling studies investigating tropical storm frequency, simulate a decrease in the overall number of storms, though there is less confidence in these projections and in the projected decrease of relatively weak storms in most basins, with an increase in the numbers of the most intense tropical cyclones. Model projections show fewer mid-latitude storms averaged over each hemisphere, associated with the poleward shift of the storm tracks that is particularly notable in the southern hemisphere, with lower central pressures for these poleward-shifted storms. The increased wind speeds result in more extreme wave heights in those regions (Meehl et al., 2007).

However, according to the projections of the PRECIS climate model, the mean wind speed greater than 5 m/s in Cyprus during the future period 2021-2050 is not expected to present substantial changes, on the contrary, it presents minor decreases in general. With regard to the current exposure to high wind speeds of the coastal tourist areas, PRECIS shows that in western (Pafos, Chrysochou) and southeastern (Larnaca, Ayia Napa) areas the number of days with mean wind speed > 5 m/s is approximately 80 while southern (Limassol) regions present about 40-50 days with mean wind speed > 5 m/s. Figure 4-6 depicts PRECIS projections of the changes in the number of days with mean wind speed greater than 5 m/s. As it is shown, in western, and southeastern coastal areas a decrease of about 12 days is anticipated. Also southern areas present a slight decrease of about 5 days. Consequently, it is expected that the future exposure of coastal tourist areas to storm surges is limited.

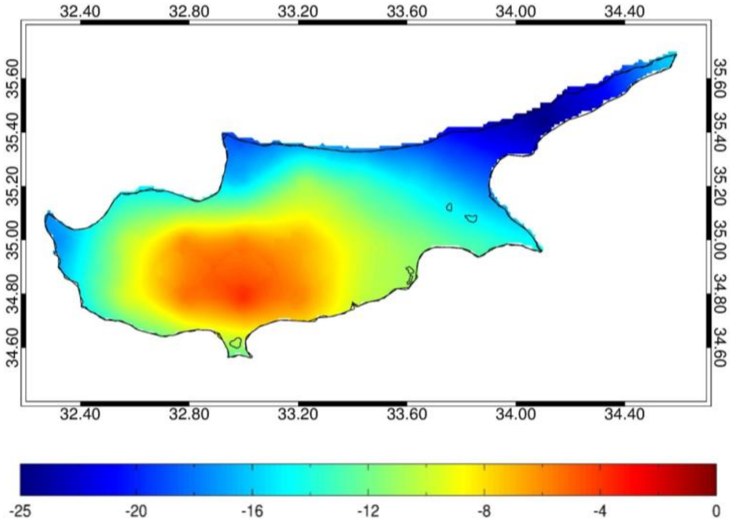

Figure 4-6: Changes in the number of days with mean wind speed > 5m/s between the future (2021-2050) and the control period (1961-1990)

The coasts mostly exposed to large waves are those located on the western part of the island (Demetropoulos, 2002).

The climate projection model used for the case of Cyprus does not provide estimates for the frequency and intensity of floods in the future. Nevertheless, there is an indicator referring to the annual maximum total precipitation over one day indicating heavy rainfall which could also be associated with flood risk. However, the PRECIS model showed that a slight increase of about 2-5 mm is anticipated in western, inland and mountain regions. Additionally, southern and southeastern areas present an increase of about 1 mm in annual max total rainfall over 1 day (Figure 4-7). It must be noted though that this indicator alone is not sufficient for estimating flood risk since other factors play an important role as well.

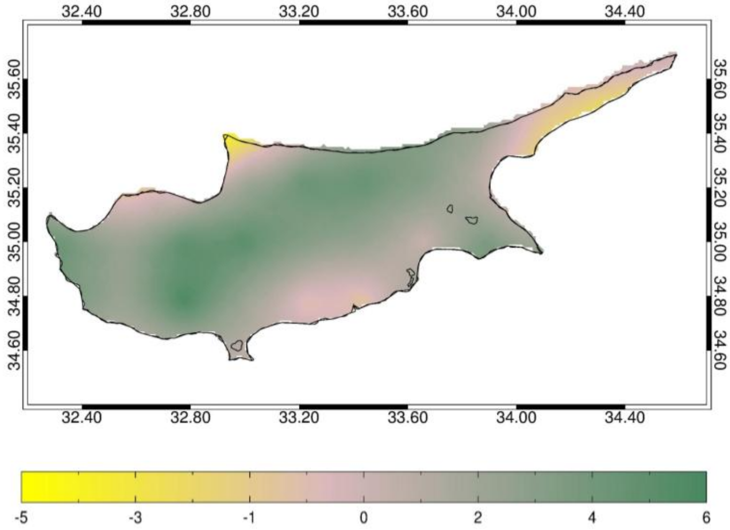

Figure 4-7: Changes in annual maximum total precipitation over 1 day between the future (2021-2050) and the control period (1961-1990)

As also mentioned before, the sea level changes in Cyprus as observed during the period 1993 and 2000 show an increase of 5-10 mm/year (Figure 4-5). Taking into consideration the land lift up of 0-1 mm/year that Cyprus is experiencing, the exposure of Cyprus to sea level rise in the future is considered to be limited to moderate.

To this end, the future exposure of the coastal zone of Cyprus against erosion is considered to be **moderate to high**.

1.2.3.4. Assessment of adaptive capacity

The resilience of coastal zones to coastal erosion depends on the ability to recharge sediment supply mostly from rivers. However, as most rivers in Cyprus are dammed, the sediment supply to coasts from rivers is blocked.

As far as human interventions for the protection from coastal erosion in Cyprus are concerned, these are mainly hard coastal defense structures such as breakwaters and groynes for enhancing depositional processes along the coast. Hard coastal structures have been considered for several decades the remedy for combating coastal erosion. The years proved that in the long run, hard interventions can have serious negative impacts both on coastal morphology and coastal environment. The sustainable development of the coastal areas asks for combining erosion control and good environmental practices, within the framework of Integrated Coastal Zone Management schemes. Coastal defense and protection structures are usually constructed as emergency measures, without taking into consideration environmental and social impacts. Generally, people and generally public opinion and decision makers support strongly the construction of hard coastal works, such as breakwaters, as the solution to coastal erosion problem and they do not accept easily demolition of structures (Loizidou and Loizides, 2007).

An important step in the direction for introducing integration in coastal protection actions was the Environmental Impact Law of 2001 (Law 57(I)/2001), through which it is necessary to proceed with an Environmental Impact Study before the construction of any coastal protection work (Loizidou and Loizides, 2007).

As far as the funding of these construction works is concerned, the Council of Ministers took a Ministerial Decision in 2000, arranging the funding cooperation among competent authorities concerning coastal structures. The Decision defines the following percentage of each authority’s financial participation in the total cost for the construction of coastal structures (Loizidou and Loizides, 2007):

- If the structures are needed for coastal protection to counteract erosion, then the Government contributes the 50% and the Local Authority the rest 50%
- If erosion is not a serious problem and the structures are needed mainly to enable recreational uses of the coast, then the contribution of the Government goes down to 30% and the rest 60% is covered by the Local Authority. The 30% of the Local

Authority's contribution can be covered by private funding, from the Hotel owners who are going to benefit from the structures.

Non Governmental Organizations (NGO's) in Cyprus focused on coastal zone protection (like CYMEPA and AKTI) organized several awareness raining campaigns for the public. Local Authorities hosted workshops and happenings. The effort was and is to give people and the Local Authorities the information on the alternative, environmental friendly coastal protection methods and promote the need for integration. The Environmental Service and Coastal Unit of the Ministry of Agriculture, Natural Resources and Environment of Cyprus support this effort (Loizidou and Loizides, 2007) as well.

Regarding beach nourishment, this was firstly applied on a specific area in Limassol. In addition, in a certain area of the Famagusta region a number of hotel owners used sand nourishment to improve the quality of the beach and create more friendly access to the beach (in rocky areas). It must also be mentioned that, small pilot nourishment projects with sand were carried out in Larnaca and Pafos District. However, the responsible Municipality/Local Authority did not have the financial resources to continue the project and replace any sand losses undertaken during the year.

Finally, another measure that was undertaken for the reduction of the pressures exerted on the coastal zones of Cyprus, causing erosion is the prohibition of sand and gravel mining activities by law.

The adaptive capacity of the coastal zones in Cyprus to coastal erosion is characterized by high reversibility, as where proper coastal defense works have been implemented, satisfactory results have been observed and the problem of erosion has been restored. However, considering that the coastal zones continue to be subject to several pressures causing erosion that are not expected to be reduced in the future and that coastal defence works have not been implemented to all the areas with erosion problems, the future adaptive capacity of the coastal zone against erosion can be characterized as **moderate**.

Following, additional recommended adaptation measures (Shoukri & Zachariadis, 2012; DoE, 2010b) that are considered to further enhance adaptive capacity towards this impact are presented indicatively. Nevertheless, their assessment and final selection for implementation will be made through the use of the Multicriteria Analysis (MCA) tool which will be developed and implemented in the framework of Actions 4 and 5 of the CYPADAPT project.

- Prepare an inventory of coastal areas already suffering from erosion as well as those vulnerable to erosion and evaluate the measures already taken
- Examine the possibility of other measures to combat coastal erosion
- Protection of wetlands and sand dunes as a measure to combat erosion

- Sea level rise considerations in existing and new coastal developments/ infrastructure
- Research on sea level rise, increase monitoring sites and apply model simulations
- Enforcement of the framework strategy "Integrated Management of Coastal Areas"
- Integration of environmental assessment economic instruments and of specific tax measures in the development plans

4.4.3 Degradation of coastal ecosystems

1.2.3.5. Assessment of sensitivity and exposure

Sensitivity

All coastal ecosystems are sensitive to sea level rise and extreme weather events (e.g. storms, floods, tidal waves) due their impacts on them, i.e. inundation, shrinkage -when there is no available area for retreating landwards-, reduction in sediment supply and biomass due to erosion, and soil salinity due to the salinization of coastal aquifers and the irrigation with low quality (saline) water – except for saltlakes and saltcedars (trees and shrubs) that are adjusted to saline conditions.

Sand dunes, salt flats, salt lakes, salt marshes as well as freshwater marshes occur in the Cyprus coastal belt although they are limited to few areas. Salt lakes are distributed around the east and south coasts. Coastal sand dunes are species-rich habitats and are among the most vulnerable habitats of Cyprus as they are subject to high-intensity recreational and other uses (DoE, 2010a). Sand dune ecosystems are confined to 22 sites (Hadjichambis et al., 2003).

Estuaries and coastal aquifers are sensitive to sea level rise due to the saltwater intrusion induced especially in low-lying areas. The main estuaries of Cyprus (6 in total) are located mostly in the southern coasts of the island and are presented in the following figure.

Figure 4-8: Estuaries of Cyprus

A total of 15 out of the 19 groundwater bodies in Cyprus which are under government control, are coastal or part of them is located at the coast. As also mentioned before, less than 5% of Cyprus coastline is comprised of low-lying areas[3] with the main low-lying area being Larnaca (EC, 2009).

As for the coastal ecosystems that are referring to wetlands, they are exposed to acidity changes and circulation patterns at coastal waters. For the case of Cyprus, it is expected that the coastal circulation patterns will change because of changes in temperatures, wind speed and currents in the coastal zone (Harrould-Kolieb et al., 2009).

Drainage is associated with climate changes as increased extreme weather events such as floods and decreased soil moisture lead to drainage and nutrient enrichment of agriculture and domestic effluents. Approximately 36% of the Cyprus coastline consists of agricultural areas (see Table 4-1). Salt lakes are currently threatened by drainage (DoE, 2010a).

The coastal ecosystems in Cyprus of high biodiversity value are the Larnaca salt lake, the Akrotiri peninsula wetland, the Akamas peninsula and especially the Lara/Toxeftra Turtle Reserve, the Cape Greko marine caves and the Poli Chrysochous coastline (Parari, 2009). It is estimated that approximately 55 km or 19% of the Cyprus coastline (area under government control) which is comprised of such areas is under protection status (see Table 4-1).

However, it must be mentioned that the sensitivity of these systems increases if taking into account the existing anthropogenic pressures that are subjected to.

Thus, the sensitivity of these ecosystems against degradation can be considered as **moderate to high**.

Exposure

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[3] Low-lying areas are defined as 10 km of coastal zone below 5 metres elevation

In absence of data on the degradation of coastal ecosystems in Cyprus, a number of other indicators indirectly implying exposure to degradation will be used, such as the sea level rise, the salinization of coastal aquifers, the presence of coastal erosion in Cyprus as well as the rise in sea surface temperature.

As also mentioned before, the sea level changes in Cyprus as observed during the period 1993 and 2000 show an increase of 5-10 mm/year. Taking into consideration the land lift up of 0-1 mm/year that Cyprus is experiencing, the exposure of Cyprus to sea lever rise is considered as moderate.

According to Coccosis et al. (2008), 110km or 30% of the coastline which is under the control of the Republic of Cyprus is subject to erosion while according to another older source (Research Promotion Foundation, 2006), the percentage of erosion in Cyprus reaches 37.8%, fact that places the country among the countries in the European Union with the highest rates of coastal erosion.

As regards to aquifer salinization, 12 out of 19 groundwater bodies in Cyprus have been already exposed to seawater intrusion while the coastal zones of several aquifers in Cyprus have been abandoned due to this phenomenon. In Figure 4-9, the aquifers of Cyprus exposed to salinization are presented.

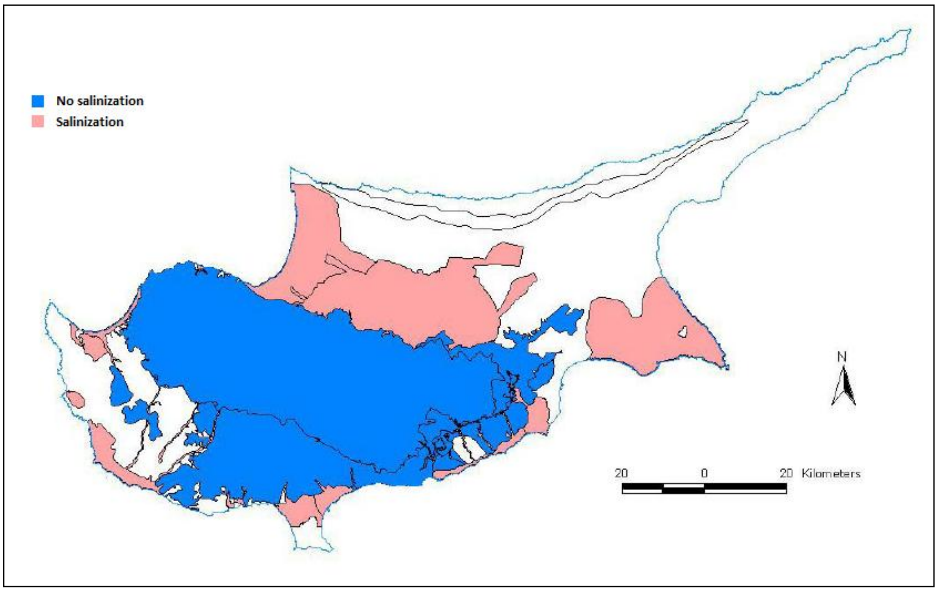

Figure 4-9: Salinization in the groundwater bodies of Cyprus

Source: Water Development Department, 2008

As for the Sea Surface Temperature (SST), the Mediterranean SST is expected to gradually increase due to climate change, although less than the global mean temperature rise (Nicholls et al., 2007).

Satellite and in situ-derived data indicate a strong eastward increasing sea surface warming trend in the Mediterranean basin from the early 1990s onwards. The satellite-derived mean annual warming rate over the period 1985–2008 is about 0.037°C year^{-1} for the whole basin and about 0.042°C year^{-1} for the eastern sub-basin where the island of Cyprus is located (Skliris et al., 2011).

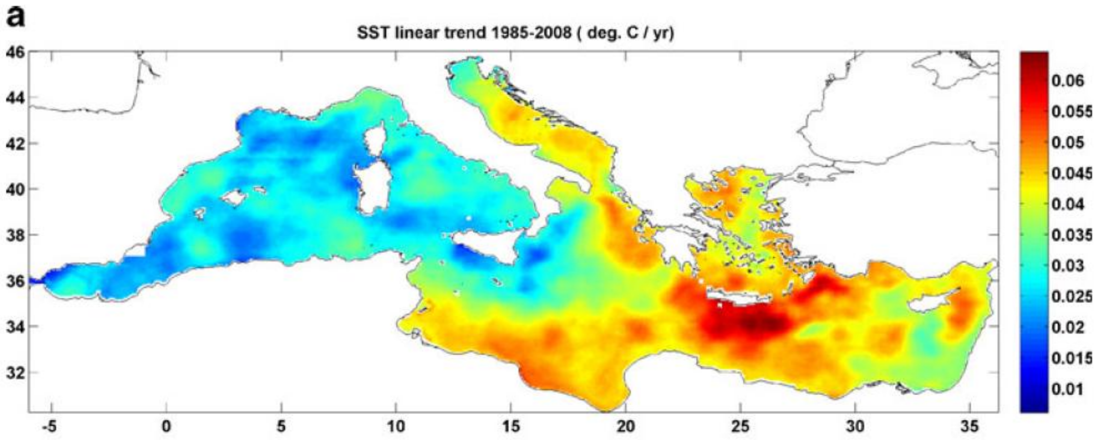

Figure 4-10: Horizontal distribution of satellite-derived SST annual linear trends (°C/year) over 1985–2008

Source: Skliris et al., 2011

In addition, analyses of annual mean satellite SST data indicate that over the last 16 years (1996-2011) a general warming has occurred over the Levantine Basin where Cyprus belongs, at an average rate of approximately 0.065°C per year (Samuel-Rhoads et al., 2012).

Given that there are no sufficient data for the assessment of exposure of coastal ecosystems in Cyprus to degradation, **no characterization** is given.

1.2.3.6. Assessment of adaptive capacity

The extent to which a coastal system is affected by sea-level rise will strongly depend on its resilience to changes. The survival of coastal wetlands is dependent upon sediment availability and/or local biomass production, as well as the potential for these ecosystems to migrate inland (Sterr et al., 2003). In addition, non-climate stresses may already have adversely affected the coastal system’s resilience and thereby its ability to cope with additional pressures (Klein, 2002).

Coastal defense structures presented in Section 4.4.1 and Section 4.4.2 also contribute towards the protection of coastal ecosystems from flooding and erosion. As for the legal measures, in line with the EU Habitat Directive, Cyprus compiled a national list of habitats identified as ‘special areas of conservation’. This list of important areas for Cyprus includes also lakes and wetlands nearby the coastline. By restricting mass-scale development in these areas, Cyprus wants to make a step towards the conservation of water-related eco-systems.

As there are no sufficient data on the exposure of coastal ecosystems to degradation, it cannot be assessed whether the adaptive capacity is satisfactory and hence, **no characterization** is given.

Following, additional recommended adaptation measures (Shoukri & Zachariadis, 2012; DoE, 2010b) that are considered to further enhance adaptive capacity towards this impact are presented indicatively. Nevertheless, their assessment and final selection for implementation will be made through the use of the Multicriteria Analysis (MCA) tool which will be developed and implemented in the framework of Actions 4 and 5 of the CYPADAPT project.

- Relocation of infrastructure and houses inland to allow coastal ecosystems to recover
- Enforcement of the framework strategy "Integrated Management of Coastal Areas"
- Integration of the tool "Imagine"[4] in the framework of politics in Cyprus
- Inclusion of the tool "Evaluation of Carrying Capacity" proposed under the CAMP project in the Construction Spatial Planning System and in the Tourism Policy
- Integration of environmental assessment economic instruments and of specific tax measures in the development plans

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[4] *The "Imagine" methodology was developed by the Blue Plan and Dr Simon Bell in order to assist stakeholder groups in gaining insights and have control over their own sustainable development, by means of sustainability indicators, scenarios and graphic, easy to understand representation of the past, present and future sustainability situation. For more information on this methodology see "A Practitioners guide to Imagine – The Systemic and Prospective Sustainability Analysis. Bleu Plan"*

4.4.4 Assessment of overall vulnerability

The principal aim of this chapter is to identify the key vulnerabilities of the coastal zones to future climate changes, as well as to assess the magnitude of these vulnerabilities. However, it must be noted that, as there were no sufficient data to evaluate all indicators further research is required.

In order to quantify the future vulnerability potential of coastal zones against a climatic change impact, the values of sensitivity, exposure, adaptive capacity and vulnerability are quantified as follows:

Degree of sensitivity, exposure & adaptive capacity		**Degree of vulnerability**		**Legend**
None	0	None	V≤0	
Limited	1	Limited	0<V≤1	🟩
Limited to Moderate	2	Limited to Moderate	1<V≤2	🟨
Moderate	3	Moderate	2<V≤3	🟨
Moderate to High	4	Moderate to High	3<V≤4	🟧
High	5	High	4<V≤5	🟧
High to Very high	6	High to Very high	5<V≤6	🟥
Very high	7	Very high	6<V≤7	🟥
Not evaluated	-	Not evaluated	-	⬜

Since vulnerability is defined by the following formula:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity * Exposure$$

“Impacts” and “Adaptive capacity” should be evaluated on the same scale (1-7). For this to be achieved, the square root of “Sensitivity x Exposure” is used. The results of the vulnerability assessment for coastal zones of Cyprus are summarized in Table 4-4.

Table 4-4: **Overall vulnerability assessment of the coastal zones of Cyprus to climate changes**

Impact	Sensitivity	Exposure	Adaptive Capacity	Vulnerability
Coastal storm flooding and inundation	Moderate to High (4)	Limited to Moderate (2)	Limited to Moderate (2)	Limited (0.8)
Coastal erosion	High (5)	Moderate to High (4)	Moderate (3)	Limited to Moderate (1.5)
Degradation of coastal ecosystems	Moderate to High (4)	Not evaluated	Not evaluated	-

As a result, it is concluded that the future vulnerability of the coastal zones in Cyprus to climate changes focuses mainly on the coastal erosion, which already constitutes an issue for Cyprus' coasts and although it is addressed in a quite satisfactory degree, it is expected that climate changes will magnify the phenomenon to some extent. The impact of coastal storm flooding and inundation is considered to present limited vulnerability for Cyprus' coasts taking into consideration the fact that this is not such an extensive issue for Cyprus for the time being, while the impact of the degradation of coastal ecosystems was not evaluated due to absence of sufficient information on the subject.

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5 BIODIVERSITY

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Abbreviations and Acronyms

FWI	Fire Weather Index
CAMP	Coastal Area Management Programme
CBD	Convention on Biological Diversity
CIESM	la Commission Internationale pour l'Exploration Scientifique de la Mer Méditerranée
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
DMFR	Department of Fisheries and Marine Research
DoA	Department of Agriculture
DoE	Department of Environment
DoF	Department of Forests
EC	European Commission
EastMed	Scientific and Institutional Cooperation to Support Responsible Fisheries in the Eastern Mediterranean
EEA	European Environment Agency
ESSEA	Earth System Science Education Alliance
FAO	Food and Agriculture Organization
GSD	Geological Survey Department
IPCC	Intergovernmental Panel on Climate Change
JRC	Joint Research Centre
MA	Millennium Ecosystem Assessment
MANRE	Ministry of Agriculture, Natural Resources and Environment, Republic of Cyprus
MAP	Mediterranean Action Plan
MCA	Multi Criteria Analysis
MedSeA	Mediterranean Sea Acidification in a Changing Climate
NGO	Non-Governmental Organization
NRE	Natural Resources and Environment
RAC/SPA	Regional Activity Centre for Specially Protected Areas
RCM	Regional Climate Change
UN	United Nations
PRECIS	Providing Regional Climates for Impact Studies
SCI	Sites of Community Importance
SPA	Special Protection Areas
SSS	Sea Surface Salinity
SST	Sea Surface Temperature
UNCBD	United Nations Convention on Biological Diversity

UNEP	United Nations Environment Programme
USAID	United States Agency for International Development
WCMC	World Conservation Monitoring Centre
WDD	Water Development Department
WHO	World Health Organization

5.1 Climate change and biodiversity

The United Nations Convention on Biological Diversity (UNCBD) defines biodiversity highlighting the importance of biodiversity: "the variability among living organisms from all sources including, inter alia, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems".

Projected changes in climate, combined with land use change and the spread of exotic or alien species are likely to limit the capability of some species to migrate and therefore will accelerate species loss (CBD, 2007). Nevertheless, there is allready ample evidence that climate change affects biodiversity. According to the Millennium Ecosystem Assessment, climate change is likely to become one of the most significant drivers of biodiversity loss by the end of the century.

Cyprus due to its geographical position in the eastern part of the Mediterranean Sea, bears all the characteristics of a semi-arid climate and some of the deficits of the global climate change. Direct impacts of climate change on Cyprus biodiversity arise mainly from decreased rainfall and increased temperature, droughts, fluctuations in intensified precipitation, sea level rise and increased atmospheric CO_2. Based on projected climatic changes the future impact of climatic changes and the related vulnerability of biodiversity are reassessed.

The impact, vulnerability and adaptive measures for biodiversity in Cyprus regarding climatic changes were assessed in Deliverable 1.2. The main indicator for assessing the vulnerability of the terrestrial biodiversity towards climate changes for the current situation appeared to be the landscape fragmentations of the island, as species cannot move neither northern nor higher after a certain point. Instead, the main advantage of the marine biodiversity for the current situation is the ability of migration, which can also be counted as a disadvantage due to the intrusion of harmful invasive alien species. On the other hand, freshwater biodiversity is also threatened due to the landscape fragmentations and the deteriorated freshwater quality especially for groundwater bodies. Considering the above, it is assumed that the first vulnerability priority of the biodiversity in Cyprus to climate changes for the current situation is the distribution of species in terrestrial ecosystems while the second priority is the biodiversity of aquatic ecosystems.

Future climate change impact, vulnerability and adaptation measures in the sector of biodiversity will be reassessed for the case of Cyprus, in the framework of this study, in order for the future vulnerability to be quantified. Future vulnerability priorities for the biodiversity will be identified in order appropriate adaptation measures to be implemented.

Each climatic parameter (temperature, precipitation, wind and dry spell) was analyzed for the future situation with the use of the PRECIS regional climate model through comparison between a control period (1961–1990) and a future period (2021–2050). Regional Climate Models of the ENSEMBLES project have also been used. The results of models were used as an ensemble mean for testing and comparing the respective results of PRECIS. Detailed information is available in Deliverable 3.2 while the main model used in this report is the PRECIS (Providing Regional Climates for Impact Studies) regional climate model. The reason is that while, in the other simulations models, Cyprus is placed in the south-eastern part of the domain in PRECIS simulations, Cyprus lies at the center of the study domain. The future period 2021-2050 has been chosen specifically for the needs of stakeholders and policy makers to assist their planning in the near future, instead of the end of the twenty-first century as frequently used in other climate impact studies.

5.2 Baseline situation

The rich biodiversity of Cyprus is the result of the combination of the geographical structure, landscape isolation due to its insular character, surrounding sea, topographic relief, geological structure and of course climatic conditions. The flora and fauna of the island are adapted to the various natural biotopes and climatic conditions, resulting in a large number of endemic and rare species (DoE, 2000).

In order to present the diversity of nature in Cyprus, two of the terms which define biodiversity will be used: the ecosystem diversity and the species diversity.

Ecosystem diversity

The ecosystems in Cyprus include 48 habitat types, 14 of which are priority habitat types according to the Habitats Directive of the European Union (Council Directive 92/43/EEC, 1992) and 4 are endemic habitat types (*Serpentinophilous* grasslands of Cyprus 62B0*, Peat grasslands of Troodos 6460*, Scrub forest of *Quercus alnifolia* 9390* and *Cedrus brevifolia* forests 9590*) (DoE, 2000).

Species diversity

Flora

The flora of the island includes in total 1910 taxa (species, subspecies, varieties, forms and hybrids) as native or naturalized. The 143 of these taxa are endemic and more than 400 are cultivated (Unit of Environmental Studies). Overall, the percentage of Cyprus' endemism (calculating all the taxonomical levels) is 7.39%, which is one of the highest in Europe (Hadjichambis & Della, 2007). The recorded indigenous plant taxa in the area consist of 52 trees, 131 shrubs, 88 subshrubs and 1637 herbs (DoF, 2005; Endreny & Gokcekus, 2008). Most of the endemic plants of Cyprus are located in the two mountain ranges of the island, as 94 endemic plants are developed in the mountain range of Troodos (only the National Forest Park Troodos hosts a total of 786 plant taxa) and 56 in the mountain range of Pentadaktylos (DoE, 2000). Another characteristic of the mountain areas of Cyprus is the tree nature-monuments (or Giant Trees), meaning trees or high shrubs with usually large dimension and age, which generally exceed two or three centuries (DoF). Mushrooms, bryophytes and lichens have not been adequately studied but there is evidence that numerous species exist. Furthermore, the sea around Cyprus is characterized by a diverse array of important habitats and hosts a considerable number of endangered species. Coastal vegetation is mostly low and sparse, and five endemic plants are found in this belt (DoE, 2000).

Fauna

Cyprus is considered as a biodiversity "hotspot" area (Myers et al., 2000), because it is the only centre of birds endemism in Europe and the Middle East (Bibby et al., 1992; Kourtellarides, 1998), a centre of insects endemism (Makris, 2003), a centre of plant diversity (WCMC, 1992; Pantelas et al., 1993; Hadjikyriakou, 1997; Tsintides et al., 2002; Tsindides & Kourtellarides, 1995) and a centre of mammals endemism (with six out of its 11 wild mammals being endemic) (Hadjisterkotis & Masala, 1995; Hadjisterkotis, 1996; Hadjisterkotis, 2003a; Bonhomme et al., 2004; Cucchi et al., 2006; Unit of Environmental Studies). At present, there are about 32 mammal species (DoE, 2000), 24 reptile species (DoE, 2000), 3 turtle species -2 of which are marine (DoF), 3 amphibian species (frog species), 385 bird species (53 of which are permanent residents) (DoE, 2000), 250 fish species and approximately 6000 insects species (including 52 butterfly species) recorded in the island (DoF, 2012).

Pressures

Biodiversity is affected by numerous factors concerning the climate, ecology, society, culture, economy and technology. These features are necessary to be mentioned in order to present the current situation in Cyprus. A list of factors retrieved from a relevant study of the United Nations University (2005) and adjusted for the case of Cyprus, is presented in the following table (Table 5-1):

Table 5-1 : List of factors affecting biodiversity

Categories	Factors
Climate aspects	Variability (uneven geographic distribution and temporality of precipitation)
	Reduction of frequency of precipitation
	Increase of frequency of rainfall's intensity
	Increase of temperature (and certain variables of temperature)
	Heat-wave
	Reduction of snow cover in Troodos
	Increase of evapotranspiration (contributes to the intensification of soil drying)
	Other climate aspects
Ecological aspects	Temperature limitations
	Water variability (drought and heavy rains)
	Unfavorable climate (incl. variability)
	Geological instability (e.g. periodic seismic activity, geological erosion and sediment loads)
	Topographic difficulties (steepness, roughness)
	Restricted soil fertility and susceptibility
	Vulnerability of land resources

Categories	Factors
	Climate change
	Plant and animal diseases
	Natural hazard deposition
	Environmental pollution (e.g. waste and construction, pollution form quarrying)
	Deforestation
	Other ecological aspects
Socio-cultural aspects	Outmigration, manpower availability
	Missing of undapted land use regulations
	Land ownership and privatization
	Tradition and culture
	Education and knowledge on resource use
	Attitude and awareness towards land resources
	Abandonment of the rural areas and overexploitation of the left agricultural areas
	Overgrazing
	Geopolitical pressures between countries (more water drillings in the southern part of Cyprus after 1974)
	Other socio-cultural aspects
Economic aspects	Limited economic performance of agriculture
	Restricted market access, economic isolation
	Energy dependence on oil inputs
	Other economic aspects
Technological aspects	Lack of land use alternatives and arable land
	Poor land use (e.g. urban sprawl, commercial development, vehicle off-roading)
	Absence of crop rotation and fallow periods
	Overuse of fertilizers
	Too many water drillings and near the seashore
	High land use intensity (e.g. overgrazing, poor pasture management, poorly regulated hunting, poor tourism development in coastal and mountain areas)
	Unadapted irrigation practices (e.g. poor soil and water management for irrigated and rainfed crop production)
	Other technological aspects

The above mentioned pressures (Table 5-1) in combination with the factors of climate change are expected to deteriorate even more some environmental phenomena or create new more complicated conditions for the biodiversity of Cyprus. The major pressures on the biodiversity of Cyprus as a result of several activities are listed below:

- Stress in the coastline environment due to tourism development (changes of land use).

- Abandonment of primary agricultural areas due to urbanization.
- Reduction in quantity and range of invertebrate and seed food due to intense agricultural practises.
- Impacts on the biodiversity of small mammals due to intense agricultural practises (Unit of Environmental Studies).
- Eutrophication due to contaminated waters.
- Contamination of freshwaters from livestock waste (I.A.CO Ltd, 2007).
- Degradation of soil productivity due to desertification (I.A.CO Ltd, 2007)
- Overexploitation of fisheries stocks (DoE, 2000).
- Changes in plant species distribution due to the localised overgrazing (DoE, 2000).
- Threat of certain animal populations due to illegal hunting (DoE, 2000).
- Changes in plant species distribution due overexploitation and contamination of surface and ground water (DoE, 2000).
- Changes in forest plant species distribution in the abandoned parts of the unprotected state forests.
- The dam construction in Cyprus provided new habitats for the local animal population and for the migratory waterfowl. However, the local society in order to provide the additional opportunity of sport fishing introduced big populations of 16 species of exotic freshwater fish and the crayfish Procambarus clarkii in every dam. In 1995 only, the species of Mirror Carp (Cyprinus carpio), mosquito fish (Gambusia affinis) and Rainbow trout (Oncorhynchus myskiss) were introduced for fishing in the dams, but by 2000 largemouth bass (Micropterus salmoides) and crayfish (Procambarus clarkii) were added and later the Roach (Rutilus rutilus). Except roach all these species are known to be fed on either stage with amphibians (frogs, tadpoles and spawn). This combination of fish and crayfish eliminated the frog population from each dam and inevitably led the grass snake Natrix natrix cypriaca into extinction (Unit of Environmental Studies).

The above factors are used additionally, in order to assess the future vulnerability of biodiversity due to climatic changes in a more integrated perspective.

5.3 Future impact assessment

According to the Millennium Ecosystem Assessment (MA, 2005), impacts on biodiversity due to climate change have had a very rapid increase[i] over the last century, especially in dry lands, mountains and polar regions.

The climatic factors that may have an impact on the biodiversity of Cyprus include the decreased rainfall and increased temperature, droughts, fluctuations in intense precipitation events, sea level rise, increased atmospheric CO_2 and changes in fire regimes. According to PRECIS projections for the future period 2021-2050, the average annual temperature in Cyprus is expected to increase by 1-2^{o}C with respect to the control period 1960-1990, while precipitation is expected to decrease in seasonal level and in minor degree in annual level. In addition, the maximum length of dry spells (precipitation<0.5mm) is expected to increase 10 to 12 days on average while heat wave days (temperature >35^{o}C) will be increased averagely about 10-30 days on annual basis, depending on the region. Concerning future changes of annual max total rainfall over 1 day, PRECIS projections show that a slight increase of about 1-4 mm is anticipated. Finally, regarding the highest annual total precipitation, falling in 3 consecutive days, a negligible increase of about 1-2 mm of rainfall is expected.

In this section the climate change impacts on the biodiversity sector, as these have been identified in Deliverable 1.2, will be reviewed in light of the climate projections for the future. The general correlations between the estimated climate changes in Cyprus and the impacts on biodiversity on terrestrial and aquatic ecosystems of temperate climates are listed in the following table (Table 5-2).

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[i] The ranking of climate change by the Millennium Ecosystem Assessment (MA, 2005) is based on evidence that climate change has already been affecting biodiversity (Secretariat of the Convention on Biological Diversity, 2007).

Table 5-2: Relationship between potential climate changes and impacts on biodiversity

Potential climate change in Cyprus	Future impacts on biodiversity in temperate climates			
	Terrestrial ecosystems		Aquatic ecosystems	
	Flora	Fauna	Flora	Fauna
Decreased rainfall & increased temperature	Decrease of soil moisture and thickness of soil layer affecting the associated plant species. (MOA)	Changes in food availability which are responsible for the changes in the distribution of animal species. (MOA)	Changes in ocean currents, in the temperature of the upper sea layers, in salinity and in the global thermoline are responsible for the changes in the distribution of plant species (UNEP, MAP, RAC/SPA, 2010).	The changes in sea currents routes can be correlated with effects on fish recruitment, mainly for the Lessepsians species. Also, alterations in sea currents routes are leading to changes in abundance of juvenile fish and therefore can be correlated with production in marine and fresh water. The fluctuations in sea water temperatures are responsible for changes in physiology and sex ratios of fished species, alteration in timing of spawning, migrations, and/or peak abundance and also, for the increasing of invasive species, diseases and algal blooms. These impacts are leading to reduced production of target species in marine and fresh water systems. Changes in the marine food-webs cause alterations to the food availability of fish, birds and marine mammals. Potential mismatch between prey (plankton) and predator (fished species) (Allison, et al., 2009).
Droughts	Soil droughts cause localized catastrophes of plants, extinction of plant species,	Soil droughts cause changes in habitats and food availability, affecting the	Changes in lake water levels and water flows in rivers and consequently to the bank side	Changes in lake water levels and water flows in rivers and consequently to the associated fauna species.

Potential climate change in Cyprus	Future impacts on biodiversity in temperate climates			
	reduction of wild plants' resilience and alterations in the distribution of plant species (MOA).	associated animal populations (MOA).	vegetation.	
Heavy and/or intense precipitation events	Increased soil slippage events, which are responsible for localized catastrophes of plant species. Floods are responsible for localized catastrophes of plant species. Water logging of soils is responsible for the reduction of soil productivity. (MOA).	Landslides are responsible for the loss of animal populations (MOA). Floods are responsible for the drowning of animals (MOA).	Changes in timing and latitude of upwelling, in stratification and in mixing of nutrients in lakes and marine upwellings. (EEA, JRC, WHO, 2008)	Changes in pelagic distribution and productivity (EEA, JRC, WHO, 2008).
Sea level rise	A potential sea level rise or coastal floods are responsible for the salinization of coastal soils, hence the changes in soil pH and inevitably the changes in vegetation (EEA, JRC, WHO, 2008).	A potential sea level rise or coastal floods are responsible for the flooding of the coastline, salinization of coastal soils and changes in vegetation. These parameters are critical for the survival of the animals of the coastline (EEA, JRC, WHO, 2008).	The increased superlittoral and supralittoral inundation and the general changes in the structure of marine ecosystems can affect the spatial distribution of plant species, whose tolerance limit is depended on the maximum depth limit (e.g. *Posidonia oceanica* has a maximum depth tolerance limit of 42 meters in Cyprus, *Cymodocea nodosa* predominates in shallower waters of 2-10 meters, *Cystoseira*	Sea level rise can cause flooding, coastal erosion and the loss of flat and low-lying coastal regions. It increased the likelihood of storm surges, enforces landward intrusion of salt water and endangers coastal ecosystems and wetlands (EEA, JRC, WHO, 2008).

Potential climate change in Cyprus	**Future impacts on biodiversity in temperate climates**			
			spp. habitats are found in shallow waters until 37m, *while Caulerpa prolifera* and *Halophyla stipulacea* are found in deeper waters (Hadjichristophorou, 2000; Parari, 2009).	
Increased atmospheric CO2	An enriched CO_2 atmosphere is responsible for the increased water use efficiency of some plants and as a result the altered competitive interactions of species (EEA, JRC, WHO, 2008).	Changes in food availability are responsible for the changes in the distribution of animal species (EEA, JRC, WHO, 2008).	Ocean acidification and changes in sea water pH lead to the saturation state of of calcium carbonate ($CaCO_3$) minerals affecting the distribution of plant species (MedSeA, 2011).	The combined effect of the Mediterranean seawater acidification -absorbing anthropogenic CO_2 per unit area- with the low tropospheric warming on the Mediterranean biogeochemistry and ecosystems, and the ecosystem services they support, through the direct impacts on its highly adapted calcareous and non-calcareous organisms, may be larger in the Mediterranean than in other European regions (MedSeA, 2011).
Changes in fire regimes (increased number of wildfires)	Localised catastrophes of plant species (DoF, 2005).	The challenge of forest fires leads to the expansion of grasslands and as a result to extinctions of forest animal species (DoF, 2005).		

For the purpose of this assessment, the impacts of climate change are grouped in the following impact categories (Table 5-3) and assessed in the sections that follow.

Table 5-3: List of the selected impacts for evaluation

Selected impacts for evaluation	
Terrestrial ecosystems	Distribution of plant species in terrestrial ecosystems
	Plant phenology of terrestrial ecosystems
	Distribution of animal species in terrestrial ecosystems
	Animal phenology of terrestrial ecosystems
Aquatic ecosystems	Marine biodiversity
	Freshwater biodiversity
	Phenology of aquatic ecosystems

Source: EEA, JRC, WHO, 2008

5.3.1 Impacts on terrestrial ecosystems

5.3.1.1 Distribution of plant species in terrestrial ecosystems

Climate change, with the expected milder winters, is expected to affect even more the number of species, services of plants and plant communities. So far northward and uphill movements of plants and extinctions of species have been observed, emerging the concern about the resilience of wild plants to the rate of climate change. Another impact that is expected to be exacerbated the is introduction of alien species[2], having caused ecological changes throughout the world in the past few hundred years (Clout & Lowie, 1997; Unit of Environmental Studies), such as diseases of local species and alterations of keystone species[3]. The invasive alien species alter or even extinct populations and native species in the natural ecosystems.

In Cyprus: The general characteristics of the plant distribution in Cyprus are the low species richness, the sensitive endemic plant species and the several invasive plant species. In the current situation in Cyprus, due to its semi-arid climate and the continuous droughts, species richness is further affected.

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[2] An additional reason, recorded in Cyprus, is the human transportation of alien species across biogeographical boundaries.

[3] Keystone species are the species with the greater abundance in an area.

Species richness in Cyprus will be even more affected in the future period (2021-2050) were drought periods are anticipated to be increased. More specifically maximum length of dry spell is anticipated to have an increase of 10 days in mountain regions, inland, southern regions and southeastern regions. Only in western regions no increase is anticipated.

5.3.1.2 Plant phenology of terrestrial ecosystems

In temperate regions, with warm summers and cold winters, the length of growing season depends mostly on temperature. In places such as Europe, growing seasons last as long as eight months. Indicators for the length of growing seasons are the distance from the Equator (the further away a place is from the Equator, the shorter the growing season) and the height above sea level (higher elevations usually have colder temperatures).

There are two ways to determine the growing season in temperate regions. The first, and more usual, is the calculation of the average number of days between the last frost in spring and the first severe frost in autumn. The second, depending on crops, is the calculation of the average number of days that the temperature rises high enough for a particular crop to sprout and grow. Climate change affects the cold weather events which determine the growing season length, such as the radiation frost in small geographic regions and the advection frost for large geographic regions (Wake, 2005). As a result, changes have been noticed in plant phenology (Menzel, et al., 2006) hence in ecosystem functioning too. More specifically, changes such as the timing of seasonal events (budburst, flowering, dormancy, migration and hibernation) are included in the term of phenology (EEA, JRC, WHO, 2008).

In Europe, there is clear evidence of changing phenology the latest decades (Parmesan & Yohe, 2003; Root et al., 2003; Menzel et al., 2006). Changes in plant phenological phenomena due to climate change have been observed, such as a percentage of 78% of leaf unfolding, advancing trends for flowering and fruiting and only a 3% of a significant delay. Furthermore, an average advance of spring and summer has been observed and estimated to be 2.5 days per decade for the time period 1971-2000 (Menzel et al., 2006). This evidence reveals the markedly changes of spring’s procedures over autumn’s, which is actually the main responsible for the phenomenon of additional life cycles of species in a year (EEA, JRC, WHO, 2008).

In addition, there are observations such as the increased concentration of pollen in the atmosphere and its earlier start (on average 10 days earlier than 50 years ago), due to the changes of flowering (Nordic Council, 2005). These trends in seasonal events are generally believed that most certainly will continue to advance as temperature rises in the following decades (EEA, JRC, WHO, 2008).

Some effects of the phenological changes include changes in the wildlife, timing of procedures of farming (such as tilling, sowing, harvesting and earlier ripening of fruits), forestry and gardening (e.g. more frequent and longer periods of cutting grass) (EEA, JRC, WHO, 2008).

In Cyprus: Changes in phenological responses of plants have been noticed in several places of Europe, but there is no data available for Cyprus. The only relevant information about Cyprus is its participation in the survey "Growing Season Temperatures in Europe and Climate Forcings over the Past 1400 Years" (Guiot, Corona & ESCARSEL members, 2010). More specifically, proxy series of tree ring series of Cyprus were used in the survey, which revealed that the climate change we are currently living has not been seen in Europe for the past 1400 years (Figure 5-1).

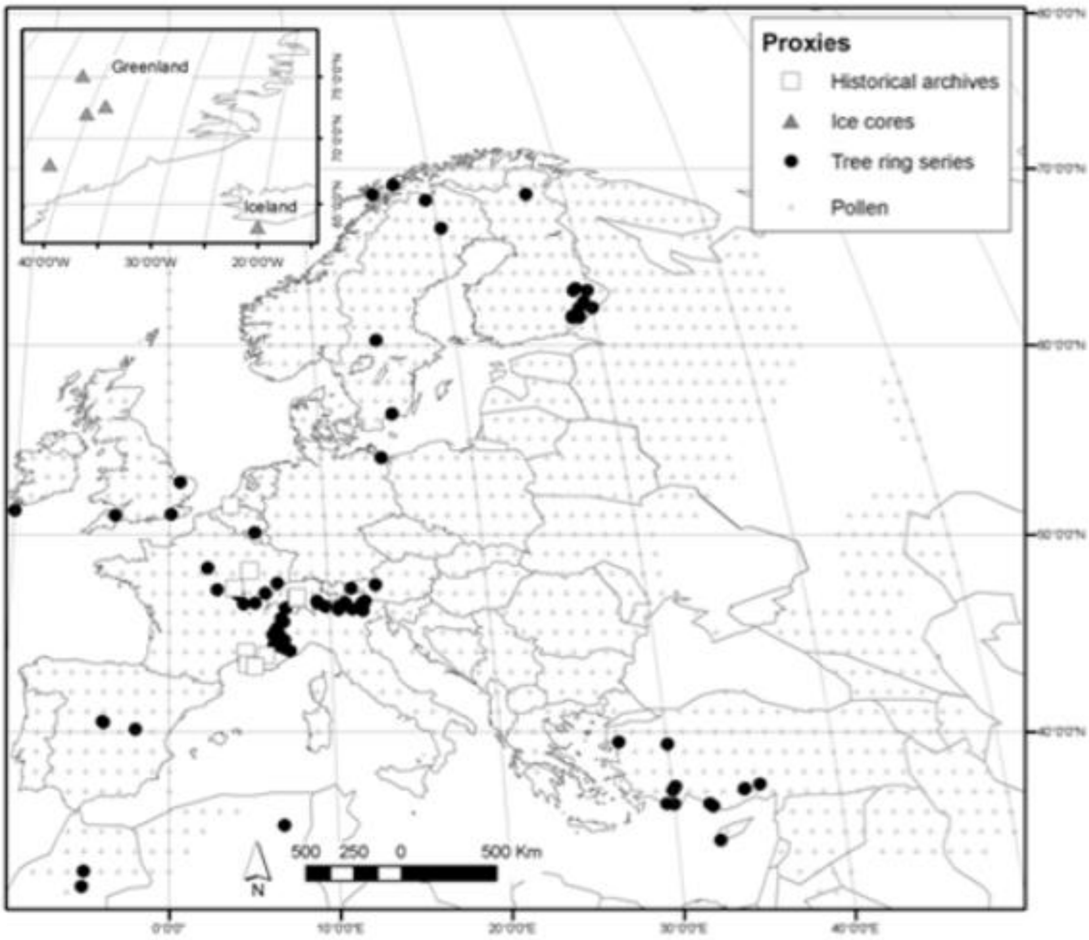

Figure 5-1: Map of the proxies used for the survey of "Growing Season Temperatures in Europe and Climate Forcings Over the Past 1400 Years"

Source: Growing Season Temperatures in Europe and Climate Forcings Over the Past 1400 Years (Guiot, Corona, & ESCARSEL members, 2010).

The rich biodiversity of Cyprus is the result of the combination of the geographical structure, landscape isolation due to its insular character, surrounding sea, topographic relief, geological structure and of course climatic conditions. The flora and fauna of the island are adapted to the various natural biotopes and climatic conditions, resulting in a large number of endemic and rare species (DoE, 2000).

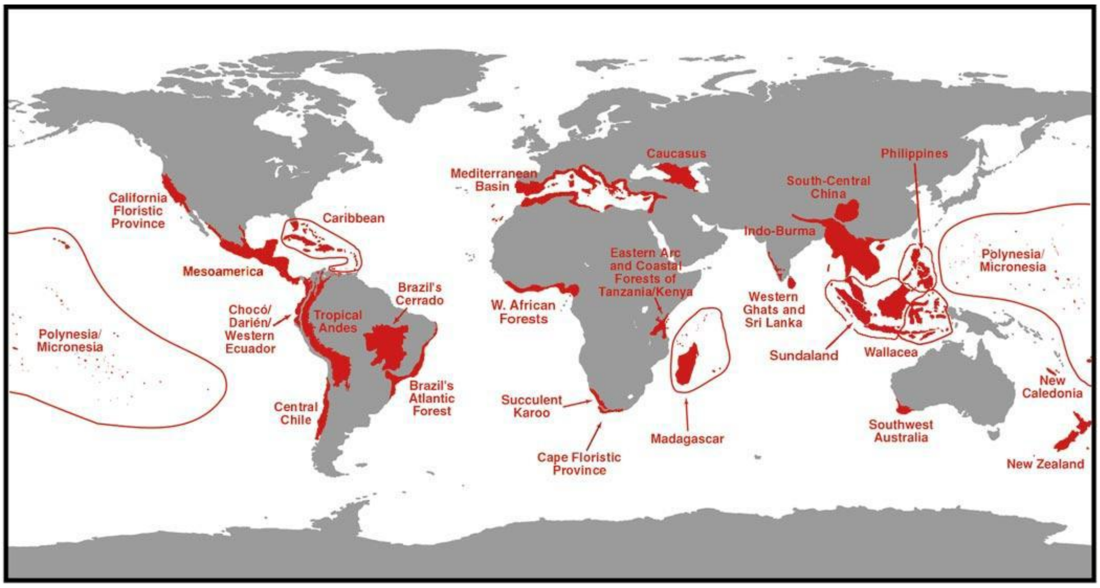

Figure 5-2: The 25 hotspots. The hotspot expanses comprise 30-3% of the red areas

Source: Biodiversity hotspots for conservation priorities (Myers et al., 2000)

In the future period (2021-2050) temperature increase of about 1-2°C on average is anticipated. More specifically, milder winters are expected. Winter minimum temperature is anticipated to have an increase of 1°C in western regions, especially in Akamas area where threatened plants are located. An increase of 1°C is also expected in mountain regions and southern regions that threatened plants also located in a significant level (Troodos mountain and Akrotiri peninsula). Finally an increase of 1 is anticipated in the inland regions and 0,8°C in southeastern regions of Cyprus were distribution of threatened species is less dense.

On the opposite increases in summer maximum temperature can affect biodiversity negatively as well. In the current period summer maximum temperature is on average 27-29°C for western regions, 30-32 °C for mountain regions, 33 °C for inland regions, 32 °C for southern regions and 33 °C for southeastern regions. In the future period it is anticipated to increase about 1.7-2 °C for western regions, 2-2.7 °C for mountain regions, 2.4 °C for inland regions, 2.3 °C for southern regions and 2.3 °C for southeastern regions on average. For western, mountain and southern regions that most of the threatened plants are located this increase of about 1.7-2.7°C can be damaging. For southeastern regions that distribution of threatened species is less dense the increase will be less damaging. However there is no data available concerning phenological responses of plants to future temperature increase. Further research on the impact of anticipated increase in temperature for the future period (2021-2050) in phenological responses of plants is required.

In order to extract safe conclusions regarding the future impact of climate changes on plant phenology, the following are also considered necessary:

- Determination of the growing season and timing of seasonal events (e.g. leaf unfolding, fruiting, budburst, flowering, dormancy, migration and hibernation) in the area
- Determination of plants' life cycles
- Data availability on plant phenological response to climate change from a long monitoring period
- Correlation with climatic conditions and clear distinction of the effect from human activities

5.3.1.3 Distribution of animal species in terrestrial ecosystems

Temperature rise in the future can affect the habitat and food availability of animal species. Thus, a population migration is possible to be caused, in order new shelter to be found. The keystone species expand their distribution over the less adaptable. As a result the invasive species bring along new threats for the host populations such as diseases. The most typical example is the establishment of new pest species -such as migratory moths, butterflies, ticks and mosquitoes- due to warmer winters.

Generally for the European area, there are estimations about animal northeast movement of 550km, 20% population shrinkage for the breeding birds by the end of the century, and serious threat for reptiles and amphibians (Hickling et al., 2006; Araújo et al., 2006) due to their limited dispersal ability (EEA, JRC, WHO, 2008). Furthermore, projections about the mammals of the Mediterranean regions suggest up to 9% risk of extinction (assuming no migration) during the 21st century (Andreou et al.).

In Cyprus: The most threatened species -in terms of population and species- are located in terrestrial environments. The main reasons for the increased sensitivity to climate change are the changes in food availability and landscape fragmentations.

It's worth mentioning that the recorded animal intrusions (mammals) in the island are the result of human intervention. According to Hadjisterkotis (2000a) and Hadjisterkotis & Heise-Pavlov (2006), five wild boars (*Sus scrofa*) were introduced to the island for game farming. Several years after the introduction of the animal, in 1994, the wild boar was illegally released in the Limassol Forest and in 1996 in the Troodos National Forest Park. In 1997, the government decided its eradication from the area (Hadjikyriakou and Hadjisterkotis, 2006). The main reasons for that decision were the prevention of a possible environmental destruction of the National Forest of Troodos (an area of high biodiversity in Cyprus, where 72 endemic plant species are located) and the danger of transmitting diseases to livestock. In January 2005, there were no wild boars seen in Troodos, Paphos and Limassol forests.

Apart from the wild boar, the introduction of pheasants for hunting in habitats and of the indigenous black francolin by the Game Service of Cyprus caused many problems due to the similar habitat requirements of both animals (Unit of Environmental Studies).

5.3.1.4 Animal phenology of terrestrial ecosystems

Climate change has affected life cycles of many species. Anticipated**,** temperature rise can be the main responsible for the changes in the metabolic limits of animals and the reduction of the thermoregulation capacity of warm blooded animal species in the future period. Another reason for the changes of the animal phenology is the milder springs, which are responsible for the length of breeding seasons and as a result for the reproduction of more generations of temperature-sensitive insects. In addition, the milder winters allow the survival of insects making their growth easier. These trends are generally projected to continue, if climate warming increases in the future (EEA, JRC, WHO, 2008).

In Cyprus: In general, there is no information available about the animal phenology for Cyprus in relation with the increasing temperature, apart from the noticed increased populations of insects in the forests of Cyprus (DoF). However increase in temperature can affect animal phenology. Thus data for anticipated temperature increase for the whole study domain is important. More specifically aaccording to PRECIS projections for the future period 2021-2050, the average annual temperature in Cyprus is expected to increase by 1-2^{o}C with respect to the control period 1960-1990. A significant warming of about 1.0 – 2.0°C is expected for the winter period and a warming of about 2.0 – 2.7°C for the summer period. Further research on the impact of anticipated increase in temperature for the future period (2021-2050) in responses of animal phenology is required.

In order to extract safe conclusions regarding the future impact of climate changes on animal phenology, the following are also considered necessary:

- Determination of the length of growing season and breeding seasons in the area
- Data availability on animal phenological response to climate change (e.g. metabolic limits of animals and thermoregulation capacity of warm blooded species) for a long monitoring period
- Correlation with climatic conditions and clear distinction of the effect from human activities

5.3.2 Impacts on aquatic ecosystems

5.3.2.1 Marine biodiversity

Levantine basin (Eastern Mediterranean Sea) is characterized by high temperature and salinity, as well as low nutrient levels, making it a challenging biological niche which constantly tests species' tolerance limits to physical components (Parari, 2009).The marine flora and fauna of Cyprus are characterized by great diversity and low biomass, making them vulnerable to climate change. Anticipated changes in temperature, salinity and nutrient levels may affect further marine biodiversity.

According to PRECIS projections, for the future period 2021-2050, the average annual temperature in Cyprus is expected to increase by 1-2°C with respect to the control period 1960-1990 (increase of about 1.0 – 2.0°C is expected for the winter period and a warming of about 2.0 – 2.7°C for the summer period).The vulnerability of marine flora and fauna of Cyprus will be increased due to the anticipated warming.

Anticipated increase in ambient temperature will affect water temperature as well. As the Red sea is characterized by generally higher temperatures than the Mediterranean, a future rise in average water temperature in the Mediterranean waters can offer an adaptive advantage to invasive species, causing the displacement of other endemic species. Invasive species enter into the Mediterranean Sea through the Gibraltar straits, the Suez Canal and by being carried in ballast water of ships. However there is no data available for the response in displacement of other endemic species due to anticipated increase in temperature. Further research is required.

Other than invasive species, local biodiversity is also threatened by shift of ocean currents, the changes in salinity and the ocean acidification. These changes may be the main reasons for the anticipated changes in the phytobenthos and phytoplankton of the Mediterranean Sea, where Cyprus is located. For example, marine habitats of neuralgic importance -such as *Posidonia oceanica* meadows- are very sensitive to salinity, temperature and sedimentation alterations. The meadows produced by this marine plant function as nursery grounds for juvenile fish, reproductive fields and fisheries stock replenishment areas are exceptionally important. A potential loss of these meadows would bring catastrophic consequences for the marine biodiversity of Cyprus and its commercial fisheries (Parari, 2009). However there is no data available for the impact on marine biodiversity due to response of shift of ocean currents, changes in salinity and the ocean acidification to future climate changes. Further research is required.

Levantine basin (Eastern Mediterranean Sea) is characterized by low nutrient levels among else, making it a challenging biological niche which constantly tests species' tolerance limits to physical components (Parari, 2009). Changes in climatic parameters will affect nutrient level of marine biodiversity. However further research is required to assess the future impact on marine biodiversity due to changes in nutrient levels.

5.3.2.2 Freshwater biodiversity

Climate change affects the inland aquatic biodiversity. Future climate change can cause enhanced phytoplankton bloom, favoring and stabilizing the dominance of harmful cyanobacteria in phytoplankton communities, resulting in increased threats to the ecological status of lakes and enhanced health risks, particularly in water bodies used for public water supply and bathing (EEA, JRC, WHO, 2008).

Furthermore, a warmer climate will generally intensify some phenomena caused by human activities such as alterations to the host environment due to the introduction of new fish species for sport fishing and eutrophication due to the increased loads of artificial or natural substances. More specifically for eutrophication, future temperature rise will increase mineralization and releases of nitrogen, phosphorus and carbon from soil organic matter and increase run-off and erosion, which will result in increased pollution transport. Also release of phosphorus from bottom sediments in stratified lakes is expected to increase, due to declining oxygen concentrations in the bottom waters (EEA, JRC, WHO, 2008). However there is no data available for the response in freshwater biodiversity (new fish species or eutrophication) due to climate change. Thus further research is required.

In Cyprus:

In Cyprus, the plants, fish and aquatic organisms of rivers and water storage reservoirs (dams) of Cyprus are generally in good condition, whereas the organisms of the groundwaters are more strained. The nitrogen pollution from untreated sewage effluent and agricultural run-off carrying fertilizers is responsible for the phenomenon of eutrophication. Phenomenon of eutrophication can be deteriorated by climate change.

The areas identified as vulnerable to nitrogen pollution, according to the Nitrates Directive 91/676/EEC (Vulnerable Nitrate Zones), are the aquifers of Kokkinohoria, Kiti-Pervolia, Akrotiri, Paphos, Poli Chrisohous and in the more recently added area of Orounta (DoA, 2011). The districts that the aquifiers are situated are affected by temperature rise. In specific, Kokkinohoria, Poli Chrisohous and Paphos sited in the western of Cyprus will have an increase in annual temperature of 1.3 ^{o}C. In Akrotiri, sited in southern Cyprus, the increase will be of 1.6 ^{o}C, in Orouta 1.8 ^{o}C and in southeastern areas (Kiti-Pervolia) about 1.6 ^{o}C. However there is temperature increase in those districts aquifires do not face an increase in water temperature.

The areas ‘Polemidhia Storage Reservoir’ and the coastal area between Cape Pyla and Paralimni have been identified as sensitive according to the Directive Urban Wastewater Treatment Directive 91/271/EEC (WDD, 2011). Another area sensitive to nitrogen and phosphorus pollution is the recorded location in Larnaca, where the seabed (muddy sand with Caulerpa) is degraded (Ramos et al., 2007). In those areas for the future period (2021-2050) an increase of about 1.6 ^{o}C in temperature is anticipated.

In order to extract safe conclusions regarding the future impact of climate changes, and especially temperature increase, on freshwater biodiversity, the following are considered necessary:

- Determination of the change in the size and bloom of phytoplankton and relevant aquatic organisms
- Evaluation of the future oxygen content in waters
- Correlation with climatic conditions and clear distinction of the effect from human activities

5.3.2.3 Phenology of aquatic ecosystems

Future changes in aquatic phenology have been estimated that are affected by climate factors, such as the temperature rise and the degree and rate of regional climate change. One of the most important effects is the change in the size and bloom of phytoplankton. The future impact of weather on the intensity of ocean mixing (and its reverse ocean stratification) can affect the light levels, surface temperature and magnitude of nutrient recycling from deep layers, thereby influencing phytoplankton growth and bloom by driving bottom-up processes (i.e. the role of members of one trophic level as food items for higher trophic levels) throughout the pelagic food chain (Hays, Richardson, & Robinson, 2005). However information about phytoplankton growth and bloom response to temperature rise is not available and further research is required.

In addition, impacts of increased water temperatures may also include more stable vertical stratification of deep lakes and increased oxygen depletion in lake bottoms, more frequent harmful algal blooms, reduced habitats for cold-water aquatic species, and increased incidence of temperature-dependent diseases (EEA, JRC, WHO, 2008). Other future impacts of temperature rise are eutrophication, reduction of oxygen content and increase in the biological respiration rates and lower levels of dissolved oxygen concentration. As a result acidification and changes in sea water pH may be causes leading saturation of calcium carbonate ($CaCO_3$) minerals which further affects the distribution of plant species. Furthermore, changes in levels of atmospheric concentration of carbon dioxide may affect the rate phytoplankton consumes carbon dioxide from the water during photosynthesis and the rate it emits oxygen as a by-product. Further research is necessary in this field that will present response of the above mentioned factors in future temperature rise.

In Cyprus: Although an increased sea surface temperature (SST) is possible for the future, this has not been associated with the anticipated aquatic phenology of Cyprus.

In order to extract safe conclusions regarding the future impact of climate changes on marine phenology, the following are considered necessary:

- Determination of the change in the size and bloom of phytoplankton
- Determination of the mixing pattern of the sea and nutrient recycling from deep layers
- Determination of the mixing pattern of the freshwater bodies nutrient recycling from deep layers
- Evaluation of the future dissolved oxygen content
- Correlation with climatic conditions and clear distinction of the effect from human activities

5.4 Future vulnerability assessment

In this section, the future vulnerability of biodiversity to climate change impacts is assessed in terms of their sensitivity, exposure and adaptive capacity based on the available quantitative and qualitative data for Cyprus and the climate projections for the period 2021-2050. In particular, sensitivity is defined as the degree to which biodiversity is affected by climate changes, exposure is the degree to which biodiversity is exposed to climate changes and their impacts while the adaptive capacity is defined by the ability of biodiversity to adapt to changing environmental conditions which is also enhanced by the measures implemented in Cyprus in order to mitigate the adverse impacts of climate change on the sector.

The sensitivity, exposure and adaptive capacity of Cyprus biodiversity to climate change impacts is assessed with using the same indicators, used for the assessment of current vulnerability of biodiversity. The indicators used for the assessment of sensitivity, exposure and adaptive capacity of Cyprus biodiversity to climate change impacts are summarized in Table 5-4.

Table 5-4: Indicators used for the future vulnerability assessment of climate change impacts on the biodiversity of Cyprus

Future Vulnerability Variable	Selected indicators
Distribution of plant species in terrestrial ecosystems	
Sensitivity	– Landscape fragmentations – Species richness – Percentages of the sensitive endemic plant species – Percentages of invasive plant species
Exposure	– Distribution of the critically endangered plant species on the island – Temperature rise – Changes in precipitation – Drought periods/ dry spell
Adaptive capacity	– Resilience of wild plants to the rate of climate change* – List with the Critically Endangered (CR) plants – Cleaning of some areas of the island from invasive plants – Law 24/1988 on the ratification of the Bern Convention on the conservation of European wildlife and natural habitats – Law 153(I)/2003 on the protection and management of nature and wildlife – Law 4(III)/1996 on the ratification of the Convention on Biological Diversity (1992). – Law 20/1974 on the ratification of the Convention on the International Trade in Endangered Species of Wild Fauna and Flora (CITES)

Future Vulnerability Variable	Selected indicators
Distribution of animal species in terrestrial ecosystems	
Sensitivity	– Loss of species* – Landscape fragmentations – Food availability
Exposure	– Migration of species* – Temperature rise – Dry spell – Populations of animal species*
Adaptive capacity	– Genetic adjustment* – Uphill migration – List of endangered and threatened animal species – Designation of SCI/SPA areas – Law 24/1988 on the ratification of the Bern Convention on the conservation of European wildlife and natural habitats – Law 152(I)/2003 on the protection of wild birds and “controlled game” (Birds Directive 2009/147/EC) – Law 153(I)/2003 on the protection and management of nature and wildlife (Habitats Directive 92/43/EEC) – Law 20/1974 on the ratification of the Convention on the International Trade in Endangered Species of Wild Fauna and Flora (CITES) – Law 17(III)/2001 on the ratification of the Bonne Convention on the conservation of Migratory Species of Wild Fauna. – Law 8 (III) / 2001 on the ratification of the Ramsar Convention – Law 4(III)/1996 on the ratification of the Convention on Biological Diversity (1992).
Marine biodiversity	
Sensitivity	– Number of invasive alien species* – Northward movement of marine species* – Variety of indigenous marine species – Low biomass – Changes in temperature, salinity and nutrient levels – Alien species*
Exposure	– Proximity to natural and manmade nautical channels which favor species migration and relocation – Marine zone – Changes in temperature
Adaptive capacity	– Genetic adjustment* – Recording of marine Invasive Alien Species – Ratification of the Barcelona Convention on the protection of Mediterranean Sea – Ratification of the Barcelona Convention

Future Vulnerability Variable	Selected indicators
	– Protection of aquatic species through the provisions of national law since 1971 – Law 24/1988 on the ratification of the Bern Convention on the conservation of European wildlife and natural habitats – Law 153(I)/2003 on the protection and management of nature and wildlife – Law 4(III)/1996 on the ratification of the Convention on Biological Diversity (1992). – The Fisheries Law and Regulations – Plan for the control of the population of Lagocephalus sceleratus (IAS) in the coastal waters of Cyprus – Subsidies through the National Strategy Plan for Fisheries 2007-2013 (reduction of fishing effort, use of more selective fishing gear, withdrawal of trawlers) – Law 13(I)/2004 on the protection and management of water resources enforcing the Water Framework Directive (2000/60/EC) – Mediterranean Action Plan (MAP) – Coastal Area Management Programme (CAMP)
Freshwater biodiversity	
Sensitivity	– Indigenous fish species – Indigenous plant species – Human activities – Stratification* – Oxygen depletion* – Dominance of harmful cyanobacteria in phytoplankton communities* – Nitrogen and phosphorus pollution in surface waters – Water quality – Endangered plant species* – Endangered aquatic species*
Exposure	– Perennial rivers – Number of lakes – Number of water bodies – Water quality – Temperature rise – Increase in precipitation
Adaptive capacity	– Genetic adjustment* – Buffer zones of protection of the environment – Enforcement of good fertilization practices in agriculture – Repair of existing infrastructures – Law 24/1988 on the ratification of the Bern Convention on the conservation of European wildlife and natural habitats – National law on the protection of aquatic species of inland and marine waters since 1971 and its related regulations

Future Vulnerability Variable	Selected indicators
	– Ratification of the Barcelona Convention on the protection of Mediterranean Sea – Law 20/1974 on the ratification of the Convention on the International Trade in Endangered Species of Wild Fauna and Flora (CITES) – Law 4(III)/1996 on the ratification of the Convention on Biological Diversity (1992). – Law 13(I)/2004 on the protection and management of water. – Law 34/2002 on the nitrogen pollution of waters (based on the European Directive 91/676/EEC). – Law 42/2004 on the control of nitrogen polluted waters. – Law 41/2004 on the control of water pollution. – Law 517/2002 on the control of water pollution. – Law 56(I)/2003 on waste management. – Law 108(I)/2004 on sewerage systems. – Law 772/2003 on urban wastewater. – Law 254/2003 on the nitrogen pollution of waterbodies. – Law 106(I)/2002 on the control of the water and soil pollution. – Captive breeding program in order to manage the problem of the artificial introduction of exotic fish in the dams of Cyprus

* No date available for this indicator

The relationship between sensitivity, exposure and adaptive capacity is based on the following qualitative equation:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity * Exposure$$

Sensitivity, exposure and adaptive capacity are evaluated on a 7-degree qualitative scale ranging from “none” to “very high”.

In the sections that follow, the vulnerability is assessed for the impact categories presented in Section 5.3:

1. Distribution of plant species in terrestrial ecosystems
2. Distribution of animal species in terrestrial ecosystems
3. Marine biodiversity
4. Freshwater biodiversity

It is noted that, the future vulnerability of “Plant phenology of terrestrial ecosystems”, “Animal phenology of terrestrial ecosystems” and “Phenology of marine ecosystems” was not assessed due to lack of relevant research findings.

The future vulnerability of biodiversity varies substantially as it is related to the different rate and magnitude of climate change in different parts of Cyprus due to the variability of the air pollution levels, altitude, temperature and rainfall variations, meteorological conditions (e.g. wind, moisture), local geomorphology and soil characteristics.

It must be noted that, there are no sufficient scientific evidence and data to evaluate or correlate all future impacts and indicators to climate changes. Consequently, further research is required in order to provide concrete information for a more detailed and descriptive assessment of the future vulnerability of the sector. Nevertheless, an attempt was made to provide a preliminary assessment of the future vulnerability. In case additional data are provided by the competent authorities of Cyprus, the future vulnerability of the sector could be re-assessed.

5.4.1 Terrestrial ecosystems

5.4.1.1 Distribution of plant species in terrestrial ecosystems

5.4.1.1.1 Assessment of sensitivity and exposure

Sensitivity

The general characteristics of the plant distribution in Cyprus which indicate a sensitive environment to climate change plant species are the following: (i) low species richness, (ii) sensitive endemic plant species and (iii) several invasive plant species.

i) Low species richness

The number of plant species in Cyprus is generally considered low in comparison with the levels in Europe (Figure 5-3 and Figure 5-4), perhaps due to the semi-arid climate of the island and the more frequent presence of consecutive years of droughts according to Biosoil project (Hiederer & Durrant, 2010). Nevertheless studies undertaken in Cyprus indicate that the percentage of Cypru's endemism is 7,39% which is one of the highest in Europe (Hadjichambis & Della, 2007).

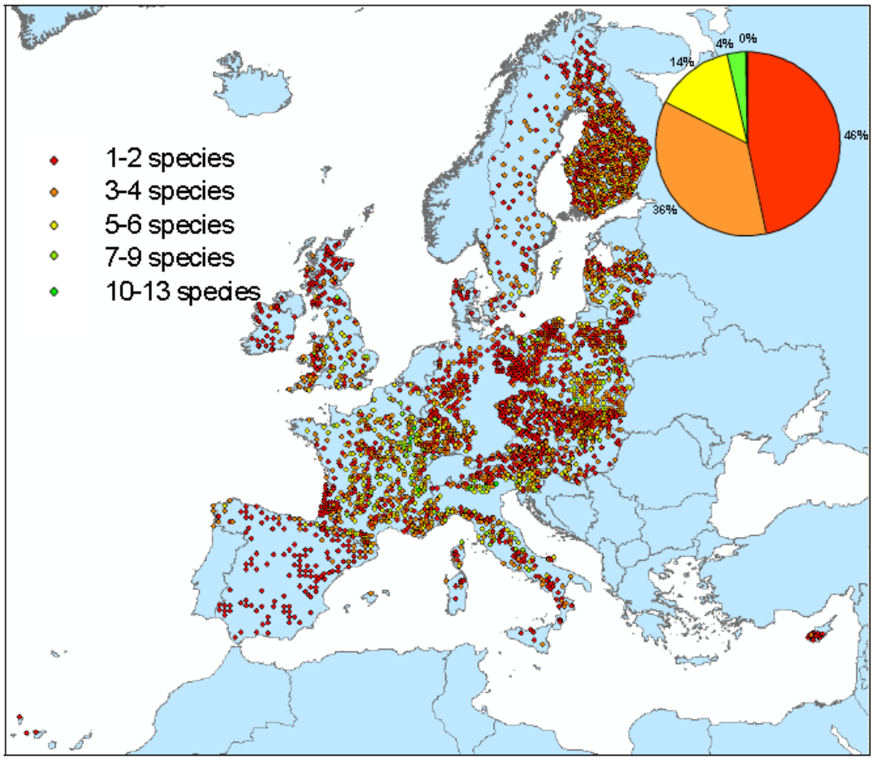

Figure 5-3: Species richness according to the European Forest Type Classification score (EFTC)

Source: Evaluation of BioSoil Demonstration Project Preliminary Data Analysis (Hiederer & Durrant, 2010)

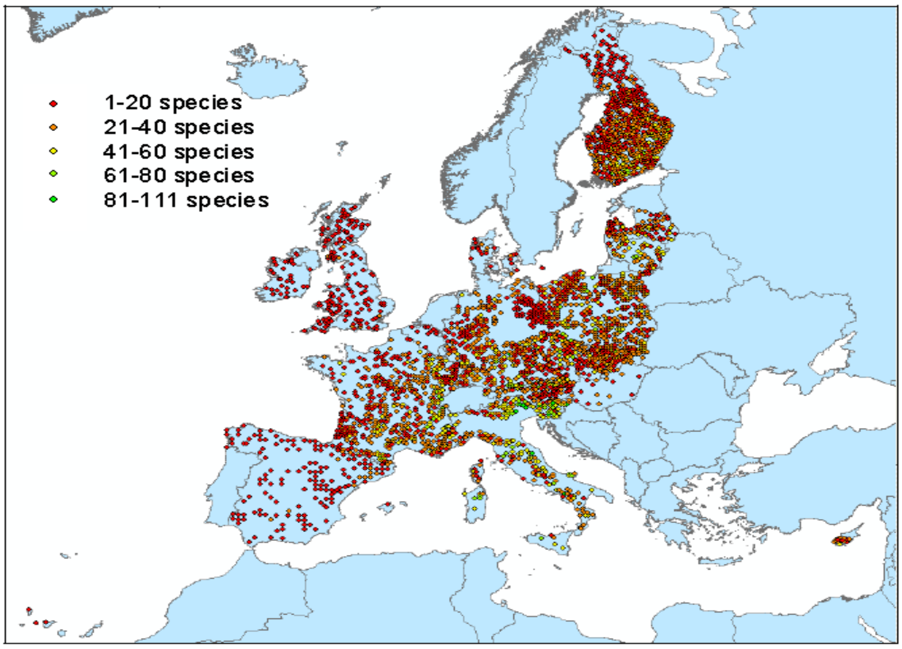

Figure 5-4: Ground vegetation species richness

Source: Evaluation of BioSoil Demonstration Project Preliminary Data Analysis (Hiederer & Durrant, 2010)

ii) Sensitive endemic plant species

The more sensitive plant species are considered those that belong to relic populations and those that are less capable to adapt in the new environmental conditions. The populations in mountain ecosystems are more sensitive, due to the global phenomenon of uphill tree line migration and the landscape fragmentations (Kullman, 2006; Kullman, 2007; Pauli et al., 2007; EEA, JRC, WHO, 2008). Forests in Cyprus cover mountain areas equivalent to the 16.7% of the total surface of the island. As a result, forest plant species of Cyprus are particularly sensitive to climate change.

More specifically, according to the Red Book of Flora of Cyprus (Tsintides et al., 2007), 7% of the plant taxa in Cyprus is Regionally Extinct (RE/?RE), 14% of endemic plants of Cyprus is characterized as Critically Endangered (CR), 19.5% as Endangered (EN), 39% as Vulnerable (VU), 4,6% as Close Threatened (NT) and 2.2% as Low Danger (LC) (Figure 5-5).

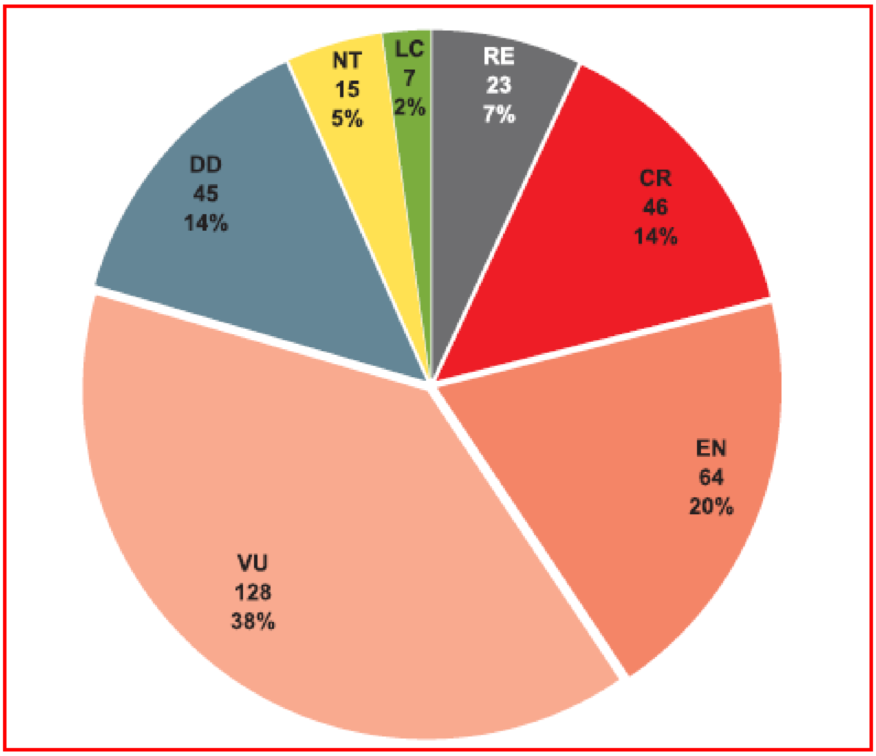

Figure 5-5: Distribution of evaluated plant taxa in the IUCN Red List Categories

Source: The Red Data Book of the Flora of Cyprus (Tsintides et al., 2007)

In addition, an important percentage of the endemic plants of Cyprus, which are characterized as Critically Endangered (CR) (Table 5-5), can only be found in Cyprus or in other three countries at most (Figure 5-6 and Table 5-5).

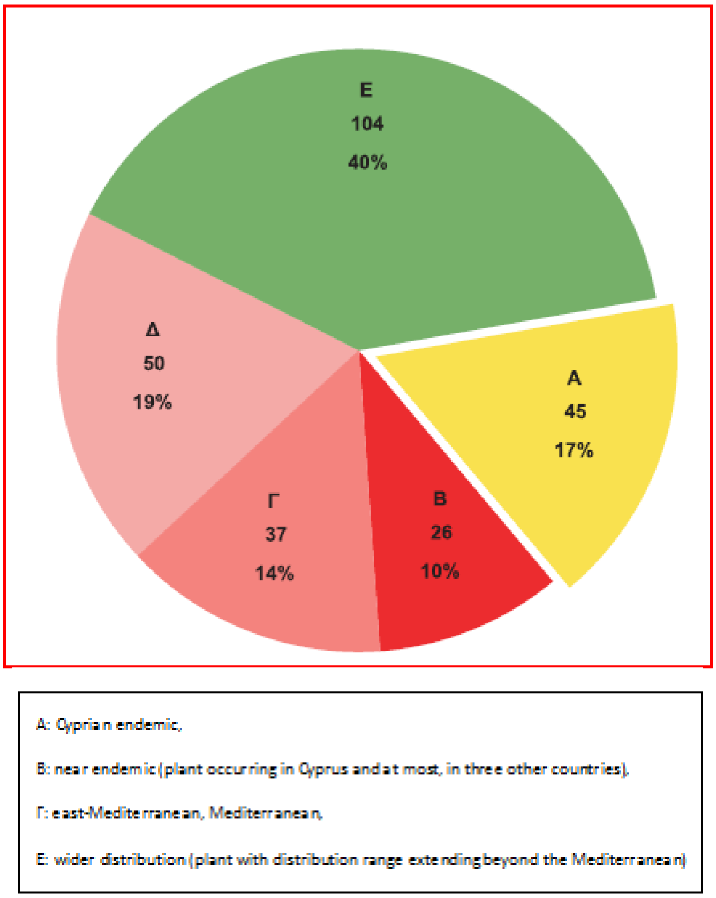

Figure 5-6: Chorology of the threatened and extinct plants

Source: The Red Data Book of the Flora of Cyprus (Tsintides et al., 2007)

Table 5-5 : List with the Critically Endangered (CR) plants of Cyprus

Plant Species	Location
Arabis kennedyae Meikle	Troodos, Triptilos(in altitude 900-1350m)
Astragalus macrocarpus subsp. lefkarensis Agerer-Kirchhoff & Meikle	Only in Cyprus in Leykara, Asgata, Alaminos and Kelokedara.
Centaurea akamantis T. Georgiadis & G.Chatzikyriakou	Only in Akamas of Cyprus.
Delphinium caseyi B. L. Burtt	Only in Cyprus, in Pentadaktylos (tops of Saint Ilarionas and Kyparrissovouno)
Scilla morrisii Meikle	Exclusively at southwest of Cyprus (Monastiri, Agia Moni, Saint Neofytos)
Salvia veneris Hedge	West of Kithreas villages
Erysimum kykkoticum G. Hadjikyriakou & G. Alziar	One the rarest endemic species. It is located in the valley of Xeros (Agrakin of Pissokremmou)

Source: The top 50 plants of the Mediterranean Island Plants (de Montmollin & Strahm, 2005)

iii) Invasive plant species

According to the studies of Georgiades (1994) and Hadjikyriakou & Hadjisterkotis (2002), 152 adventive species have been recorded (Unit of Environmental Studies) (Table 5-6). More specifically, the *Acacia saligna (Labill.) (H.Wendl.)* is described as the most dangerous invasive species in Cyprus, threatening many natural habitats, invading maquis, garigue, phrygana, marshy areas and agricultural land. It has been recorded as a serious threat to the habitat of the salt lake of Larnaca and it was considered necessary to remove a number of its population from the area (Atlantis Consulting Cyprus Ltd). Likewise, the *Robinia pseudoacacia* L. has spread in forests, maquis, garigue and phrygana vegetation. In addition, the observed for the first time *Ailantus altissimma* (Mill.) *Swingle and Casuarina cunninghamiana* Miq. is also spreading, threatening natural habitats such as forests and maquis.

Table 5-6: List of the 16 adventive species spreading to natural habitats and the observed for the first time adventive species also spreading to natural habitats

Adventive species spreading to natural habitats	Adventive species, observed for the first time, spreading to natural habitats
1. *Vinca major L.* 2. *Cistus ladanifer L.* 3. *Tagetes minuta L.* 4. *Tanacetum balsamita L.* 5. *Tanacetum parthenium (L.)* Sch.Bip. 6. *Corylus maxima Mill.* 7. *Iris albicans* Lange 8. *Acacia saligna (Labill.)* H.Wendl. 9. *Robinia pseudoacacia L.* 10. *Epilobium angustifolium L.* 11. *Oxalis pes-caprae L.* 12. *Eschscholzia californica* Cham. 13. *Papaver somniferum L.* 14. *Dodonaea viscosa (L.)* Jacq. 15. *Antirrhinum majus L.* 16. *Vitis vinifera*	1. *Celtis australis L.* 2. *Cercis siliquastrum L.* 3. *Prunus dulcis* (Mill.) D.A.Webb 4. *Ailantus altissimma* (Mill.) *Swingle and Casuarina cunninghamiana Miq*.(its spreading status threatens natural habitats invading forests and maquis) 5. *Fraxinus angustifolia Vahl* subsp. *Angustifolia* 6. *Pyrus malus* L. 7. *Prunus persica* (L.) Batasch

Source: Review of biodiversity research results from Cyprus that directly contribute to the sustainable use of biodiversity in Europe (Unit of Environmental Studies)

Considering the above, the sensitivity of the distribution of plant species (including Invasive Alien plant Species) in Cyprus for the future period (2021-2050) can be characterized **high.**

Exposure

The distribution of the critically endangered plant species (Table 5-5) on the island, seems to be in many and scattered areas such as Madari, Akamas peninsula, Akrotiri peninsula, cape

Greko and in some potential areas[4] such as the mountains (the National Forest of Troodos, the National Forest of Paphos and Pentadaktylos) (Figure 5-7).

There is no scientific data available concerning phenological responses of plants to future (2021-2050) temperature increase. Further research is required. Nevertheless the annual warming of about 1 – 2 °C that Cyprus will experience is anticipated to affect distribution of threatened plants. The extent of the area that threatened plants are located and temperature increase affect their phenological response.

All areas with threatened plants will be affected by anticipate climatic changes. As PRECIS predictions indicate, Akrotiri, Troodos and Paphos forest where threatened species are located with high density will have milder winters in the future since the increase in average winter temperature there, will be about 1.2-1.3°C. In Akamas area, with also high density of threatened species, the increase in average winter temperature will be lower around 1°C. In Cape Greco temperature increase will be about 1°C. As far as average summer maximum temperature is concerned Akrotiri and Akamas area will have a lower average increase in temperature of about 2.2°C and 1.8 °C in the future period in comparison with Troodos and Paphos mountain areas that the increase will be about 2.3-2.7 °C. Less increase in summer maximum temperature of about 2°C is anticipated for Cape Greco area.

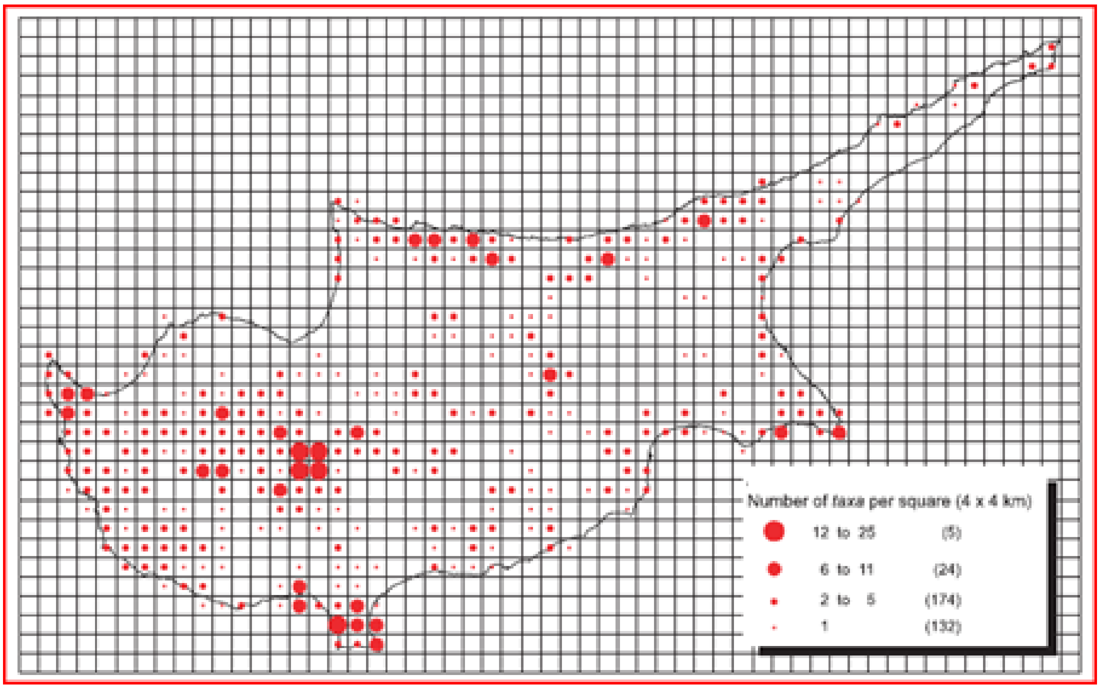

Figure 5-7: Geographic distribution of the threatened plants of Cyprus

Source: The Red Data Book of the Flora of Cyprus (Tsintides et al., 2007)

However, as it is obvious from the previous figure, except from places with a dense distribution, most regions in Cyprus are covered by a certain degree by threatened plants.

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[4] The populations in mountain ecosystems are more sensitive, due to the global phenomenon of uphill tree line migration (Kullman, 2006; Kullman, 2007; Pauli et al., 2007; EEA, JRC, WHO, 2008).

Thus it is important to refer to temperature increase in those areas since the degree of exposure will be increased along with increase in temperature levels. In specific winter minimum temperature is anticipated to have an increase of 1°C in western regions, mountain regions, inland and southern regions and an increase of 0,8°C in southeastern regions. Summer maximum temperature in the current period is 27-29°C for western regions, 30-32 °C for mountain regions, 33 °C for inland regions, 32 °C for southern regions and 33 °C for southeastern regions. In the future period it is anticipated to increase about 1.7-2 °C for western regions, 2-2.7 °C for mountain regions, 2.4 °C for inland regions, 2.3 °C for southern regions and 2.3 °C for southeastern regions. Winter minimum and summer maximum temperature projections for areas of particular concern are presented as the most extreme seasonal cases. More information about the seasonal changes are available in Deliverable 2.3.

In general, the area that the majority of threatened plants are situated will face increases in average winter minimum temperature of about 1°C which may favor certain species. This is not the case in summer since the anticipated increases in average summer temperatures as well as the increase in the maximum summer temperatures (>30°C) will threaten even more these species. The extent of the area that threatened plants are located and the increase in length of dry spell will determine the final degree of exposure.

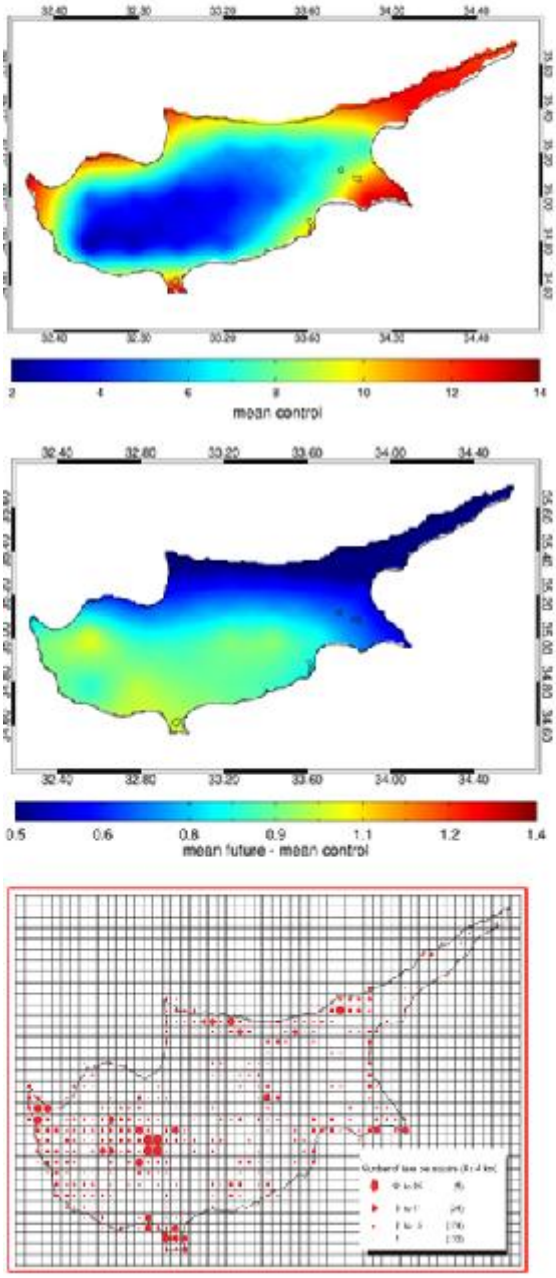


Figure 5-8: Average winter minimum temperature for control period using PRECIS RCM model (a) Changes in average winter minimum temperature in the near future (Future – Control period) using PRECIS RCM model (b) and Geographic distribution of the threatened plants of Cyprus (c)

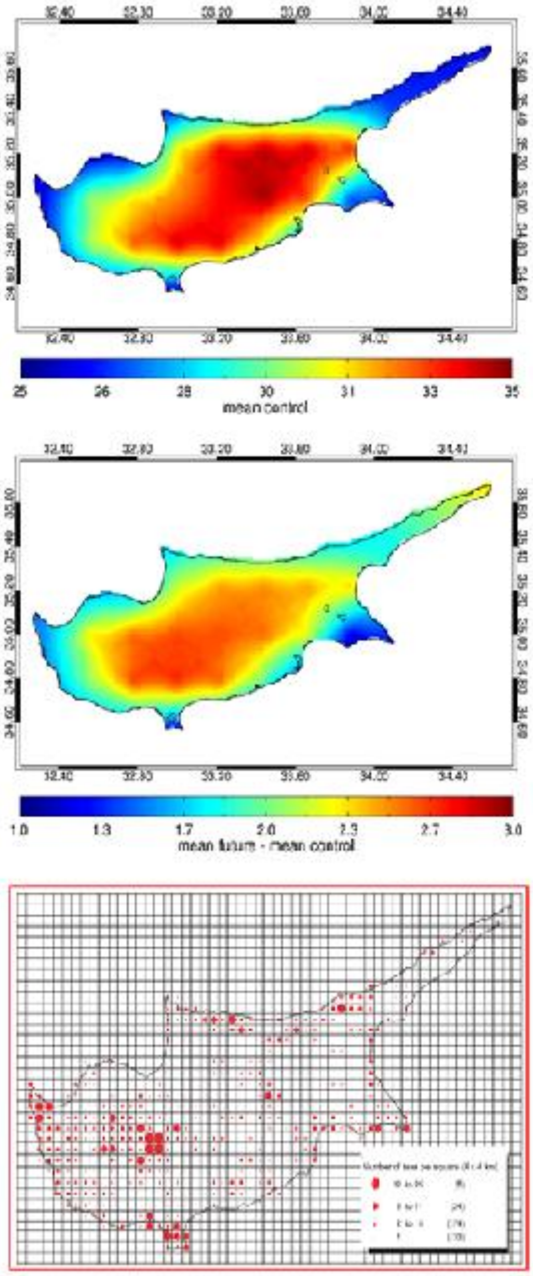


Figure 5-9: Average summer maximum temperatures for control period using PRECIS RCM model (a) Changes in average summer maximum temperature in the near future (Future – Control period) using PRECIS RCM model (b) and Geographic distribution of the threatened plants in Cyprus (c)

There is no scientific data available concerning phenological responses of plants to future (2021-2050) changes in precipitation and associated length of dry spell. Further research is required. Nevertheless, increase in maximum length of dry spell is anticipated to increase the exposure in areas where distribution of threatened plants is more dense. Combination of density, width and dry spell increase will determine the degree of its final exposure.

More specifically Figure 5-10 shows that maximum length of dry spell will increase 0-15 days for the whole domain. In specific, regions of Akrotiri peninsula and Akamas peninsula will increase 0-5 days in the future period (2021-2050) while in Madari and Troodos forest the increase will be about 10-15 days. The increase in maximum length of dry spell will affect in a different level the various areas where threatened plants are situated. In general according to the following maps the majority of the affected areas with threatened plants are less affected and thus the degree of exposure will not increase significantly.

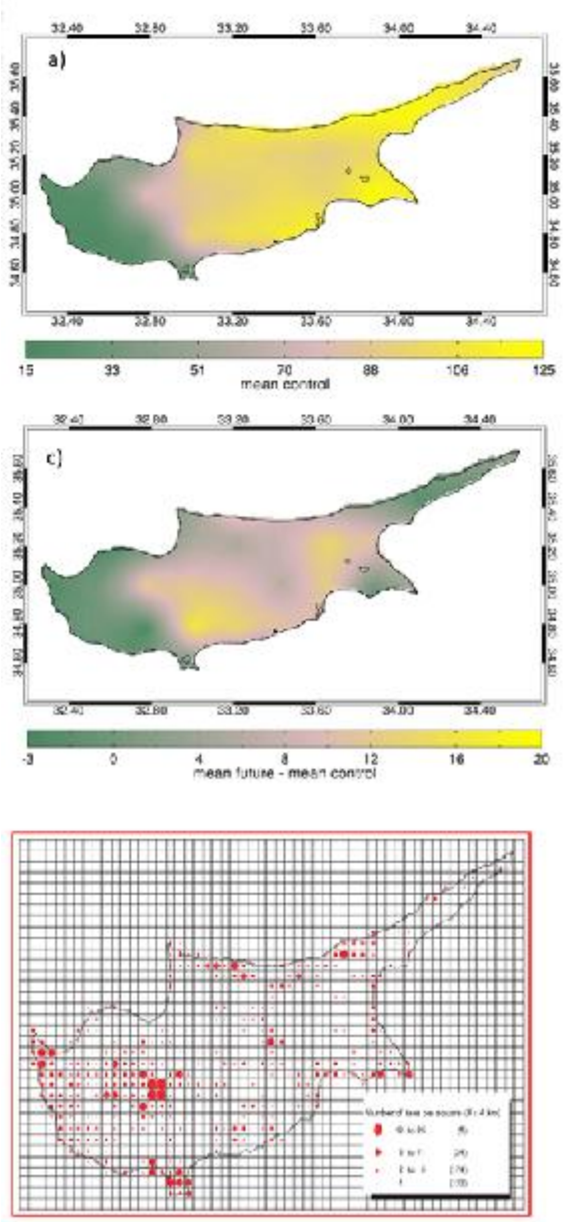


Figure 5-10: Maximum length of dry spell for control period using PRECIS RCM model (a) Changes in maximum length of dry spell in the near future (Future – Control period) using PRECIS RCM model (b) and Geographic distribution of the threatened plants in Cyprus (c)

Taking into consideration the above findings the distribution of plant terrestrial ecosystems for the future period (2021-2050), is preliminary assessed as **high**.

5.4.1.1.2 Assessment of adaptive capacity

The resilience of plants towards climate change refers to their ability to genetically adjust to changing environmental conditions as well as to their ability for uphill migration. However, more research in this field is necessary to be done. In addition, the government of the Republic of Cyprus has recorded the flora species of the island (Red Data Book), and has transposed to the national legislative framework (i) the Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora (with the Law 153(I)/2003), (ii) the ratification of the Bern Convention on the conservation of European wildlife and natural habitats (with the Law 24/1988), (iii) the Convention on International Trade in Endangered Species of Wild Fauna and Flora, (iv) CITES (with the Law 20/1974) and (v) the Convention on Biological Diversity (with the Law 4(III)/1996). The protection status of the endangered plant species in Cyprus is presented in the following table (Table 5-7).

Table 5-7 : Protection status of the endangered plant species in Cyprus

Plant Species	Measures
Arabis kennedyae Meikle	1.Annex I, Bern Convention 2. Annexes II, IV, European Habitat Directive. 3. Red Data Book of the Flora of Cyprus
Astragalus macrocarpus subsp. lefkarensis Agerer-Kirchhoff & Meikle	
Centaurea akamantis T. Georgiadis & G.Chatzikyriakou	
Delphinium caseyi B. L. Burtt	
Scilla morrisii Meikle	
Salvia veneris Hedge	1.Under the protection of the legislation for the National Forest of Lakkovounara 2. Annex I, Bern Convention 3.Annexes II, IV, European Habitat Directive 4. Red Data Book of the Flora of Cyprus
Erysimum kykkoticum G. Hadjikyriakou & G. Alziar	1.Under the protection of the legislation for the National Forest of Paphos 2. Red Data Book of the Flora of Cyprus

Source: The top 50 plants of the Mediterranean Island Plants (de Montmollin & Strahm, 2005)

However, it must be noted that the abovementioned legislative measures aim mainly to reduce human pressures posed on biodiversity, while little can be done to reduce the effects from adverse climate conditions.

Regarding the spreading of harmful invasive species is addressed with localized actions, as for example the Action Plan for the planting control and eradication of the Invasive Alien Species of *Acasia* in Natura 2000 areas. The plan was completed with great success.

Following, the additional indicative recommended adaptation measures that are considered to further enhance adaptive capacity towards this impact are presented. Nevertheless, their assessment and final selection for implementation will be made through the use of the Multicriteria Analysis (MCA) tool which will be developed and implemented in the framework of Actions 4 and 5 of the CYPADAPT project.

- Inclusion of the tool "Evaluation of Carrying Capacity" in the Construction Spatial Planning System and in the Tourism Policy
- Control entering / exiting of non-indigenous species into / from the Republic of Cyprus
- Control of the premises in which non-indigenous species live (nurseries, florists, aquariums, fish farms, research labs, zoos gardens, circuses and pet shops)
- Precise recording of licensed non-native species and development of a database that includes details on the types and their geographical distribution / dispersion

- Resolve any problems caused by non-native species found in Cyprus and effective management
- Creation of ecological data file and database (BIOCYPRUS) for the Network "Natura 2000"
- Creation of an inventory of species populations, distribution and genetics
- Preparation of Management Plans for all areas of the network "Natura 2000"
- Protection and sustainable use of local flora and fauna populations
- Coordination of the management measures relating to prevention and control of terrestrial and offshore sources of marine pollution, combating pollution accidents and the protection and management of marine biodiversity
- Protection and management of Larnaca salt lakes (area RAMSAR) and of other wetlands
- Promote research on biodiversity and ecosystems, monitoring of biotic and abiotic parameters
- Maintain or strengthen ecological coherence, primarily through providing for connectivity.
- Establishment of ecological networks (protected sites and corridors)
- Prepare and implement a Strategic Plan on Biodiversity
- Incorporate in other policies and plans [Local Plans, Environmental Impact Assessment (EIA), Strategic Environmental Assessment (SEA)] the priority of biodiversity and ecosystems protection in relation to climate change
- Horizontal integration of ecosystem based adaptation to other policies and plans
- Sustainable use of ecosystem services and natural resources, particularly in areas of importance to biodiversity conservation
- Special attention to the protection of priority and threatened species and their habitats
- Enhance/strengthen the Seed Bank and Ex situ conservation
- Monitoring of highly sensitive species should be monitored as indicators of climate change, i.e. amphibians and reptiles
- Avoid planting and releasing of alien animal species
- Avoid overfishing and any destructive fishing practices
- Protection of coastal and marine ecosystems from invasive species (prevention-detection control)
- Legislative actions to protect the artificial reefs areas that will serve as fish shelters and will contribute to the increase in biodiversity and in fisheries production
- Restoration of damaged ecosystems (i.e. artificial dispersal of seeds, restore water bodies/flows, soil quality, remove alien species etc),
- Assessment of the impacts of pollination disruptions on plant reproduction, protection of pollinators
- Waste management to avoid pollution, ecosystem degradation and surface and ground water deterioration
- Control overgrazing
- Control overmining and quarrying activities

Considering the above the adaptive capacity can be considered as **limited to moderate** for the future period (2021-2050).

5.4.1.2 Distribution of animal species in terrestrial ecosystems

5.4.1.2.1 Assessment of sensitivity and exposure

Sensitivity

According to the studies conducted by Levinsky et al (2007) and Lemoine et al. (2007), widespread species may be less vulnerable while threatened endemics –which are already under pressure- will be at greatest risk despite their spatial variation (EEA, JRC, WHO, 2008). The inability of migrating to other habitats represents an important constraint for many species, either due to landscape fragmentations or because of their physical characteristics.

Furthermore soil droughts cause changes in habitats and food availability and affect the associated animal populations (MOA). Anticipated decrease in precipitation is expected to further reduce soil moisture. This will cause a further stress on food availability and may affect the current distribution of associated animal populations. In the following Figure 5-11 the current terrestrial sites, marine site and special protection areas of birds are presented while in Figure 5-12 is presented the anticipated changes in annual total precipitation for the Cyprus areas.

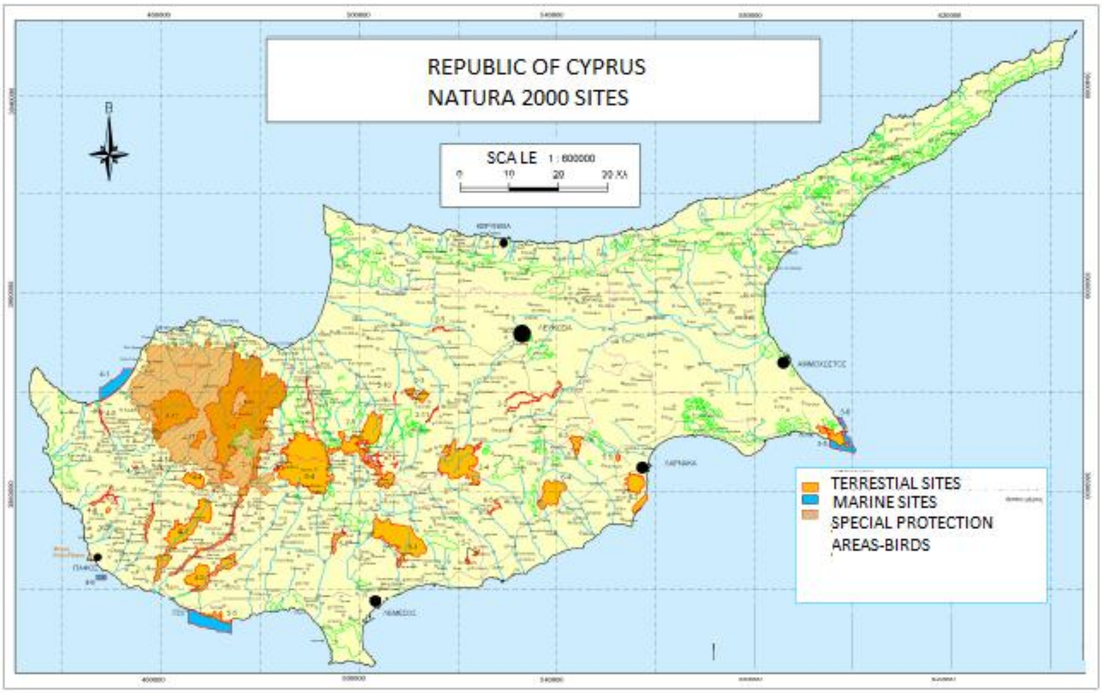


Figure 5-11: Cyprus Natura 2000 sites

All northern coasts are expected to receive less annual total precipitation in the future, than that estimated for the recent past 1961-1990 (Figure 5-12). In these areas no terrestrial, marine and special protection areas are situated and as a result there will be a minor effect on food availability and geographic movement of animal species. In the Cyprus regions that terrestrial, marine and special protection areas are situated, the annual total precipitation appears to have minor decreases or no changes at all. Thus, in those areas, the effect of decreased precipitation on food availability and geographic movement of animal species is anticipated to be less. The only region with an increase in total annual precipitation, minor though (up to 5mm) that may have a more important effect on food availability and animal distribution, is the area around Orites Forest, east of Paphos.

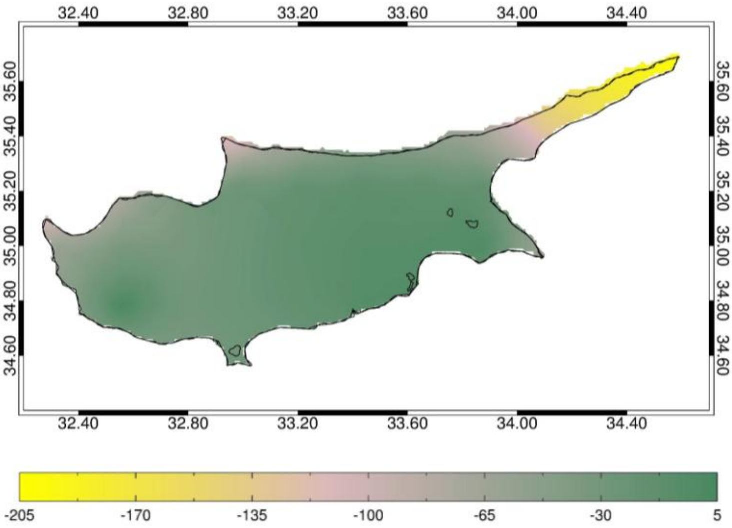


Figure 5-12: Changes in annual total precipitation between the future (2021-2050) and the control period (1961-1990)

To sum up sensitivity of animal distribution to climate changes for the island of Cyprus for future period (2021-2050) is **high**.

Exposure

Based on the conclusions of the World Resources Institute for the period 2002-2003, the most threatened species -in terms of population number- are located in terrestrial environments as shown in Figure 5-16. Some of the most endangered species are the Cyprus muflon (Olcis orientalis ophion), the Rousettus aegyptiacus, 332 migratory species, the bird Griffon, the snake Columber cypriensis and 11 more terrestrial reptiles.

Geographic movement of animal species may be affected by the anticipated increase in maximum length of dry spell (precipitation<0.5mm). Areas of Nicosia and Larnaca and Troodos mountain will have increases in maximum length of dry spell of about 10 days. The dry spell will reach 110 days in Larnaca and Nicocia Districts and 70 days in Paphos and Troodos mountain. In those areas the geographic movement of animal species is anticipated to be affected. Conversely, in western area, that less Natura areas are located, no increases are anticipated. Thus there geographic movement of animal populations is affected less.

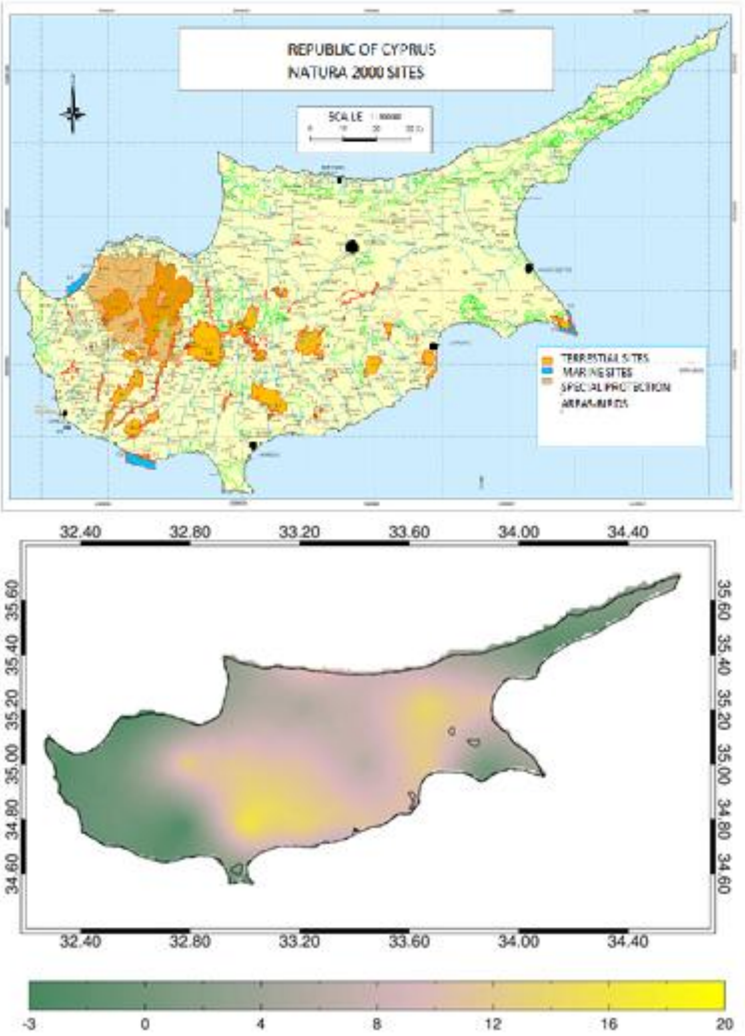


Figure 5-13: Natura areas in Cyprus (a), Changes in maximum length of dry spell (RR<0.5mm) between the future (2021-2050) and the control period (1961-1990) (b)

Geographic movement of animal species and animal phenology may be affected by the anticipated increase in temperature, as well. According to PRECIS projections for the future period 2021-2050, the average annual temperature in Cyprus is expected to increase by 1-2^{o}C with respect to the control period 1960-1990. The effect is anticipated to be more evident in summer and winter seasons that the increases will be more significant. On average warming of about 1.0 – 2.0°C is expected for the winter period and a warming of about 2.0 – 2.7°C for the summer period for the whole domain of study.

In specific, southeastern regions were a number of Natura sites located are anticipated to have an increase about 2.3°C in summer maximum temperature and about 0.8°C in winter maximum temperature. In those areas the geographic movement of animal species and animal phenology is anticipated to be affected. In Pafos district and Troodos mountain, that the majority of natura sites are situated, temperature is anticipated to increase about 1°C on average in winter respectively and 22.7°C on average in summer. In those areas the geographic movement of animal species and animal phenology is anticipated to be affected more.

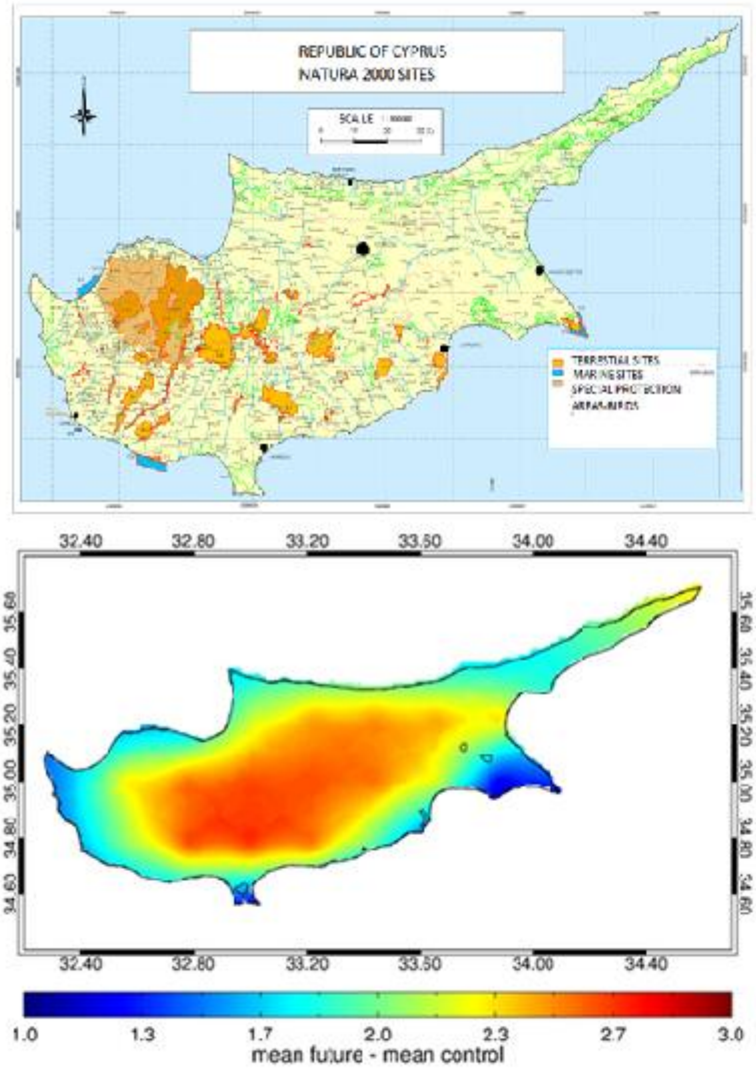


Figure 5-14: **Natura areas in Cyprus (a), Changes in average summer maximum temperature in the near future (Future – Control period) using PRECIS RCM model (b)**

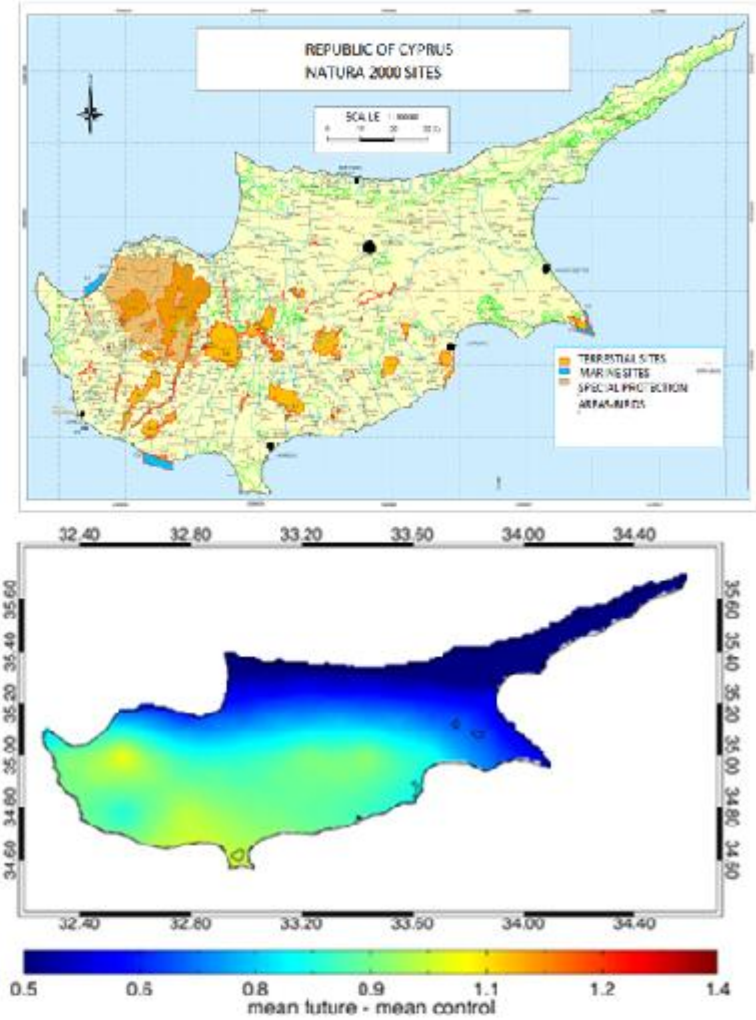


Figure 5-15: Natura areas in Cyprus (a), Changes in average winter minimum temperature in the near future (Future – Control period) using PRECIS RCM model (b)

Further research is required to define the future impact of temperature increase on geographic movement of animal species and animal phenology.

Consequently the exposure for the future period (2021-2050) can be considered as **high**.

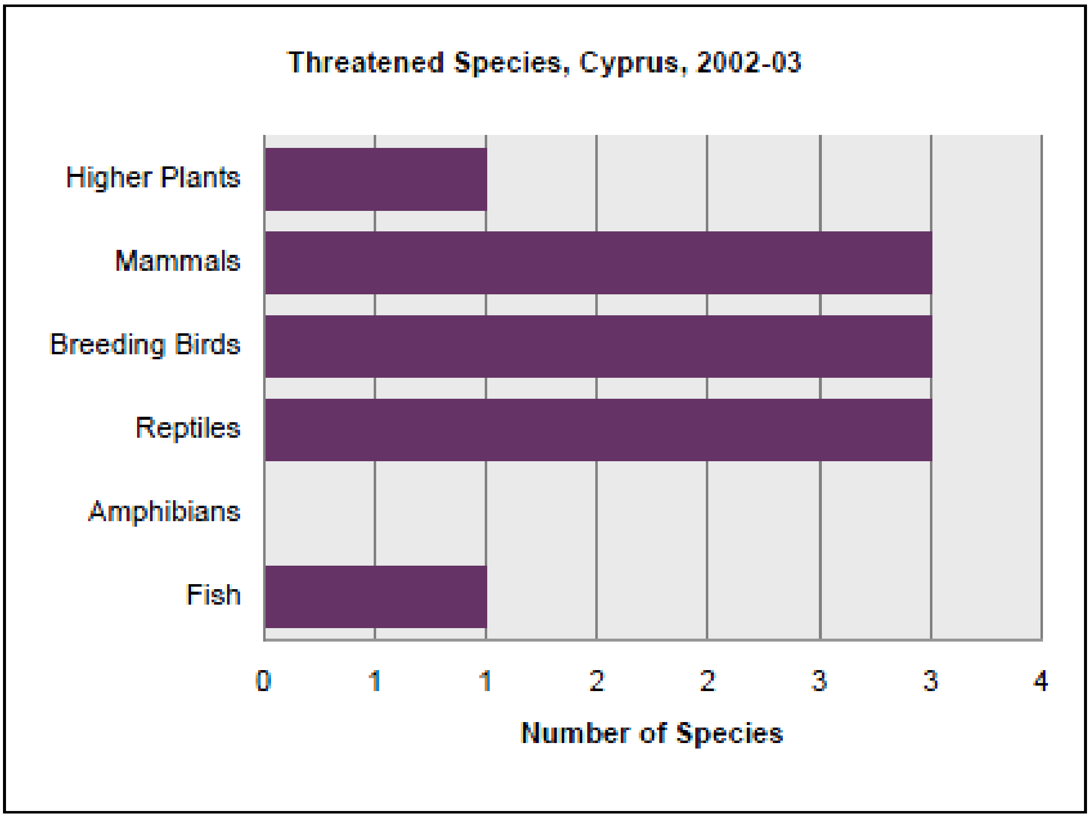


Figure 5-16: Threatened Species in Cyprus, 2002-03

Source: Biodiversity and Protected Areas-Cyprus (World Resources Institute)

5.4.1.2.2 Assessment of adaptive capacity

The resilience of animals towards climate changes refers to their ability to genetically adjust to changing environmental conditions as well as to their ability for uphill migration. There are no data available for the animal population movements in Cyprus. In addition, the government has taken measures such as the transposition to the national legislative framework of the Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora (with the Law 153(I)/2003) and the Directive 2009/147/EC on the conservation of wild birds (with the Law 152(I)/2003) as well as the ratification of the Bern Convention on the conservation of European wildlife and natural habitats (with the Law 24/1988), the Bonn Convention on the conservation of migratory species of wild animals (with the Law 17(III)/2001) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora, CITES (with the Law 20/1974) and the Convention on Biological Diversity (with the Law 4(III)/1996). The protection status of the endangered animal species of the terrestrial ecosystems in Cyprus is presented in the following table (Table 5-8).

Table 5-8: Protection status of the endangered animal species of the terrestrial ecosystems in Cyprus

Protected fauna species		Measures
Reptiles	*Mauremys caspica*	Protected under Annex IV of Habitats Directive 92/43/EEC, Annex II of Bern Convention
	Coluber cypriensis - EN	Protected under Annex II* and IV of Habitats Directive 92/43/EEC, Annex II of Bern Convention
	Emys orbicularis	Annex II of Bern Convention
	10 other species	Protected under Annex II of Habitats Directive 92/43/EEC
Birds	*Numenius tenuirostris*	Protected under Annex II of SPA protocol [1], Annex II of Bern Convention
	Pelecanus crispus - VU	Protected under Annex II of SPA protocol [1]
	Oxyura leucocephala - EN	Protected under Annex II of Bern Convention
	Branta ruficollis - VU	Protected under Annex II of Bern Convention
	Crex crex - LR	Protected under Annex II of Bern Convention
	Emberiza aureola	Protected under Annex II of Bern Convention
	Gallinago media	Protected under Annex II of Bern Convention
	Larus audouinii - LR	Protected under Annex II of Bern Convention
	Emberiza cineracea	Protected under Annex II of Bern Convention
Mammals	*Ovis orientalis ophion* (Cyprus muflon) – VU	Protected under Annex II* and IV of Habitats Directive 92/43/EEC
	Rhinolophus Euryale - VU	Protected under Annex II of Habitats Directive 92/43/EEC
	Capra aegagrus (Cyprus goat) - VU	Protected under Annex II and IV of Habitats Directive 92/43/EEC, Annex II of Bern Convention
	Rousettus aegyptiacus	Protected under Annex II and IV of Habitats Directive 92/43/EEC

Source: Hadjichristophorou, 2000; DoE, 2010b; USAID, 2006

Nevertheless, the genetic adjustment of animals and the measures taken are not enough for combating the increasing risk of terrestrial animals towards climate change;

Following, additional recommended adaptation measures that are considered to further enhance adaptive capacity towards this impact are presented indicatively. Nevertheless, their assessment and final selection for implementation will be made through the use of the Multicriteria Analysis (MCA) tool which will be developed and implemented in the framework of Actions 4 and 5 of the CYPADAPT project.

- Inclusion of the tool "Evaluation of Carrying Capacity" in the Construction Spatial Planning System and in the Tourism Policy
- Control entering / exiting of non-indigenous species into / from the Republic of Cyprus

- Control of the premises in which non-indigenous species live (nurseries, florists, aquariums, fish farms, research labs, zoos gardens, circuses and pet shops)
- Precise recording of licensed non-native species and development of a database that includes details on the types and their geographical distribution / dispersion
- Resolve any problems caused by non-native species found in Cyprus and effective management
- Creation of ecological data file and database (BIOCYPRUS) for the Network "Natura 2000"
- Creation of an inventory of species populations, distribution and genetics
- Preparation of Management Plans for all areas of the network "Natura 2000"
- Protection and sustainable use of local flora and fauna populations
- Coordination of the management measures relating to prevention and control of terrestrial and offshore sources of marine pollution, combating pollution accidents and the protection and management of marine biodiversity
- Protection and management of Larnaca salt lakes (area RAMSAR) and of other wetlands
- Promote research on biodiversity and ecosystems, monitoring of biotic and abiotic parameters
- Maintain or strengthen ecological coherence, primarily through providing for connectivity.
- Establishment of ecological networks (protected sites and corridors)
- Prepare and implement a Strategic Plan on Biodiversity
- Incorporate in other policies and plans [Local Plans, Environmental Impact Assessment (EIA), Strategic Environmental Assessment (SEA)] the priority of biodiversity and ecosystems protection in relation to climate change
- Horizontal integration of ecosystem based adaptation to other policies and plans
- Sustainable use of ecosystem services and natural resources, particularly in areas of importance to biodiversity conservation
- Special attention to the protection of priority and threatened species and their habitats
- Enhance/strengthen the Seed Bank and Ex situ conservation
- Monitoring of highly sensitive species should be monitored as indicators of climate change, i.e. amphibians and reptiles
- Avoid planting and releasing of alien animal species
- Avoid overfishing and any destructive fishing practices
- Protection of coastal and marine ecosystems from invasive species (prevention-detection control)
- Legislative actions to protect the artificial reefs areas that will serve as fish shelters and will contribute to the increase in biodiversity and in fisheries production
- Restoration of damaged ecosystems (i.e. artificial dispersal of seeds, restore water bodies/flows, soil quality, remove alien species etc),
- Assessment of the impacts of pollination disruptions on plant reproduction, protection of pollinators
- Waste management to avoid pollution, ecosystem degradation and surface and ground water deterioration

- Control overgrazing

The adaptive capacity of this factor for Cyprus for the future period (2021-2050) is estimated as **limited to moderate**.

5.4.2 Aquatic ecosystems

5.4.2.1 Marine biodiversity

5.4.2.1.1 Assessment of sensitivity and exposure

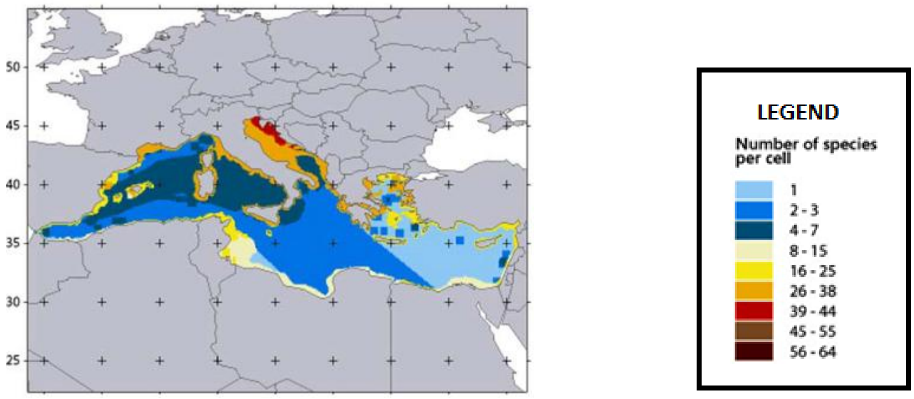
Sensitivity

The high Sea Surface Salinity (SSS) and Sea Surface Temperature (SST) of Cyprus in comparison with the rest of the Mediterranean region results in a relatively high species diversity (Figure 5-17a) and very low biomass.

Temperature rise is the main reason for the northward movement of marine species, changing the composition of local and regional marine ecosystems (Brander et al., 2003; Beare et al., 2004; Beare et al., 2005; Perry et al., 2005; Stebbing et al., 2002; EEA, JRC, WHO, 2008). These changes in combination with salinity and nutrient level changes and some physical characteristics, such as the variety of indigenous marine species and the low biomass, increase sensitivity to climate change even more. Thus both distribution of fish and the socioeconomic situation of local fishermen is affected heavily.

The increasing intrusion of exotic fish in the Mediterranean Sea (Figure 5-17 b,c) has not yet been determined whether it constitutes a serious threat for the extinction of the endemic species (Ben Rais Lasram & Mouillot, 2009) or has been underestimated (Zenetos et al., 2008), but what has been proved is that the northward movement of species is affected by the global warming.

(a)



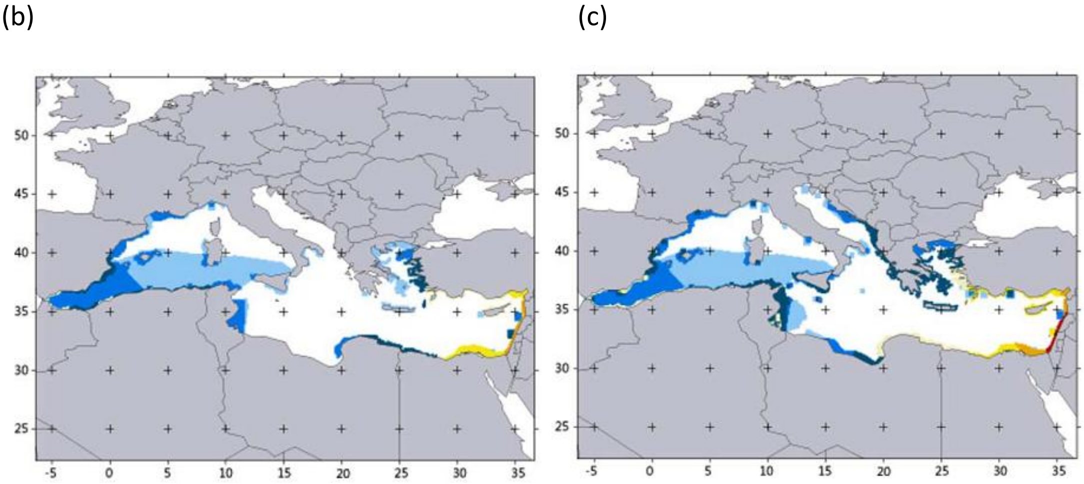


Figure 5-17: Maps illustrating the patterns of diversity (number of species per cell) for endemic fish species (a), for exotic species during the eighties (b) and for exotic species in 2006 (c)

Source: Increasing southern invasion enhances congruence between endemic and exotic Mediterranean fish fauna (Ben Rais Lasram & Mouillot, 2009)

The number of invasive species introduced in the coastal and offshore waters of Cyprus has grown over the last 50 years, as shown in the following figure (Figure 5-18). Studies have shown that the rate of new biological invasions in the Mediterranean Sea is as high as 1 new species every 9 days (Zenetos et al., 2008. Considering the above, the sensitivity for the future period (2021-2050) can be characterized **moderate.**

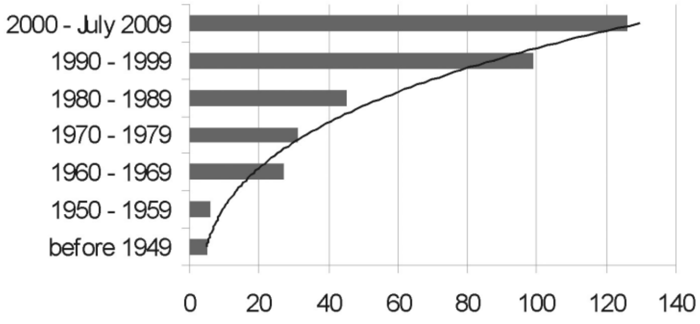


Figure 5-18: Cumulative number of alien marine species in Cyprus per decade, based on the reported year sighting

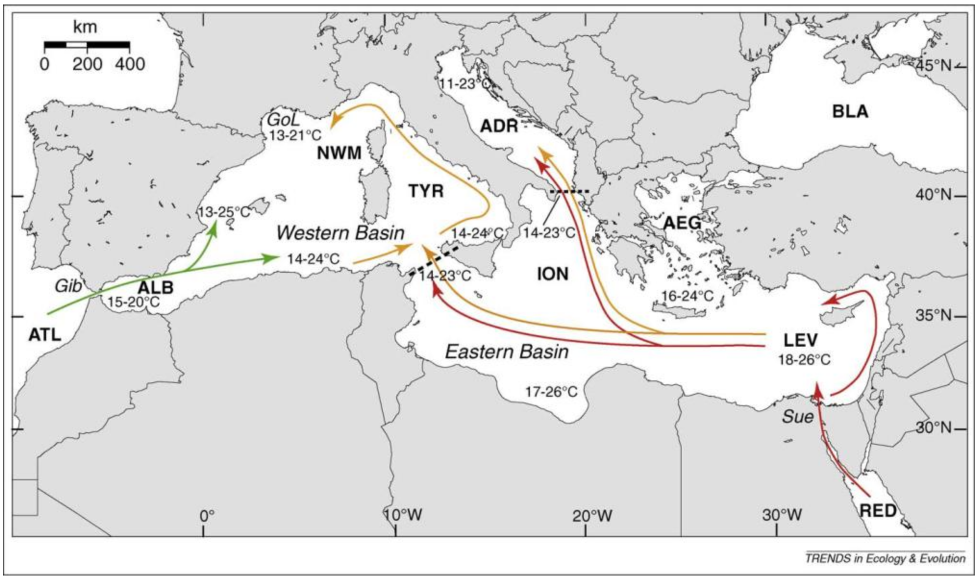
Source: Inventory of alien marine species of Cyprus (Katsanevakis et al., 2009)

Exposure

The number of alien biota in the Mediterranean Sea appears to be underestimated. Some hot spot areas for possible species introductions, such as the coasts of the Levantine basin, are not well studied (Zenetos et al., 2005).

The Mediterranean Basin is characterised as a receptacle for exotic species while being a hotspot for endemism. The increasing southern invasion enhances congruence between endemic and exotic Mediterranean fish fauna (Ben Rais Lasram & Mouillot, 2009), which has been confirmed by the increased successful introductions from the Red Sea and lower latitudes of the Atlantic and the increasing overlap between the spatial distributions of endemic and exotic species richness (Figure 5-19), all of which are correlated to the temperature rise.

Cyprus is located near the manmade nautical channel of Suez which favours the migration and relocation of the Lessepsian species. However there is no data available for the anticipated effect of temperature increase on the displacement of marine biodiversity. Further research is required.



Bold capital abbreviations correspond to the main Mediterranean sub-regions (ALB: Alboran Sea; NWM: North Western Mediterranean; TYR: Tyrrhenian Sea; ADR: Adriatic Sea; ION: Ionian Sea; AEG: Aegean Sea; LEV: Levantine Basin) and adjacent seas (ATL: Atlantic Ocean; BLA: Black Sea; RED: Red Sea). Italic abbreviations correspond to some remarkable Mediterranean locations (Gib: Gibraltar Straits; GoL: Gulf of Lions; Sue: Suez Canal). Reported temperatures correspond to winter–summer mean sea-surface temperatures. Arrows represent main routes of species range expansion according to their origin: Mediterranean natives (orange), Atlantic migrants (green) and Lessepsian migrants (red).

Figure 5-19: Geography of the Mediterranean Sea with the main routes of species range expansion

Source: Climate change effects on a miniature ocean: the highly diverse, highly impacted Mediterranean Sea (Lejeusne et al., 2009)

Mediterranean Sea Surface Temperature (SST) is expected to gradually increase due to climate change, although less than the global mean temperature rise (Nicholls et al., 2007). Satellite and in situ-derived data indicate a strong eastward increasing sea surface warming trend in the Mediterranean basin from the early 1990s onwards. The satellite-derived mean annual warming rate over the period 1985–2008 is about 0.037°C year–1 for the whole basin and about 0.042°C year–1 for the eastern sub-basin where the island of Cyprus is located (Skliris et al., 2011).

Anticipated changes in temperature, as already presented, may cause fluctuations in sea water temperatures. Changes in sea water temperatures are responsible for changes in physiology and sex ratios of fished species, alteration in timing of spawning, migrations, and/or peak abundance and also, for the increasing of invasive species, diseases and algal blooms. These impacts are leading to reduced production of target species in marine systems. However further research is required.

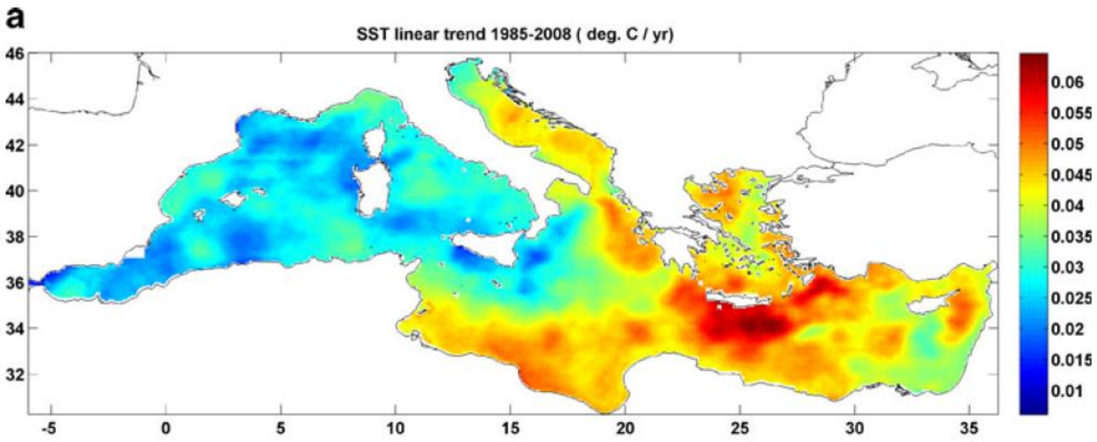


Figure 5-20: Horizontal distribution of satellite-derived SST annual linear trends (°C/year) over 1985–2008

Considering the above, the exposure for the future period (2021-2050) can be characterized **high to very high.**

5.4.2.1.2 Assessment of adaptive capacity

Scientific recording of the populations of marine species reveals some[5] of the extent of the threat for the marine host species. The genetic adjustments of the host organisms to new conditions need many reproductive cycles, and as a result the most common way of survival is the migration to other latitudes.

In addition, there are numerous institutional measures for the protection of marine ecosystems. In Cyprus, there are six marine protected areas, including the coastal protected area of Lara-Toxeftra, which encompasses the most important breeding biotope for the sea

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[5] *"The biased scientific interest towards taxa with well-known taxonomy and established historical distribution records (e.g. benthic organisms, fish) coupled with the chaos in nomenclature and fragmentary and sporadic information have led to a possible underestimation of the extent of aliens' presence particularly of the small, less-conspicuous, less-studied speci*es" (Zenetos et al., 2008).

turtles (*Chelonia mydas* and *Caretta caretta*). The area is protected since 1989 by the Fisheries Law and related regulations. The areas are protected by the 'Natura 2000' network (DoE, 2010) under the supervision of the Department of Fisheries and Marine research, Ministry of Agriculture, Natural Resources and Environment.

Figure 5-21: Marine protected areas of Cyprus

Source: Department of Fisheries and Marine Research, 2012

In Cyprus, the protection of aquatic species of inland and marine waters, is implemented through the provisions of national law since 1971 and its related regulations, as well as through the Law 153(I)/2003 which harmonizes Directive 92/43/EEC on the Conservation of Natural Habitats and Wild Fauna and Flora. In addition, Cyprus has ratified the Barcelona Convention for the Protection of the Mediterranean Sea against Pollution and in particular the SPA Protocol concerning Specially Protected Areas and Biodiversity in the Mediterranean. Complementary to these are the Convention on Conservation of European Wildlife and Natural Habitats (Bern Convention), the Convention on the International Trade in Wild Fauna and Flora (CITES) and the Convention on Biological Diversity (CBD). In particular, protected marine species and habitats are those listed in the aforementioned Directives and Conventions, as well as those in the Fisheries Law and Regulations, including all species of sea turtles, dolphins, seals and a species of sand crab (DoE, 2010), as shown in Table 5-9.

Table 5-9: Protected fauna aquatic species in Cyprus

Protected fauna species		Measures
Fish	Aphanius fasciatus	Protected under Annex II of SPA protocol [1], Annex II of Bern Convention

Protected fauna species		Measures
	Hippocampus hippocampus	Protected under Annex II of SPA protocol [1], Annex II of Bern Convention
	Hippocampus ramulosus	Protected under Annex II of SPA protocol [1], Annex II of Bern Convention
	Mobula mobular - VU	Protected under Annex II of SPA protocol [1], Annex II of Bern Convention
	Carcharodon carcharias - VU	Annex II of SPA protocol [1], Annex II of Bern Convention
Mammals	Monachus monachus – CR	Annex II of SPA protocol [1], Annex II of Bern Convention
	Delphinus delphis – EN	Annex II of SPA protocol [1], Annex II of Bern Convention
	Stenella coeruleoalba	Annex II of SPA protocol [1], Annex II of Bern Convention
	Tursiops truncatus	Annex II of SPA protocol [1], Annex II of Habitats Directive 92/43/EEC, Annex II of Bern Convention
Reptiles	Caretta caretta - EN	Protected under Annex II of SPA protocol [1], Annex IV of Habitats Directive 92/43/EEC, Annex II of Bern Convention
	Chelonia mydas - CR	Protected under Annex II of SPA protocol [1], Annex IV of Habitats Directive 92/43/EEC, Annex II of Bern Convention
	Natrix natrix cypriaca	Protected as freshwater fauna under the Fisheries Regulations (Reg. 273/90)
Amphibia	Bufo viridis	Protected under Annex IV of Habitats Directive 92/43/EEC, Annex II of Bern Convention, Fisheries Regulations (Reg. 273/90)
	Hyla savignyi	Protected as freshwater fauna under the Fisheries Regulations (Reg. 273/90)
Arthropods	Ocypode cursor	Protected under Annex II of SPA protocol [1], Annex II of Bern Convention
	Potamon potamios	Specifically protected under national legislation
	Artemia salina	Specifically protected under national legislation
Molluscs	Charonia tritonis	Protected under Annex II of SPA protocol [1], Annex II of Bern Convention
	Erosaria spurca (Cypraea spurca)	Protected under Annex II of SPA protocol [1], Annex II of Bern Convention
	Luria lurida	Protected under Annex II of SPA protocol [1], Annex II of Bern Convention
	Tonna galea	Protected under Annex II of SPA protocol [1], Annex II of Bern Convention
	Lithophaga lithophaga	Protected under Annex II of SPA protocol [1], Annex II of Bern Convention
	Pholas dactylus	Protected under Annex II of SPA protocol [1], Annex II of Bern Convention
	Pinna nobilis	Protected under Annex II of SPA protocol[1], Annex IV of Habitats Directive 92/43/EEC
Echinoderms	Asterina panceri	Protected under Annex II of SPA protocol [1], Annex II of Bern Convention
	Ophidiaster ophidianus	Protected under Annex II of SPA protocol [1], Annex II of Bern Convention

Protected fauna species		Measures
	Centrostephanus longispinus	Protected under Annex II of SPA protocol[1], Annex IV of Habitats Directive 92/43/EEC, Annex II of Bern Convention
Porifera	Axinella polypoides	Protected under Annex II of SPA protocol [1]
	Axinella cannabina	Protected under Annex II of SPA protocol [1]
	Geodia cydonium	Protected under Annex II of SPA protocol [1]

IUCN categorization: Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Low Risk (LR)

[1] *Protocol concerning Specially Protected Areas and Biodiversity in the Mediterranean –Barcelona Convention*

Source: Hadjichristophorou, 2000; DoE, 2010b; USAID, 2006

In addition, a number of research and monitoring programs focusing on the marine biodiversity conservation and protection of endangered habitats and species (e.g. *Posidonia oceanica*, turtles etc.), the designation of Marine Protected Areas and the assessment of the ecological status of coastal waters within the framework of the Water Framework Directive (2000/60/EC) are undertaken. Furthermore, the Oceanography Centre of the University of Cyprus is currently participating in two Mediterranean-wide projects (Tropical Signals and JellyWatch) of CIESM (the Mediterranean Science Commission) focusing on marine biodiversity and its impacts from climate change.

Additionally, action plans are taking place in relation to the protection of Cyprus due to the Mediterranean Action Plan (MAP) and the enforcement of its regulations and actions, in order to protect the biodiversity and development of coastal and marine areas (species, habitats, and landscapes) integrating the special development strategies under the Coastal Area Management Programme (CAMP) in a pilot area of the island. The program serves a dynamic process for the sustainable use and management of the coastal and marine areas and resources (DoE, 2010).

Finally, the Department of Fisheries and Marine Research, taking into account the reports from fishermen regarding the substantial increase and spread of the population of the IAS of Lagocephalus and the damage caused to the fishing gear and catches, prepared a study on the species in the coastal waters of Cyprus. After evaluating the results of the study, the DMFR developed a management plan entitled "Plan for the control of the population of Lagocephalus sceleratus in the coastal waters of Cyprus", and in 2012 announced the call for proposals for the implementation of the plan in the framework of the "Project Grants for collective actions in the Fisheries Sector". The purpose of the call is to eliminate the populations of lagocephalus from the coastal commercial fleet of Cyprus, with the exercise of intense fishing pressure on breeding population of the species, just before and during the breeding season, in the main breeding areas of the species.

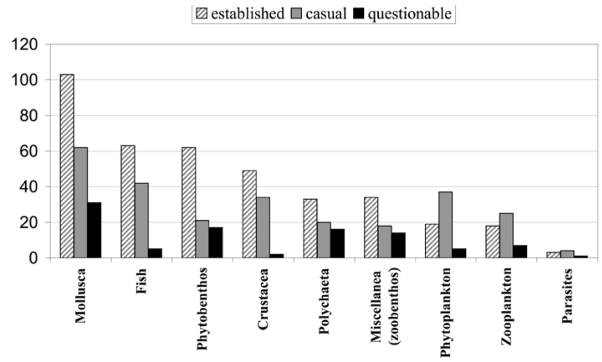
Another interesting intervention was the captive breeding program by Dr. Birgit Blosat, who was hired by the government in order to manage the problem of the artificial introduction of exotic fish in the dams of Cyprus (Unit of Environmental Studies).

Furthermore, the marine and fisheries policy aims at the protection and conservation of the fish stock as well as of marine biodiversity. The foreseen measures within the National Strategy Plan for Fisheries 2007-2013 such as the reduction of fishing effort, the use of more selective fishing gear and the withdrawal of trawlers, incorporate the ecosystem approach. These measures are undertaken in accordance with the EU Common Fisheries Policy and contribute to the minimization of the impact of fishing activities on the marine ecosystem and aim at promoting sustainability of marine resources.

There is a number of Laws and Regulations set in Cyprus that focus on issues such as the reduction of fishing intensity (hours and periods of fishing, types of networks, minimum allowable sizes for fishing marine organisms, technical restrictions on gear -number of hooks, length and height of nets, minimum distances from shore fishing and bottom fishing etc), the creation of protected fishing areas and habitats, the ban of certain fishing gear and practices, the application of restrictions on recreational fishing, the development of Management Plans and the management control of fishing shelters.

In addition, the Regulation 1967/2006/EC concerning management measures for the sustainable exploitation of fisheries resources in the Mediterranean Sea, has been gradually integrated to the Cyprus legislation. This is the most important Regulation containing technical measures, implementation of which has important consequences in the Cyprus fisheries. This include, inter alia, improvement of the fishing gear, the creation of management plans for specific fisheries (e.g. trawling) and the creation of protected areas for fisheries.

Overall, the designation of well-preserved important habitats along the coastal waters of Cyprus are evidence that the marine environment of Cyprus is still in a good state with minor environmental impacts (DoE, 2010b). Nevertheless, the increased number of successful intrusions of marine species in the area (Ben Rais Lasram & Mouillot, 2009) (Figure 5-22), indicates changes due to climate change.



Miscellanea (zoobenthos) include Foraminifera, Echinodermata, Ascidiacea, Cnidaria, Sipuncula, Pycnogonida, Enteropneusta, Porifera and Bryozoa.

Figure 5-22: Establishment success per ecofunctional Pycnogonida/taxonomic group

Source: Annotated list of marine alien species in the Mediterranean with records of the worst invasive species (Zenetos, et al., 2005)

Following, additional recommended adaptation measures that are considered to further enhance adaptive capacity towards this impact are presented indicatively. Nevertheless, their assessment and final selection for implementation will be made through the use of the Multicriteria Analysis (MCA) tool which will be developed and implemented in the framework of Actions 4 and 5 of the CYPADAPT project.

- Inclusion of the tool "Evaluation of Carrying Capacity" in the Construction Spatial Planning System and in the Tourism Policy
- Control entering / exiting of non-indigenous species into / from the Republic of Cyprus
- Control of the premises in which non-indigenous species live (nurseries, florists, aquariums, fish farms, research labs, zoos gardens, circuses and pet shops)
- Precise recording of licensed non-native species and development of a database that includes details on the types and their geographical distribution / dispersion
- Resolve any problems caused by non-native species found in Cyprus and effective management
- Creation of ecological data file and database (BIOCYPRUS) for the Network "Natura 2000"
- Creation of an inventory of species populations, distribution and genetics
- Preparation of Management Plans for all areas of the network "Natura 2000"
- Protection and sustainable use of local flora and fauna populations
- Coordination of the management measures relating to prevention and control of terrestrial and offshore sources of marine pollution, combating pollution accidents and the protection and management of marine biodiversity
- Protection and management of Larnaca salt lakes (area RAMSAR) and of other wetlands
- Promote research on biodiversity and ecosystems, monitoring of biotic and abiotic parameters
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- Legislative actions to protect the artificial reefs areas that will serve as fish shelters and will contribute to the increase in biodiversity and in fisheries production
- Restoration of damaged ecosystems (i.e. artificial dispersal of seeds, restore water bodies/flows, soil quality, remove alien species etc),
- Assessment of the impacts of pollination disruptions on plant reproduction, protection of pollinators
- Waste management to avoid pollution, ecosystem degradation and surface and ground water deterioration
- Control overgrazing

Considering the above, the adaptive capacity in the future period (2021-2050) can be characterized as **moderate**.

5.4.2.2 Freshwater biodiversity

5.4.2.2.1 Assessment of sensitivity and exposure

Sensitivity

The indigenous fish species richness in Cyprus is exceptionally poor and susceptible to numerous threats due to landscape fragmentations. The introduction of freshwater fish and crayfish in the artificial dams for recreation purposes altered the local environment and caused the reduction of the already endangered endemic grass snake *Natrix natrix cypriaca*. In addition, climate change strains in combination with the pollution caused by human activities put a stress on water quality and aquatic populations. Indicators such as dominance of harmful cyanobacteria in phytoplankton communities, stratification or oxygen depletion could not be evaluated due to lack of information. However, anticipated temperature increase may affect negatively oxygen depletion and eutrophication deteriorating thus water quality. As a result further research is required. Based on the above facts the sensitivity for the future period (2021-2050) can be considered as **moderate**.

Exposure

In Cyprus, the plants, fish and aquatic organisms of rivers and lake dams of Cyprus are generally in good condition, whereas the organisms of the groundwaters are more strained.

Climatic changes will have an impact mainly on the quality of the surface waters in Cyprus and consequently on the biodiversity. The nitrogen pollution from untreated sewage effluent and agricultural run-off carrying fertilizers is responsible for the phenomenon of eutrophication, which can possibly be deteriorated by climate change. The areas identified as vulnerable to nitrogen pollution, according to the Nitrates Directive 91/676/EEC (Vulnerable Nitrate Zones), are the aquifers of Kokkinohoria, Kiti-Pervolia, Akrotiri, Paphos, Poli Chrisohous and in the more recently added area of Orounta (DoA, 2011). The areas

'Polemidhia Storage Reservoir' and the coastal area between Cape Pyla and Paralimni have been identified as sensitive according to the Directive Urban Wastewater Treatment Directive 91/271/EEC (WDD, 2011). Another area sensitive to nitrogen and phosphorus pollution is the recorded location in Larnaca, where the seabed (muddy sand with Caulerpa) is degraded (Ramos et al., 2007).

Phenomenon of eutrophication caused by nitrogen pollution is more evident in in the surface bodies and rather than in Perennial rivers. In the following figures (Figure 5-23,Figure 5-24), the ecological and chemical status of river and lake bodies of Cyprus are depicted in the form of maps, revealing, in general, a good ecological status of river and lake bodies.

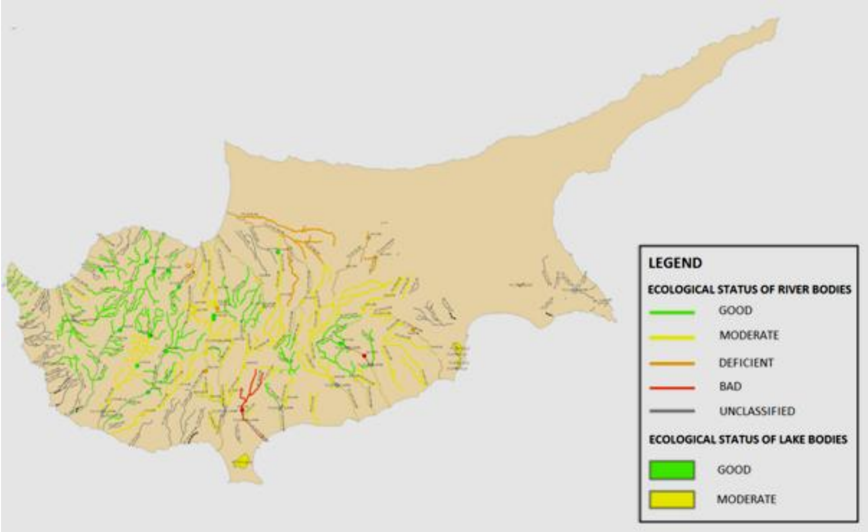

Figure 5-23: Map of the ecological status of river and lake bodies in Cyprus

Source: WDD (1)

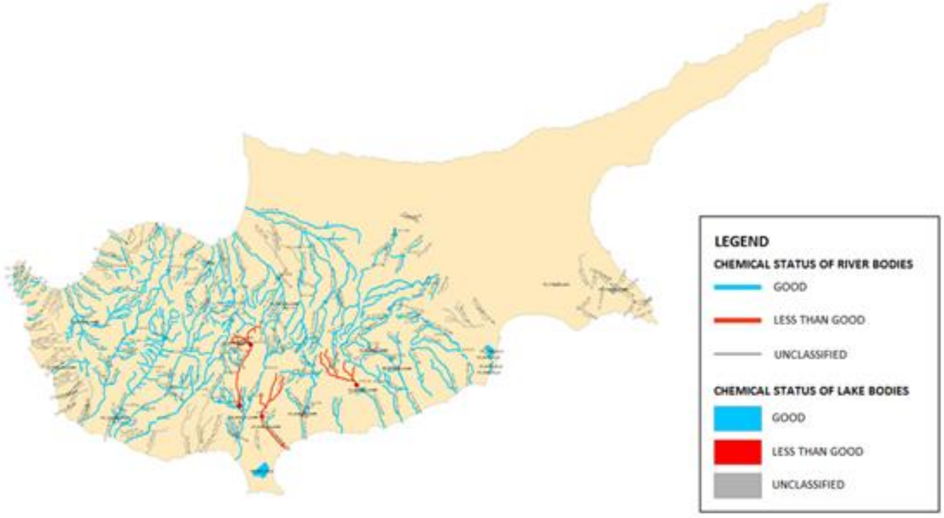

Figure 5-24: Map of the chemical status of river and lake bodies in Cyprus

Source: WDD (2)

The deterioration of water quality in Cyprus seems to be more extensive in the groundwater bodies than in the surface waters (which are limited due to the depleted aquifers and the parts of some rivers with continuous flow). The main matters which have arisen from the results of the monitoring of groundwater quality in Cyprus, were the increased nitrate and chloride concentrations (above the limits) which were found in seven water bodies, while another water body in Paphos is still under investigation. In addition, increased concentrations of sulphates, ammonium, arsenic, pesticides and increased conductivity were found in several groundwater bodies.

The main causes of pollution in Cyprus are agriculture, seawater intrusion and wastewater disposal, while industry constitutes a less significant source of pollution as the number of industries in Cyprus is limited. Moreover, the quality of groundwater in Cyprus is affected by natural causes like geological formations which release sulphate and chloride salts of sodium and boron. Furthermore, five (5) areas in Cyprus which drain into waters vulnerable to pollution from nitrogen compounds have been declared as Vulnerable Nitrate Zones (VNZ), according to the Directive 91/676/EEC. By the end of 2010 another VNZ, that of Orounda (Figure 5-25), has been delineated within the Western Mesaoria Groundwater Body. According to the available data, the total agricultural area that is located in vulnerable zones is approximately 200 km^2. Approximately 80% of this land is irrigated with intensive agricultural practices taking place (GSD, 2008).

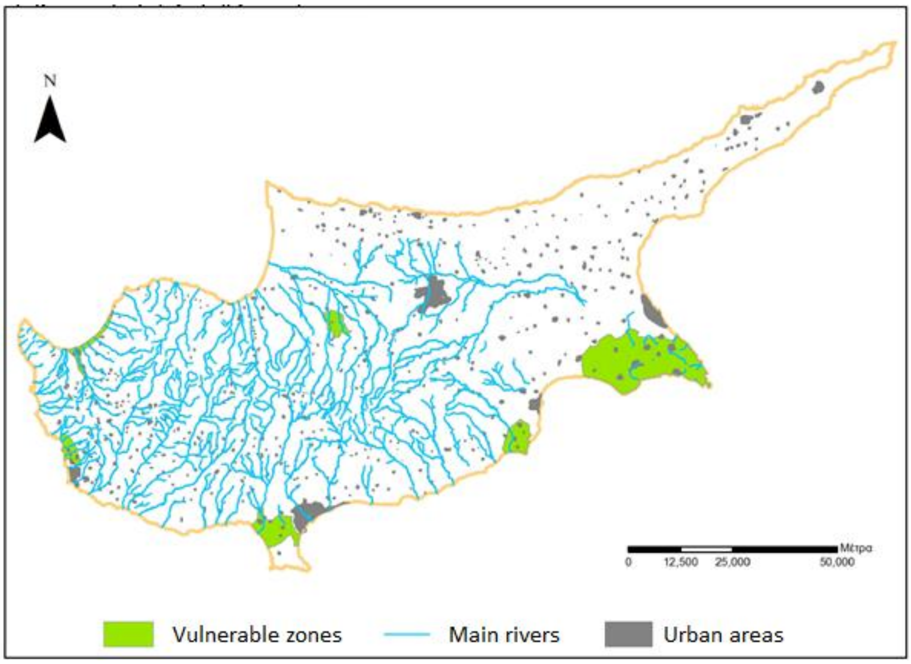

Figure 5-25: Map of Vulnerable Nitrate Zones

Source: MOA

There is no data available to correlate the effect of water quality with the change of biodiversity in freshwater bodies. Nevertheless significant reduction in precipitation which is anticipated for the autumn period may affect ecosystems of perennial rivers due to delayed flow. Furthermore reduction in recharge rates is more intense due to reduced precipitation. However further research is required to estimate response of water quality in precipitation changes.

According to PRECIS projections for the future period 2021-2050, with respect to the control period 1960-1990, annual total precipitation appears to have minor decreases and in some regions no changes at all. The most significant changes in precipitation appear in winter and autumn while in summer and spring average changes appear to be minor.

In specific, it is anticipated, a decrease of about 0-20 mm in the total rainfall for the whole domain of study. This anticipated decrease in winter may affect the chemical and ecological status of river and lake bodies in the western region of the island, which has been characterized as good. The same decrease is anticipated in mountain, southern and southeastern regions where the most vulnerable nitrate zones are situated, and where ecological and chemical status of lakes and rivers is characterized as moderate (Figure 5-26). More specifically future precipitation (2021-2050) is expected to be around 210 mm in western and mountain regions, 70mm in inland and southeastern regions and 150mm in southern regions.

A similar pattern to winter is evident for autumn precipitation where a decrease of about 10-15mm is anticipated for the whole study domain. More specifically future amounts of autumn rainfall will reach 55 mm in southeastern and southern district that the most vulnerable nitrate zones are situated (Figure 5-27), 95 mm for mountain region and 135 mm for western regions compared with current amounts which are 70 mm, 110 mm and 150mm. As already mentioned western regions depict a good ecological status of river and lake bodies while in rest of the areas the status is considered a moderate.

Generally decrease in precipitation will have a decreasing effect in recharging rates. In this frame, decrease in precipitation will affect groundwater bodies quality, when recharged from areas vulnerable to nitrogen pollution and from moderate status water bodies. Groundwater bodies recharging from areas of good ecological status may not be affected.

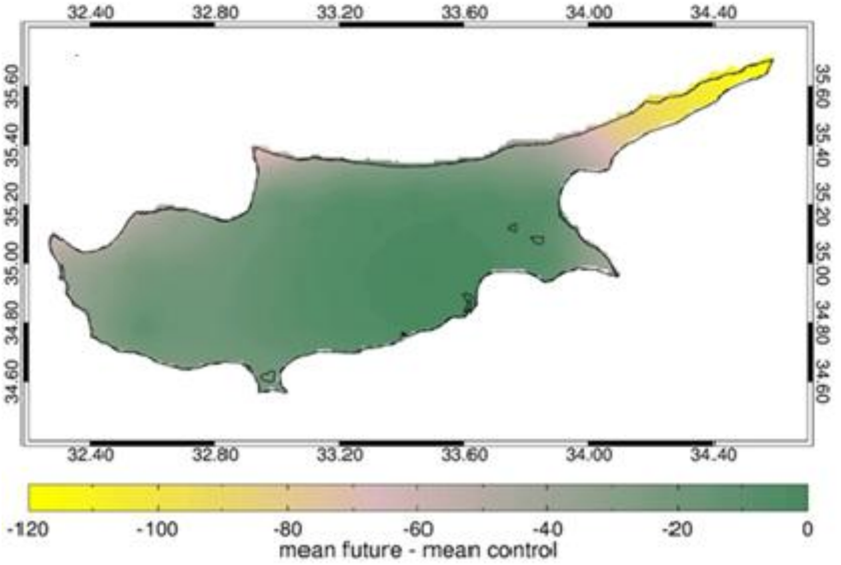

Figure 5-26: Changes in winter total precipitation in the near future (Future – Control period) using PRECIS RCM model

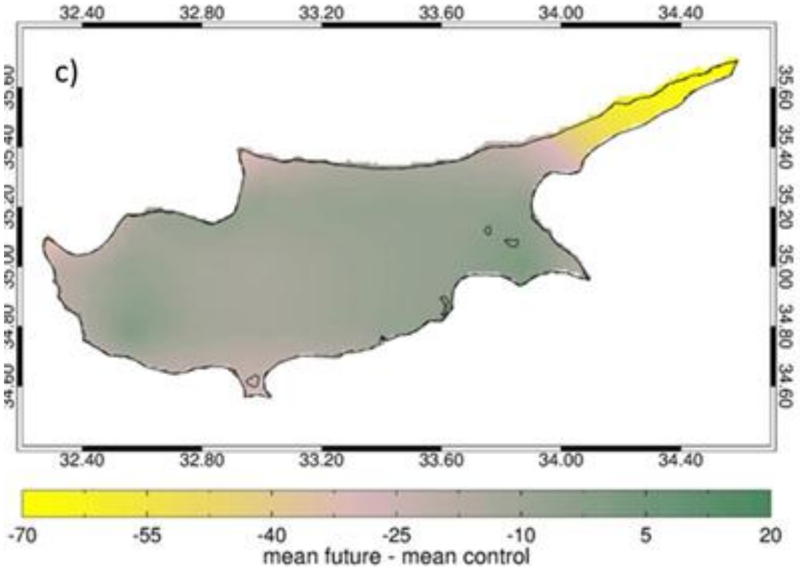

Figure 5-27: **Changes in autumn total precipitation in the near future (Future – Control period) using PRECIS RCM model**

The effect of water quality on the change of biodiversity in freshwater bodies is associated with heavy rain events. The reason is that heavy rain can affect negatively water quality by drifting fertilizers, sediments and other pollutants. However there is no data available in order to correlate water quality and heavy precipitation events. Further research is required.

PRECIS projections show that future changes of annual max total rainfall over 1 day, have a minor increase of about 2-4 mm in western and higher level regions regions. Additionally, southern and southeastern areas were the most vulnerable nitrate zones are situated and ecological and chemical status of lakes and rivers is estimated as moderate present an increase of about 1 mm in annual max total rainfall over 1 day.

Recharging rates may increase if increase in heavy precipitation exists. The anticipated increase in annual max total rainfall over 1 day, although it is not significant, may increase recharging rates of the most vulnerable nitrate zones and of lakes and rivers with moderate ecological status. Western areas, which have a better quality status anticipate a more significant increase in max total rainfall over 1 day.

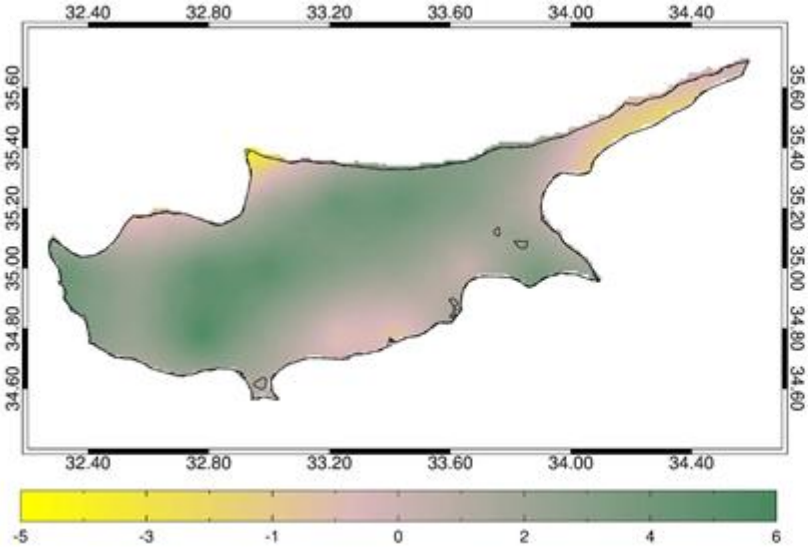

Figure 5-28: Changes in annual maximum total precipitation over 1 day between the future (2021-2050) and the control period (1961-1990).

Considering the above, the exposure of freshwater biodiversity and quality in Cyprus is considered as **moderate.**

5.4.2.2.2 Assessment of adaptive capacity

The resilience of the organisms of these habitats to climate change refers to their ability to genetically adjust to changing environmental conditions. Nevertheless, most of the times, due to landscape deterioration of this kind of habitats, the phenomena of extinction are inevitable.

The government of Cyprus has taken a series of measures, in order to limit the extent of the phenomena by protecting water resources and inland aquatic species, which constitute the environment of freshwater biodiversity.

The measures for the protection of water resources are the following:

- 13(I)/2004 on the protection and management of water.
- 34/2002 on the nitrogen pollution of waters (based on the European Directive 91/676/EEC).
- 42/2004 on the control of nitrogen polluted waters.
- 41/2004 on the control of water pollution.
- 517/2002 on the control of water pollution.
- 56(I)/2003 on waste management.
- 1/1971 on sewerage systems.
- 108(I)/2004 about sewerage systems.
- 772/2003 about urban wastewater.
- 254/2003 about the nitrogen pollution of waterbodies.
- 106(I)/2002 about the control of the water and soil pollution
- 45/1996 about the control of the water and soil pollution

-In compliance with the Article 6 of the Water Framework Directive (WFD), Cyprus has created a register of all areas lying within its river basin district, which were considered requiring special protection under specific Community legislation for the protection of surface water and groundwater or for the conservation of habitats and species directly depending on water. The register includes all water bodies identified under Article 7 of the WFD and all protected areas covered by Annex IV of the WFD

Apart from the protection of the inland aquatic species, the implementation of these measures is expected to have a central role in improving qualitative water status. However, those measures aim mainly to minimize the human activities causing deterioration of water quality, while other physical parameters such as the deterioration of water quality as a result of decreased flow and increased temperatures are not accounted for. Furthermore, it is recognized that the hydrologic processes are such that it may be many years before protective measures actually lead to improvements in water quality and thus the adaptive capacity is characterized by delayed reversibility.

Following, additional recommended adaptation measures that are considered to further enhance adaptive capacity towards this impact are presented indicatively. Nevertheless, their assessment and final selection for implementation will be made through the use of the Multicriteria Analysis (MCA) tool which will be developed and implemented in the framework of Actions 4 and 5 of the CYPADAPT project.

- Inclusion of the tool "Evaluation of Carrying Capacity" in the Construction Spatial Planning System and in the Tourism Policy
- Control entering / exiting of non-indigenous species into / from the Republic of Cyprus
- Control of the premises in which non-indigenous species live (nurseries, florists, aquariums, fish farms, research labs, zoos gardens, circuses and pet shops)
- Precise recording of licensed non-native species and development of a database that includes details on the types and their geographical distribution / dispersion
- Resolve any problems caused by non-native species found in Cyprus and effective management

- Creation of ecological data file and database (BIOCYPRUS) for the Network "Natura 2000"
- Creation of an inventory of species populations, distribution and genetics
- Preparation of Management Plans for all areas of the network "Natura 2000"
- Protection and sustainable use of local flora and fauna populations
- Coordination of the management measures relating to prevention and control of terrestrial and offshore sources of marine pollution, combating pollution accidents and the protection and management of marine biodiversity
- Protection and management of Larnaca salt lakes (area RAMSAR) and of other wetlands
- Promote research on biodiversity and ecosystems, monitoring of biotic and abiotic parameters
- Maintain or strengthen ecological coherence, primarily through providing for connectivity.
- Establishment of ecological networks (protected sites and corridors)
- Prepare and implement a Strategic Plan on Biodiversity
- Incorporate in other policies and plans [Local Plans, Environmental Impact Assessment (EIA), Strategic Environmental Assessment (SEA)] the priority of biodiversity and ecosystems protection in relation to climate change
- Horizontal integration of ecosystem based adaptation to other policies and plans
- Sustainable use of ecosystem services and natural resources, particularly in areas of importance to biodiversity conservation
- Special attention to the protection of priority and threatened species and their habitats
- Enhance/strengthen the Seed Bank and Ex situ conservation
- Monitoring of highly sensitive species should be monitored as indicators of climate change, i.e. amphibians and reptiles
- Avoid planting and releasing of alien animal species
- Avoid overfishing and any destructive fishing practices
- Protection of coastal and marine ecosystems from invasive species (prevention-detection control)
- Legislative actions to protect the artificial reefs areas that will serve as fish shelters and will contribute to the increase in biodiversity and in fisheries production
- Restoration of damaged ecosystems (i.e. artificial dispersal of seeds, restore water bodies/flows, soil quality, remove alien species etc),
- Assessment of the impacts of pollination disruptions on plant reproduction, protection of pollinators
- Waste management to avoid pollution, ecosystem degradation and surface and ground water deterioration
- Control overgrazing

Consequently, the adaptive capacity of Cyprus' freshwater biodiversity and quality to climate changes is considered to be **moderate**.

5.4.3 Assessment of overall future vulnerability

The principal aim of this chapter is to identify the key future vulnerabilities of biodiversity to climate changes, as well as to assess the magnitude of these future vulnerabilities. However, it must be noted that, as there were no sufficient data to evaluate all indicators further research is required.

In order to quantify the vulnerability potential of biodiversity against a climatic change impact, the values of sensitivity, exposure, adaptive capacity and vulnerability are quantified as follows:

Degree of sensitivity, exposure & adaptive capacity		Degree of vulnerability		Legend
None	0	None	V≤0	
Limited	1	Limited	0<V≤1	🟩
Limited to Moderate	2	Limited to Moderate	1<V≤2	🟨
Moderate	3	Moderate	2<V≤3	🟨
Moderate to High	4	Moderate to High	3<V≤4	🟧
High	5	High	4<V≤5	🟧
High to Very high	6	High to Very high	5<V≤6	🟥
Very high	7	Very high	6<V≤7	🟥
Not evaluated	-	Not evaluated	-	⬜

Since vulnerability is defined by the following formula:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity * Exposure$$

“Impacts” and “Adaptive capacity” should be evaluated on the same scale (1-7). For this to be achieved, the square root of “Sensitivity x Exposure” is used. The results of the vulnerability assessment for the biodiversity of Cyprus are summarized in Table 5-10.

Table 5-10: Overall vulnerability assessment of biodiversity in Cyprus to climate changes

Impact	Sensitivity	Exposure	Adaptive Capacity	Vulnerability
Distribution of plant species in terrestrial ecosystems	High (5)	High (5)	Limited to Moderate (2)	Moderate (3)
Distribution of animal species in terrestrial ecosystems	High (5)	High (5)	Limited to Moderate (2)	Moderate (3)
Marine biodiversity	Moderate (3)	High to Very high (6)	Moderate (3)	Limited to Moderate (1.2)
Freshwater biodiversity	Moderate (3)	Moderate (3)	Moderate (3)	None (0)

The main indicator for assessing the vulnerability of the terrestrial biodiversity towards climate changes appears to be the landscape fragmentations of the island, as species cannot move neither northern nor higher after a certain point. Instead, the main advantage of the marine biodiversity is the ability of migration, which can also be counted as a disadvantage due to the intrusion of harmful invasive alien species. On the other hand, freshwater biodiversity is not threatened. Considering the above, it is assumed that the first vulnerability priority of the biodiversity in Cyprus to climate changes is the distribution of species in terrestrial ecosystems while the second priority is the biodiversity of aquatic ecosystems.

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6 AGRICULTURE

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Abbreviations and Acronyms

AIO	Agricultural Insurance Organization of Cyprus
CYSTAT	Statistical Service of Cyprus
DERM	Department of Environment and Resource Management
EEA	European Environment Agency
EU	European Union
FAO	Food and Agriculture Organization
GCRIO	U.S. Global Change Research Information Office
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GWW	Government Water Works
ha	hectare
IENICA	Interactive European Network for Industrial Crops and their Applications
IFAD	International Fund for Agricultural Development
IPCC	Intergovernmental Panel on Climate Change
JRC	Joint Research Center
MANRE	Ministry of Agriculture, Natural Resources and Environment of Cyprus
MCA	Multi-Criteria Analysis
MCM	million cubic meters
NTUA	National Technical University of Athens
OMAFRA	Ontario Ministry of Agriculture, Food and Rural Affairs
PICIR	Potsdam Institute for Climate Impact Research
PRECIS	Providing Regional Climates for Impact Studies
RCM	Regional Climate Model
RR	Precipitation
RDP	Rural Development Programme
SMP	Skimmed milk powder
TX	Maximum temperature
USEPA	*United States Environmental Protection Agency*
WDD	Water Development Department
WW	Water Works
WWTP	Waste Water Treatment Plant

6.1. Climate change and agriculture

Agriculture serves for the direct supply of safe, nutritious and affordable food to society and plays an important role in landscape preservation and prevention of desertification (Demetriou, 2005; PICIR, 2005). According to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007), climatic condition patterns have brought and will bring about numerous changes concerning agricultural activities on a global scale and consequently will influence the world’s food supply.

The agricultural sector is highly dependent on climate since temperature, sunlight and water sources are the key factors for plant growth. Although certain impacts of climate change may be beneficial, as for instance prolonged growing seasons and rise of temperatures, there will be severe consequences that can put agricultural activities at significant risk, as well. Shifting weather conditions can cause variations in the sowing and harvest time of various crops. Moreover, extreme weather phenomena, such as heatwaves, droughts or hail can damage arable cultivations and reduce crop yields (Iglesias et al., 2007; IPCC, 2007).

Many studies have been published during the last years taking into account different sets of dynamic factors specific to given regions or countries in order to assess the future direction of the agricultural sector in a changing world governed by complex socio-economic systems. (GCRIO, 1995).

The impact, vulnerability and adaptation assessment for the agricultural sector regarding climate changes that have occurred the recent years in Cyprus (CYAPADAPT, 2012), showed that the first vulnerability priority of the agricultural sector is the impact of climate changes on crop yield, as the latter has been significantly reduced as a result of adverse climate conditions which impede crop productivity. The second priority of the sector regarding its vulnerability to climate changes was related to the damages caused to crops due to extreme weather events, taking into consideration their devastating effect and the magnitude of their effect on crops as well as the fact that extreme weather events are expected to increase in frequency and intensity. The last priority identified was the impact of climate changes on soil fertility, whose condition is already deteriorated. For the rest of the identified impacts, no evaluation took place due to lack of sufficient data.

In the sections that follow, an attempt is being made to assess the impacts of future climate changes on the agricultural sector of Cyprus based on the climate projections output produced by the PRECIS (Providing Regional Climates for Impact Studies) regional climate model as well as on other socio-economic projections for the period 2021-2050. The reason why PRECIS was selected to be used in the present study is that, unlike in other regional climate models, in PRECIS Cyprus lies at the center of the domain of the study. The future period 2021-2050 has been chosen, instead of the end of the twenty-first century as frequently used in other climate impact studies, in order to assist stakeholders and policy makers to develop near future plans.

6.2. Baseline situation

Agriculture has always been an economic activity of great importance in the Mediterranean basin and a major source of employment and income for the countries of the region, including Cyprus.

In the 1960s and after independence, water management has been a difficult challenge because of the inadequate development of the water infrastructure facilities for water supply and irrigation purposes. For this reason, the top priorities of the national government have been focused on increasing available water resources in order to achieve food security and constant supply of high quality water for irrigated agriculture. In this way, water scarcity impacts would not inhibit the socioeconomic progress of this primary sector which was the backbone of the economy with a 20% share in the country's Gross Domestic Product (GDP) (Solsten, 1991; IENICA, 2004; Papamichail, 2009).

During the period 1960 –1974, concerning the declaration of the independence of Cyprus (according to the Zurich-London Treaty), followed by the Turkish invasion in 1974, the primary sector showed a fast-paced development. Small owner-run farms contributed in almost 70% of product exports and employed one third of the island's economically active population. After 1974, the more productive part of the island contributing with 46% of total crop production and 45% of livestock production, was occupied. Consequently, the displacement of the farmers in the less productive part of the island, the shortages of forage and water resources and other difficulties caused by the invasion, resulted in a setback of the broad agricultural sector. Although intensive efforts and government actions were concentrated on land improvement, on the improvement of irrigation methods and on the increase of available water resources for irrigation so as to come within reach of the pre-1974 levels of production, there are still many problems. These problems are mainly due to the irrational use of water resources, the growing tourism sector which resulted in the shifting of the agricultural labour force to the tourist industry and to a much less extent to the spreading of plant and animal diseases coming from the occupied part of Cyprus (Solsten, 1991; IENICA, 2004; Papamichail, 2009).

In particular, in the 1990's, agriculture's share of the national economy started showing a declining trend due to the rapid development of the tertiary sector (tourism, financial and banking services). The Republic of Cyprus entered the European Union (EU) on 1 May 2004 and on January 1, 2008 joined the euro. As it was expected, the accession of Cyprus to the EU had several positive and negative impacts on the socio-economic status of the country. Even though a significant improvement of the National Economy was noted during the last years, the development in the broad agricultural sector was not that satisfactory (Solsten, 1991; IENICA, 2004; Papamichail, 2009).

At present, agriculture is still considered to be one of the major economic sectors of Cyprus due to the island's favorable climate and its location near its leading market, Western Europe. Additionally, it contributes to the social cohesion, the employment, the protection of the environment, as well as the general welfare of the society (Vakakis and Associates, 2010; Bruggeman et al., 2011a; Savvides et al., 2002).

Following, the main characteristics of the two main components of the agricultural sector, i.e. agriculture and livestock, are presented.

6.2.1. Agricultural area and crop production

Based on the CORINE 2006 database land cover, the agricultural areas cover almost half of the island's surface (47.8%). From this area, on average 71.5% was covered with permanent and temporary crops during the period 2002-2008 (CYSTAT, 2010).

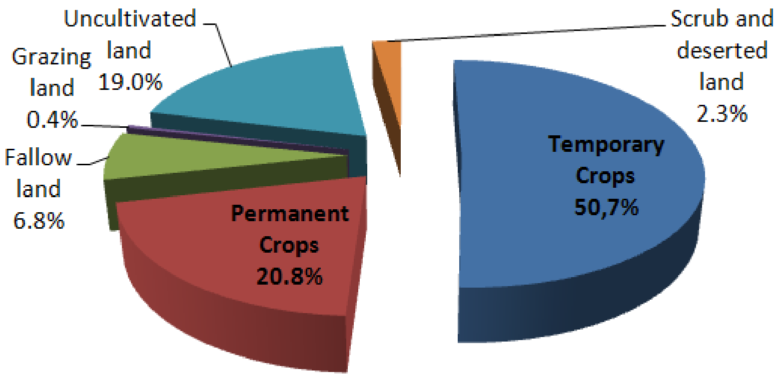

Figure 6-1: Area covered by temporary and permanent crops as a percentage of total crop area, 2002-2008 (CYPADAPT)

Source: CYSTAT, 2010

The most important crops in terms of production value are wheat, potatoes, grapes, citrus, vegetables and olives. Of the area covered with crops during the period 2002-2008, 42.8% was taken up by cereals, 20.5% by fodders, 10.3% by olives and carobs, 8.2% by vineyards (8.2%) and 6.8% by vegetables and melons while citrus, nuts and fresh fruits cover smaller areas (Figure 6-2) (CYSTAT, 2010).

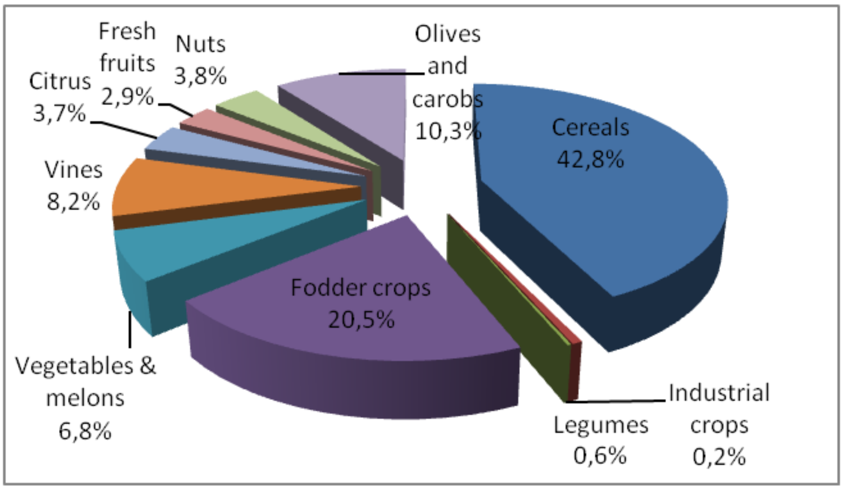

Figure 6-2: Area covered by type of crop as a percent of total crop area, 2002-2008 (CYPADAPT)

Source: CYSTAT, 2010

The average crop production (tons) in Cyprus per crop type as a percentage of the total crop production for the period 2003-2008 is presented in the following figure. As it can be seen, approximately 27% of the total crop production comprises of potatoes, 14% of barley, 11.5% of grapes, 9% oranges and 6% grapefruits while other crops have smaller contribution to the total crop production (CYSTAT, 2010).

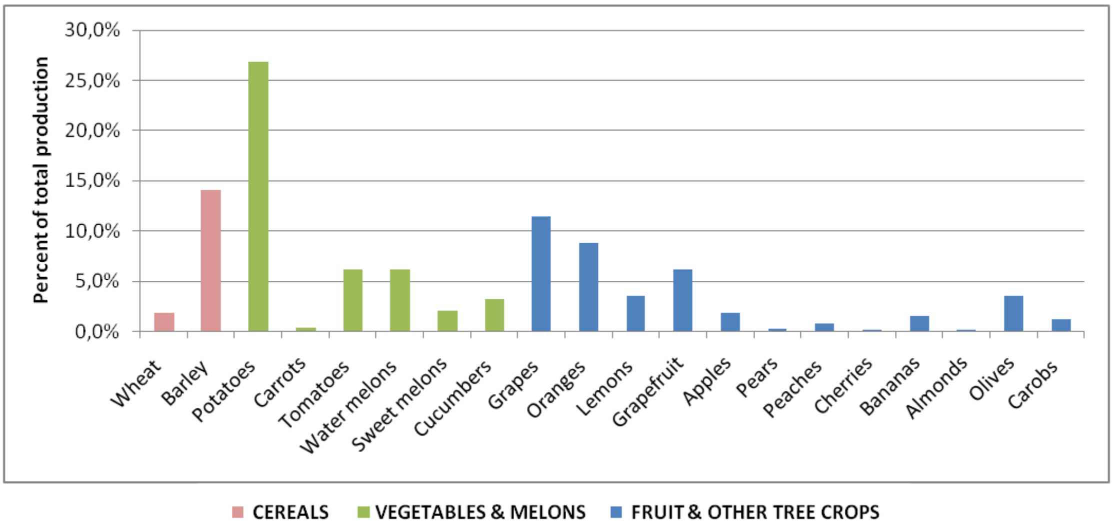

Figure 6-3: Average crop production per type of crop as a percentage of the total crop production in Cyprus, 2003-2008 (CYPADAPT)

Source: CYSTAT, 2010

6.2.2. Development of the agricultural sector

Before Cyprus accession in the EU, the income gained from agricultural activities showed increasing trends as farm holders enjoyed higher prices for their products compared to those of the other Member States. After 2004, it exhibited a decrease and reached the levels of 2000, in 2006 (at current prices). It should be noted that in 2007, the income of the farmers was 20% lower (in real terms) than the average of the EU-27. This decline is the result of the decrease in the product prices, the decrease in crop production due to water scarcity and the rapid increase of the intermediate consumption (input costs).

In general, there is a continuing miniaturization of the Cypriot agricultural sector in terms of the sector's share in the country's GDP and the employment rates, which can be noticed by the data provided by the Statistical Service of Cyprus (CYSTAT, 2010) and are illustrated in Figure 6-4. In specific, the GDP share of the agricultural sector to the total GDP of Cyprus decreased to 2% in 2008 from 5.3% in 1995 and the share of employment in agriculture with respect to the total workforce decreased to 6.3% in 2008, compared to 10.1% in 1995 (CYSTAT, 2010). However, it should be noted that the actual workforce is much higher since part-time farmers are not accounted for, neither their contribution to GDP.

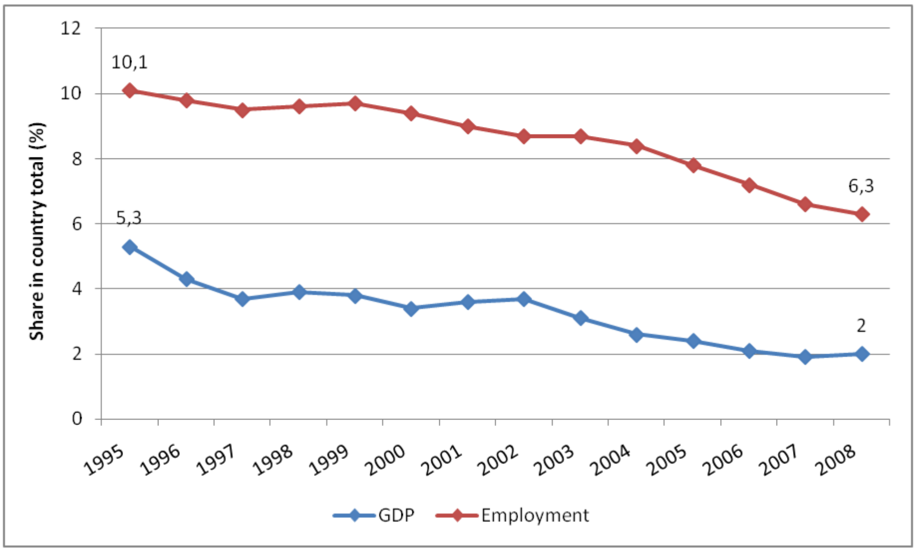

Figure 6-4: Share of agricultural sector in the country's GDP and employment (CYPADAPT)

Source: CYSTAT, 2010

In addition, as it can be seen in Figure 6-5, growth rates in gross output and value added recorded negative values for several years during the period 1995-2008.

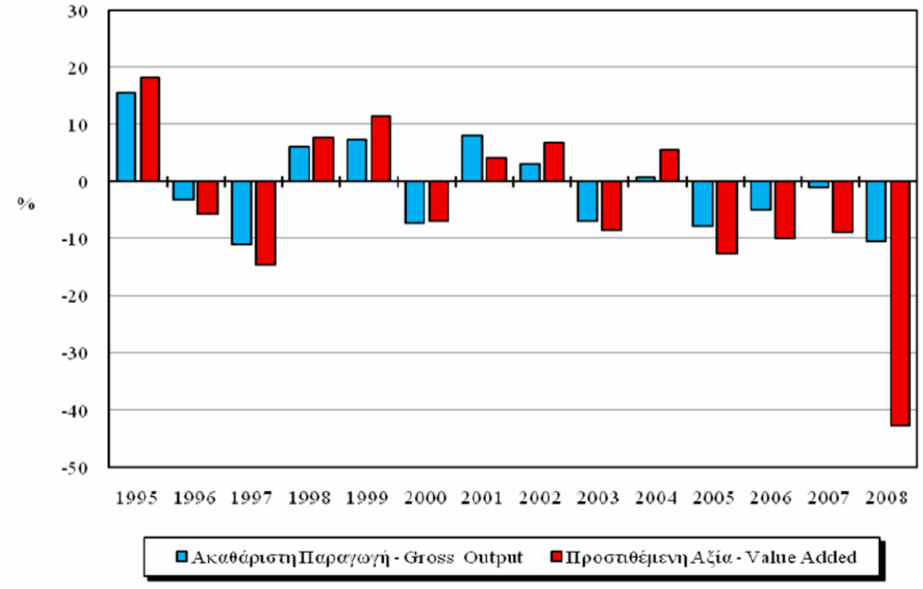

Figure 6-5: Annual real growth of output & added value, 1995-2008

Source: CYSTAT, 2010

Another contributing factor to the rate of development and the productivity of the agricultural sector in Cyprus is the structure of land holdings. Agricultural lands have been highly fragmented due to land inheritance to younger generations. Division of agricultural areas together with highway development, steep slopes and land-use changes from agricultural purposes to urban lots, led to very small plot sizes. In order to ameliorate their practice, farm holders were forced to purchase or rent plots. However, these additional small holdings are usually not adjacent to their main property and this, undoubtedly, reduces efficiency and practicality (Vakakis and Associates, 2010; Deems, 2010). In particular, the average area per agricultural holding was 3.5 ha, while each holding consisted on average of five land parcels (Table 6-1). Almost half of the land was cultivated by their owners (44%), whereas 52% was rented. Moreover, about half of the farm holders and their family members (49%) did not have agriculture as their sole or primary occupation but as supplementary employment which was needed to survive. A total number of 45,199 agricultural holdings was recorded, including 588 landless livestock farms (CYSTAT, 2006). Data regarding share and amount of employment (days) in relation to the size of the agricultural holdings is presented in Table 6-1. As it can be seen, as the size of the land holding decreases, the employment force in the agriculture sector increases and the average annual employment (days) decreases.

Table 6-1: Employment data in relation to farm holding size, Cyprus

Percentage of employees (%)	Size of agricultural holding (ha)	Average annual employment (days)
50	< 1	48
35	1-5	98
15	> 5	175

Source: Vakakis & Associates, 2010

Furthermore, the vitality of the agricultural sector is significantly affected by the age of the farm holders and consequently by the level of education. The latest survey (Agricultural Statistics 2008) revealed that the average age of farmers was 54 years old, with just 5% of them being under the age of 35 (Bruggeman et al., 2011b).

To this end, it should be noted that all the above-mentioned factors regarding the structure of land-holdings and the characteristics of the work-force related to the agrarian sector could pose limitations when considering practices to improve the adaptive capacity of the sector.

6.2.3. Exports of agricultural products

The principal and most valuable export crops in Cyprus are potatoes, citrus, vegetables and table grapes. As far as the total export activities of the agricultural sector is concerned, the data provided from the Statistical Service of Cyprus (CYSTAT, 2010) for the period 1995-2008, show an increasing trend mainly during the period 2003-2005 while during the whole period there were continuous fluctuations (Figure 6-6). It must be mentioned that, the high prices of local products driven by the decreased quality of soils, the use of solely traditional agricultural practices and the low cooperation schemes of producers have led to decreased crop yields, problems in the distribution and trade of products and have reduced the competitiveness of the sector (Papadavid, 2009; Papamichail, 2009).

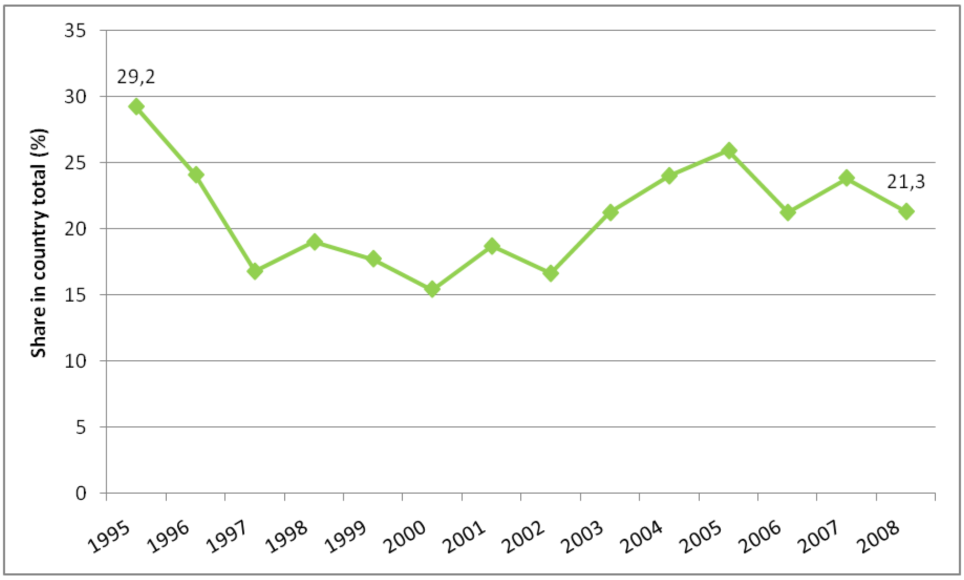

Figure 6-6: Share of agricultural sector in the country's total exports (CYPADAPT)

Source: CYSTAT, 2010

Figure 6-7 presents the trends in exports of the major agricultural products during a thirteen-year period, from 1996 to 2008 (CYSTAT, 2010).

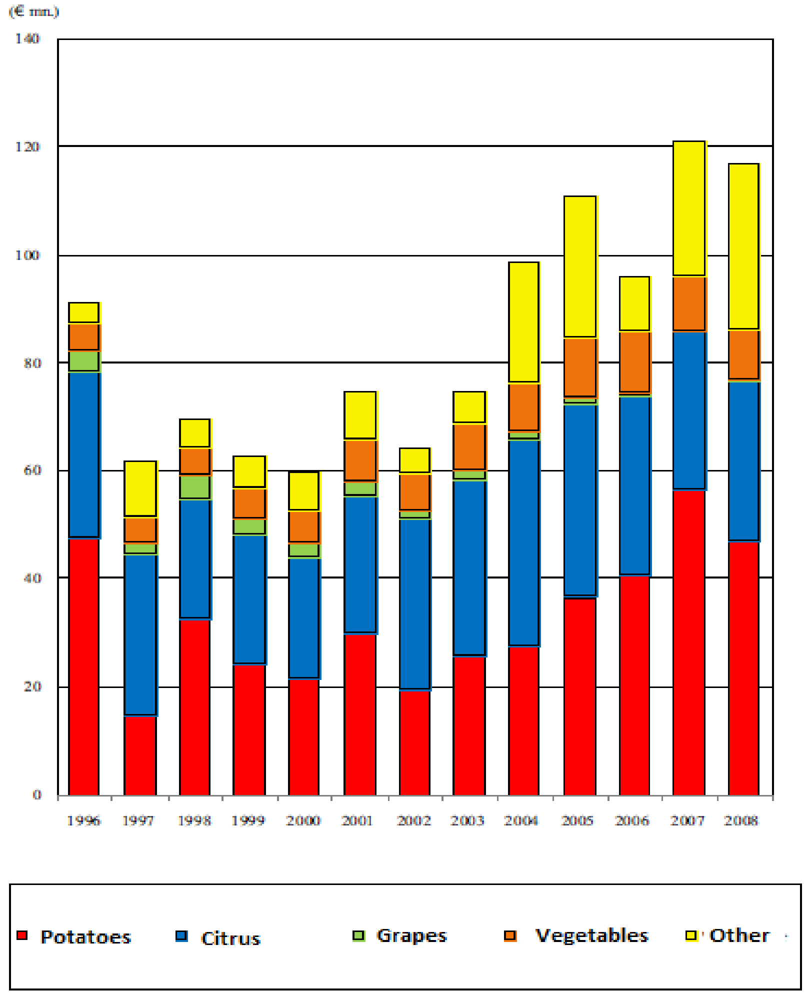

Figure 6-7: Exports of agricultural products in Cyprus, 1996-2008

Source: CYSTAT, 2010

The importance of the European market for the exports of agricultural products in Cyprus is depicted in Table 6-2, as the majority of the agricultural commodities of the island is distributed within its borders. Indicatively, in 2008 the Member States of the EU absorbed 67.1% of agricultural products exports (CYSTAT, 2010).

Table 6-2: Percentage distribution of agricultural exports of Cyprus by geographical regions, 2003-2008

Countries of destination	2003	2004	2005	2006	2007	2008
EU countries	80.0	74.9	71.1	80.4	72.6	67.1
Other European countries	15.5	6.7	7.6	12.5	11.6	11.7
Arab countries	0.7	1.2	2.0	2.4	1.2	2.3
Other countries	3.9	17.2	19.4	4.8	14.5	18.9

Countries of destination	2003	2004	2005	2006	2007	2008
Total	**100**	**100**	**100**	**100**	**100**	**100**

Source: CYSTAT, 2010

6.2.4. Livestock population and production

The second important component of Cypriot agriculture is livestock. Cattle, sheep and goats, pigs and poultry constitute the main subsectors of the animal husbandry industry. During the last years, ostrich farmers have been also established for commercial uses. Their average absolute numbers and percentages in total population during the period 1984-2008, according to data provided by the Statistical Service of Cyprus (CYSTAT, 2010), is depicted in the following figure.

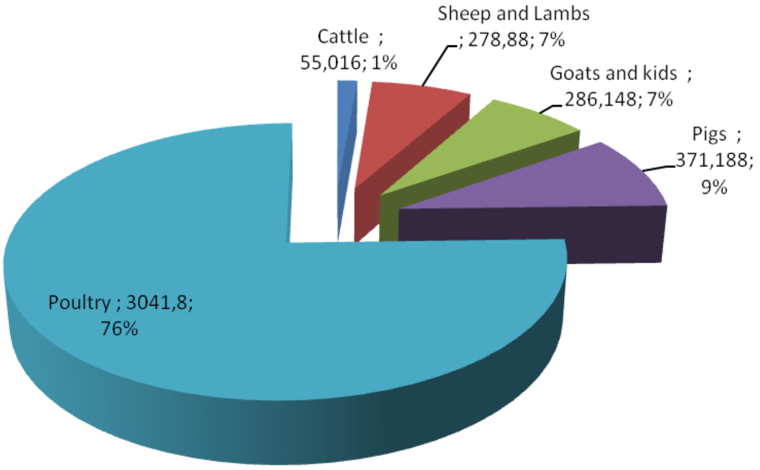

Figure 6-8: Animal population in husbandry (in thousands), average 1984-2008 (CYPADAPT)

Source: CYSTAT, 2010

Meat production during the period 2003-2008 according to CYSTAT (2010) comprised mainly by pork meat (57%) and poultry (31%) while the rest 12% of meat production comprised of beef, kids, goats, lamb, rabbits and mutton (Figure 6-9).

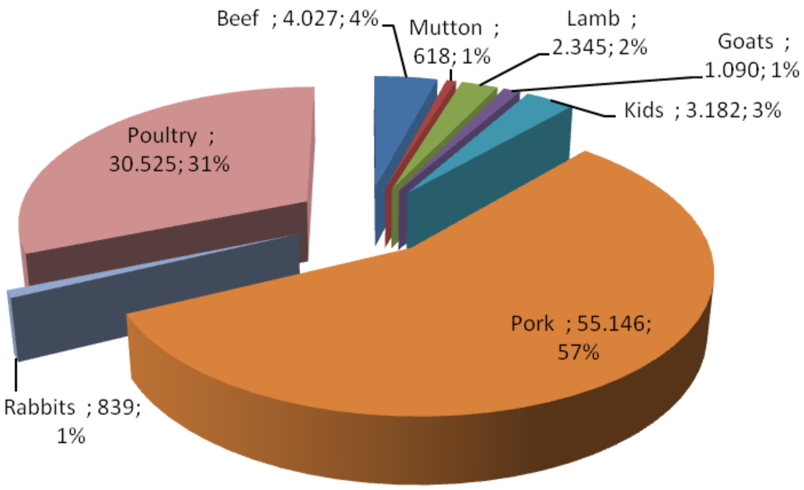

Figure 6-9: Annual meat production (in tons), average 2003-2008 (CYPADAPT)

Source: CYSTAT, 2010

The most important constraints of the livestock sector in Cyprus encompass the insufficient production of animal feed and the dependence on imports. An additional problem is waste handling and the protection of soil and water resources from practices that cause pollution.

6.2.5. Livestock imports and exports

Local needs are fully satisfied regarding fresh pork, poultry meat as well as edible eggs, thus no imports of these commodities are required. In contrast, excess quantities of fresh pork contribute occasionally to the export activities. Moreover, local production of beef /veal, mutton and lamb cover the local needs by 81% and 92% respectively and it is supplemented by imported quantities. The required quantities of pasteurized cow’s milk for liquid consumption is completely met with whereas the demand for cheese and other dairy products made from cow’s milk as well as sheep and goat’s milk is satisfied by 85% and supplemented by imports. Furthermore, the demand for evaporated milk, condensed milk, sweetened or not, whole milk powder, skim milk powder, milk for infants etc. for local use is satisfied by imports, while traditional dairy products are exported.

To conclude, in recent years, a remarkable growth in exports of meat has been witnessed, as shown in Figure 6-10. However, it is unknown whether this trend was merely coincidental or whether long-term opportunities resulted in opening new markets. This remains to be confirmed by the figures in the following years. Taking into account the increasing level of livestock production in Cyprus, if it is supported by the appropriate production and commercial practices, then a potential growth of exports of various meat types will be possible (Vakakis & Associates, 2010).

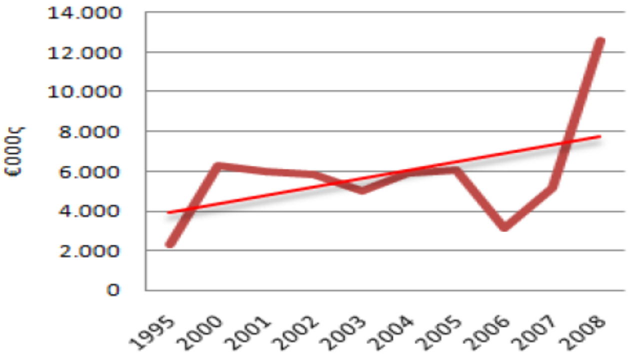

Figure 6-10: Exports of different types of meat, 1995 & 2000-2008

Source: Vakakis & Associates, 2010

6.2.6. Water use

6.2.6.1. *Irrigation*

Agriculture constitutes the dominant water user, accounting for 60% of total water demand in 2011, that is 152 Mm^3 (Figure 6-11). According to the Water Development Department of MANRE (WDD, 2009), during the period 2005-2007 irrigation water supply was provided by 73% from non GWW (mainly private boreholes) and the remaining 27% from GWW (mainly surface water). It must also be mentioned, that recently small quantities of recycled water are used for irrigation (8-9Mm^3).

The amount of available water for irrigation purposes is not stable as it exhibits significant fluctuations from year to year, depending on the weather conditions, the water storage in dams and the state of groundwater aquifers. Furthermore, during drought periods the water supply for irrigation from Government Water Works is restricted in order to meet water demand for the domestic sector first, and thus more groundwater is drilled from private boreholes in order to meet the demand for irrigation.

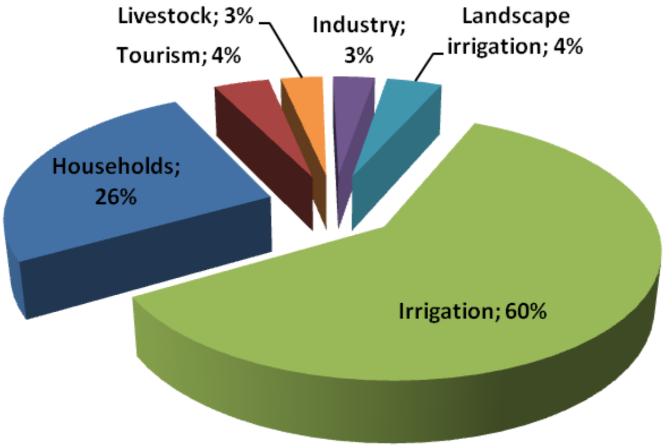

Figure 6-11: Allocation of total water consumption per sector for 2011 (CYPADAPT)

Source: WDD, 2011a

As for the future water demand in agriculture, there is no study on the projection of future crop trends, such as with population trends for example. Based on the aggregated macroeconomic and sectoral projections to 2030 for the EU Member States of the European Commission's Directorate-General for Economic and Financial Affairs, the Member States' stability programmes and long- term projections, the results of the study performed by WEFA[1], and the results of the GEM-E3 model[2] (European Commission, 2003), the Gross Valued Added of the agricultural sector (including livestock, fisheries and forestry) will increase by 50% to 2030 compared to 2010. It is assumed that water consumption from the sector will increase as the Gross Valued Added increases but with an almost logarithmic rate as water use will be more efficient. In particular, according to the Department of Agriculture of the Ministry of Agriculture, Natural Resources and Environment of Cyprus, the current trend in agriculture is characterized by the replacement of the water intensive crops with other more drought resistant crops and the use of more effective irrigation methods. On the other hand, it is expected that climate changes such as the increase in temperature and the decrease in precipitation, will increase irrigation demand. In the framework of this study, the estimation of the report of FAO (FAO, 2002) that future demand in irrigation water will not substantially change in the future, is adopted. Taking also into account the increase in the Gross Value Added of agriculture (50%) in 2030, it is assumed that the average total water demand from agriculture in the period under examination (2021-2050) is expected to increase by 25% which in absolute numbers equals to 190Mm^3 in total. Taking into account the respective changes in the water demand from other sectors (see Chapter Water Resources, Section 2), it is estimated that the share of water demand for irrigation will remain the same (61%).

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[1] WEFA (now integrated into DRI-WEFA) is an economic consultancy company which was subcontracted by NTUA to deliver a consistent macro-economic and sectoral forecast for the EU Member States.

[2] The GEM-E3 model has been constructed under the co-ordination of NTUA within collaborative projects supported by Research DG involving CES-KULeuven and ZEW

Cypriot agriculture is irrigated (vegetables, citrus, potatoes, melons, table grapes, deciduous fruit, bananas) or non-irrigated (rain fed) (i.e. cereals, fodders, olives, carobs, wine grapes, almonds) (IENICA, 2004). For the period 2002-2008, 24% of the total crop area was irrigated and 76% was rain-fed (CYSTAT, 2010). The next diagram (Figure 6-12) presents the water demand for irrigation, measured in million cubic meters (MCM) which is distributed to different types of crops. On the graphic bars, a distinction is made between the water amount provided by the Government Irrigation Schemes, as well as by other schemes. As it can be seen in the diagram, the most water-intensive crops are citrus and open-field vegetables.

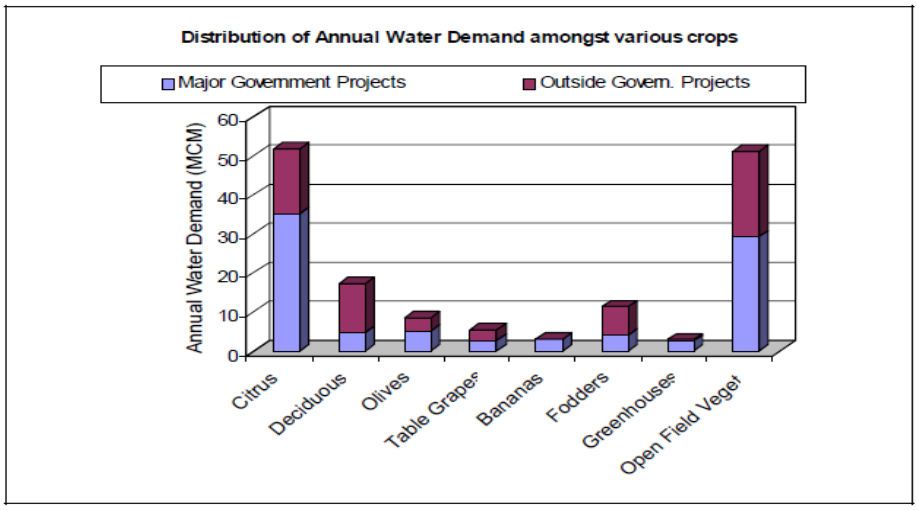

Figure 6-12: Annual water demand data for various crops

Source: WDD – FAO, 2001

The following map (Figure 6-13) depicts a territorial distribution of annual water demand for irrigation from Government Irrigation Schemes per crop.

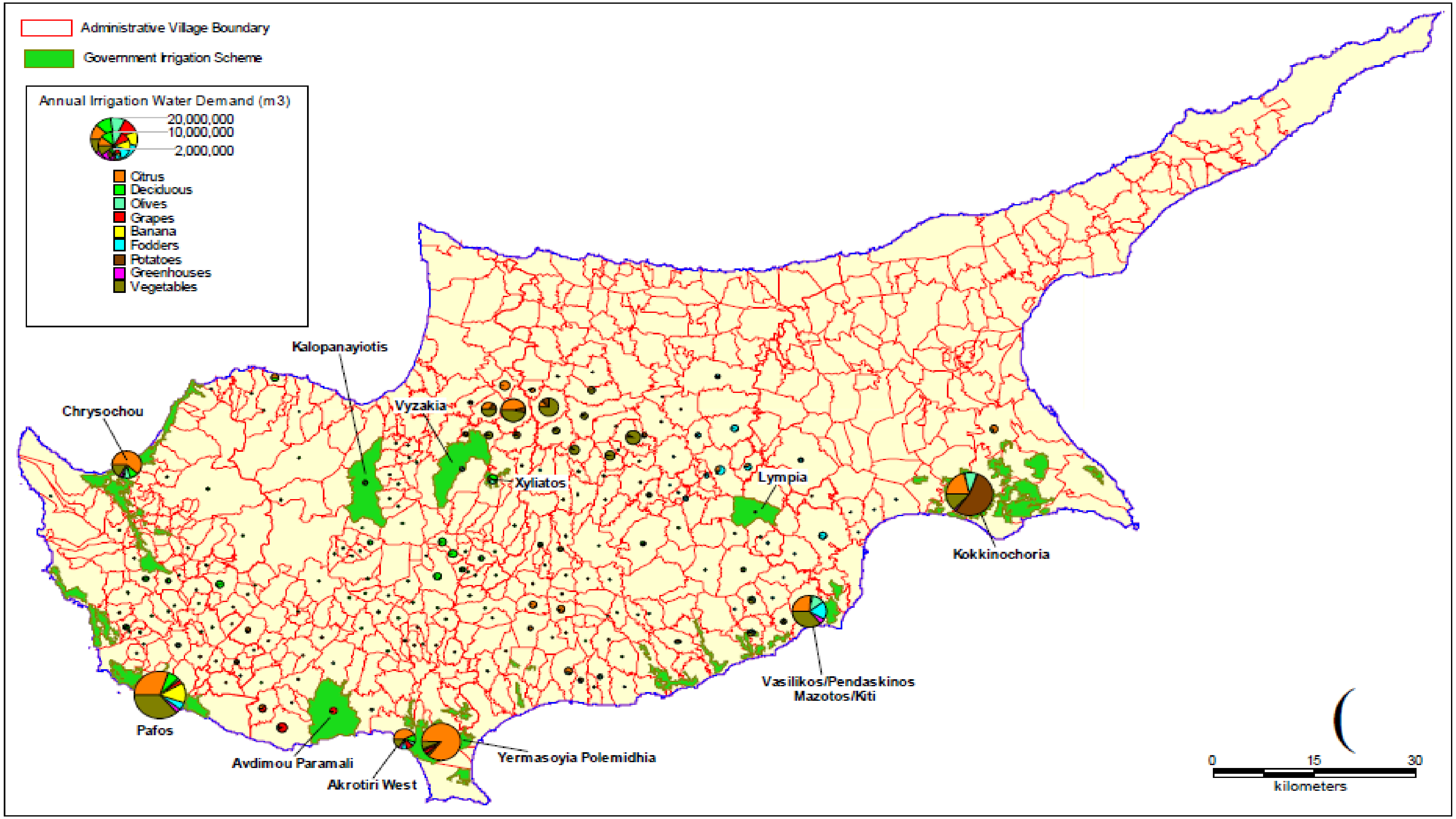

Figure 6-13: Annual irrigation water demand in Cyprus

Source: Chimonidou and Vassiliou, 2006

For the satisfaction of water demand for irrigation, several water works have been implemented by the government, as shown in the following map. It is considered that the Southern Conveyor System in conjunction with the desalination plants of the area satisfy apart from the drinking water demand of Nicosia, Limassol, Larnaca and the area of Famagusta which is under government control, the irrigation water demand of 14,000 ha of agricultural land. In addition, the Vassilikos-Pentaschinos project was developed in order to supplement with irrigation water the agricultural development of the area and to augment the domestic water supply of Nicosia, Larnaka and Famagusta districts (WDD, 2011a– Annex VII).

The Pafos WW today in conjunction with the operation of the desalination plant at Kouklia is considered to fully satisfy apart from the demand in drinking water of the greater area of Pafos, Pegeia and of some semi-mountain communities. In addition, the Pafos WW satisfies the water demand of the Pafos irrigation area which however, has been substantially reduced compared to the initial estimations due to land use change caused by touristic development (WDD, 2011a– Annex VII).

As far as the supply in irrigation water in the greater area of Chrysochou is concerned, this is less compared to the originally planned amount of irrigation water which would be necessary to satisfy the demand of the recorded irrigated areas. However, no deficits are reported since the area has undergone major land use changes mainly from rural to urban use (WDD, 2011a– Annex VII).

In addition, the Pitsilia Integrated Rural Development Project refers to a series of water works in the mountain and semi-mountain area of Troodos, which belong to the districts of Nicosia, Larnaca and Limassol. This project had as a goal to prevent the abandonment and desertification of rural areas due to internal migration. However, the recorded irrigated areas are more than double compared to the dimensioning of the water works. Respectively, the conservatively estimated water supply from the Pitsilia WW is three times smaller compared to the estimated water demand of the irrigated areas. According to the abovementioned facts, it is obvious that the total water demand in the area of Pitsilia cannot be satisfied exclusively by the available government water works (WDD, 2011a– Annex VII).

Figure 6-14: Map of Government Water Works and irrigated areas in Cyprus

The agricultural areas that are provided with water by Government Water Works are presented in Table 6-3. As it can be seen, approximately 78% of the total irrigated area is supplied with water by GWW (19% of total crop area).

Table 6-3: Irrigated area served by Government Water Works in Cyprus

Government Water Work	Irrigated area (ha)
Southern Conveyor Project	13,926
Pafos Irrigation Project	5,000
Pitsilia Integrated Rural Development Project	1,530
Vasilikos - Pentaschoinos Project	1,429
Chrysochou Irrigation Project	3,100
Sum	**24,985**
Total irrigated area (average 2002-2008)	**31,886***
Total crop area (average 2002-2008)	**134,029**

6.2.6.2. Livestock breeding

The water consumption in the animal husbandry sector, is estimated to be 3% of the total water demand in Cyprus (Figure 6-11). The *daily water requirement* of livestock varies significantly among *animal* species (Table 6-4) as the animal's size and growth stage has a strong influence on daily water requirements. Moreover, water consumption intakes can be influenced by several environmental and management factors. Air temperature, relative humidity and the level of animal exertion or production level are some examples. Moreover, the water content of the animal species' diet affects its drinking needs, as for example a type of feed with a relatively high moisture content could decrease the quantity of drinking water required (OMAFRA, 2007).

Table 6-4: Water demand for livestock

Type of unit	Aviculture units	Sheep and Goats Breeding units	Pig Breeding units	Beef cattle breeding units
Daily water needs per animal (L/day)	0.25	8	15	150

Source: WDD, 2011a

As far as the future (2021-2050) water demand for livestock is concerned, it is expected that it will reach the amount of 11 Mm^3 from 8.5 Mm^3 in 2011 (35% increase) on average during the period 2021-2050, considering a 50% increase in livestock capacity. It must be mentioned that, unlike crops, livestock’s needs in water cannot be substantially reduced.

6.2.7. Main pressures on agricultural sector in Cyprus

Following the baseline situation presentation of the agrarian sector in Cyprus, the main pressures which define and affect the productivity and competitiveness of the specific sector are highlighted as follows:

a. Small and considerable subdivision of agricultural plots (5 plots and 35 decars per farmer - Census of 2003)
b. Isolation of the population of the rural mountainous areas
c. High average age of farmers (54 years old) which are considered less receptive to the application of new advanced technological practices
d. Reduced income mainly due to limited employment opportunities and plot structure and age of farmers

e. Urbanization leading to abandonment of rural areas, desertification and reduction of natural resources.
f. Declining soil fertility (or nutrient depletion) and,
g. Limited water resources
h. Damages to crops due to extreme weather events

Other problems associated with agricultural activities refer to the produced wastes and their appropriate handling and disposal (Bruggeman et al., 2011c). All the afore-mentioned factors could be possibly linked to the falling trend in the agricultural sector. However, it should be noted that only factors (f), (g) & (h) are mainly/directly related to climate change, as declining soil fertility is associated with the phenomenon of desertification, soil erosion and nutrient removal through gaseous losses such as denitrification and volatilization, whereas limited water resources are linked to low precipitation and temperature rise projections. In addition to those addressed above, heat stress and sea level rise, along with overpumping of coastal aquifers due to extended water irrigation needs, contribute to the depletion of water and soil quality. Consequently, these pressing parameters lead to reduced crop yields and loss of arable land, and can have also a negative impact on livestock activities (DERM, 2012; EEA, 2008a).

6.3. Future impact assessment

In this section, the climate change impacts on the agricultural sector as these have been identified in Deliverable 1.2 "Climate change impact, vulnerability and adaptation assessment for the case of Cyprus" will be reassessed in light of the climate projections for the future (2021-2050).

Even though the effects of short-term and long-term climate change on the primary sector are generally difficult to be distinguished from non climatic impacts associated with the management of natural resources. Nevertheless there are some basic impacts identified which are related to global change (IPCC, 2007; EEA, 2008a). The extent of climate change impacts varies upon different ecosystems, regions and countries.

Despite the fact that certain impacts could play a positive role for farming activities in some regions of Europe, mainly concerning northern areas (lengthening of the growing season and increased crop yields because of warmer conditions), the majority of impacts, are likely to have a negative influence for the warmer regions like the Mediterranean region. Negative impacts will result in economic losses and will prevail especially in areas which are already under pressure due to socio-economic and other environmental problems, for instance water scarcity (EEA, 2008b).

According to FAO (2007), the principal climate change impacts on agriculture can be roughly divided into two categories, namely the biophysical impacts and the socio-economic impacts, as shown in Table 6-5.

Table 6-5: Climate change impacts on the agricultural sector

Biophysical impacts	Socio-economic impacts
Physiological effects on crops, pasture, forests and livestock (quantity, quality)	Decline in yields and production
Changes in land, soil, water resources (quantity, quality)	Reduced marginal GDP from agriculture
Increased weed and pest challenges	Fluctuations in world market prices
Shifts in spatial and temporal distribution of impacts	Changes in geographical distribution of trade regimes
Sea level rise, changes to ocean salinity	Increased number of people at risk of hunger and food insecurity

Biophysical impacts	Socio-economic impacts
	Migration and civil unrest

Source: FAO, 2007

Following, the potential changes in climate and their respective impacts on the agricultural sector for the case of Cyprus are presented in Table 6-6.

Table 6-6: Relationship between climate changes and impacts on the agricultural sector

Potential climate changes	Impacts
Increased Temperature	– Reduction of crop suitability and productivity – Changes in crop quality – Increased challenges of weeds, crop pests and diseases – Increased water requirements for irrigation – Water scarcity intensification – Water quality deterioration – Intensification of desertification
Decreased Precipitation	– Decreased crop productivity – Intensification of desertification – Decreased soil fertility
Increase of atmospheric CO_2	– Increased biomass production and increased potential efficiency of physiological water use in crops and weeds – Modified hydrologic balance of soils due to C/N ratio modification – Changed weed ecology with potential for increased weed competition with crops – Increased water use efficiency of some plants and as a result altered competitive interactions of species – Changes in the distribution of animal species
Increase of atmospheric O_3	– Crop yield decrease
Sea level rise	– Loss of arable land in coastal agricultural areas – Soil salinization in coastal agricultural areas – Salinization of groundwater aquifers resulting in low water quality for irrigation
Increased frequency of extreme weather events	– Crop failure – Damages to crops – Decrease in crop yield – Competition for water between different sectors (irrigation,

Potential climate changes	Impacts
(heat waves, droughts, hail, floods)	tourism, domestic etc.) due to extended drought periods – Damage to grain formation – Increase in pests – Heat stress for animals

Adopted from Iglesias, 2007; Iglesias, 2009a; FAO, 2007; EEA, 2008a

In the following sections of this chapter, the future impacts of climate change on the agricultural sector are further analyzed where relative data and information are available. The impacts are presented according to their initial categorization in the current impact assessment (CYPADAPT, 2012), namely:

- Crop yield alterations
- Soil fertility alteration
- Increase in pests and diseases
- Damages to crops from extreme weather events
- Alterations in livestock productivity
- Increase in costs for livestock catering

6.3.1. Crop yield alterations

It is recognized that increases in ambient CO_2 have positive impacts on plant growth. The major effects are on photosynthesis and respiration and thereby on growth (the accumulation of dry matter) (IPCC, 2007). Crop species such as wheat, rice and soybeans are members of the physiological class C3 which respond readily to enhanced CO_2 levels. On the other hand, corn, sorghum, sugarcane and millet belong to the C4 physiological class and tend to be less responsive to elevated concentrations of carbon dioxide even though they possess a greater photosynthetical efficiency. According to the A1B scenario of the Intergovernmental Panel on Climate Change's "Special Report on Emissions Scenarios" (Nakićenović & Swart, 2000)[3], CO_2 emissions are expected to increase with an increasing rate up to the middle of the twenty-first century while after 2050 are expected to increase with a lower rate.

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[3] The A1B scenario was selected and used in the framework of this study for the projections of climate change for the future period

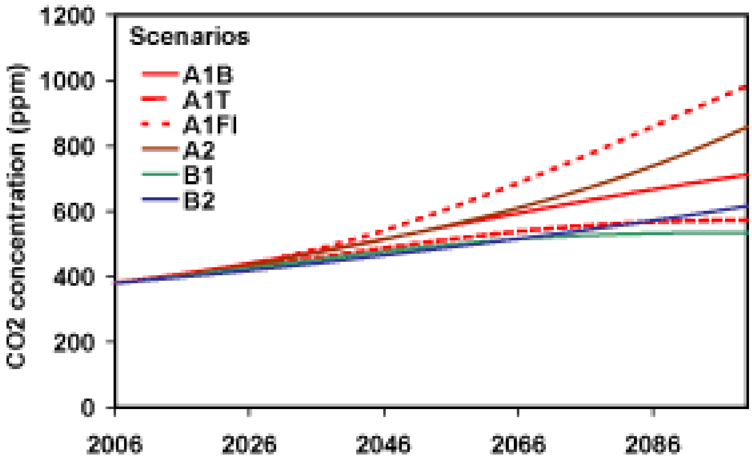


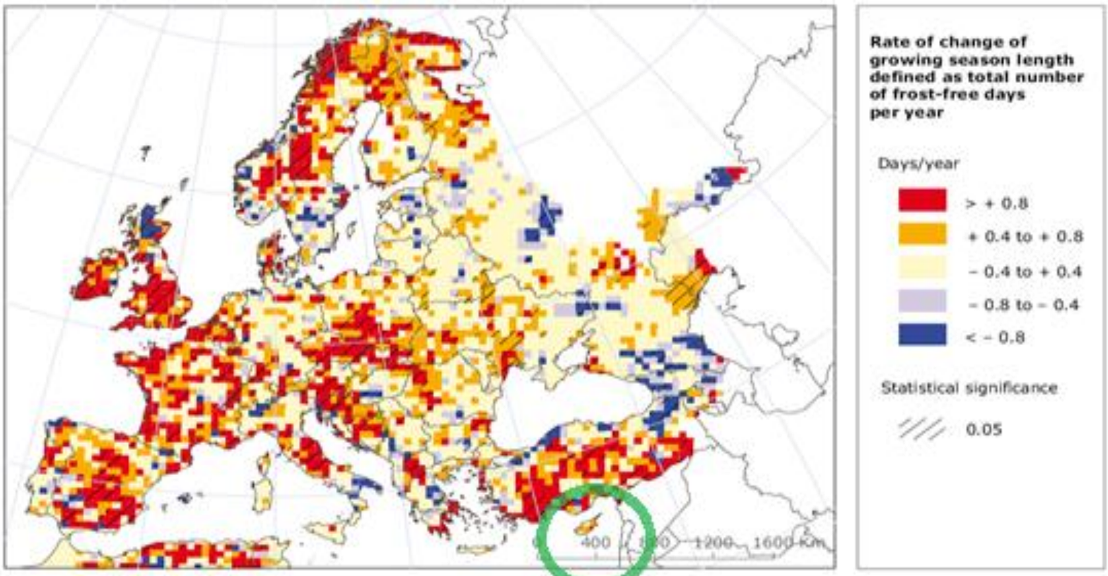
Figure 6-15: Long Term Scenarios for Greenhouse Gas Concentrations, based on data provided by IPCC WG1

Source: EPA

On average, data elaboration confirm that, compared to current atmospheric CO_2 concentrations, crop yields increase at 550 ppm CO_2 in the range of 10-20% for C3 crops and 0-10% for C4 crops (Easterling et al., 2007).

Other positive impacts are associated with the lengthening of the growing season. The length of growing season is regarded as a simple but important indicator of the climate change impacts at local level (EAA, 2008a; Brinkmann, 1979). A prolonged growing season increases crop yields as it strongly assists the optimum use of the available thermal energy, sunlight and water resources and facilitates the presence of new species in certain areas which was limited before because of unfavourable conditions. Nevertheless, a shortening of the growth period could also help prevent harsh summer stress conditions in regions that face drought problems.

According to the EEA's assessment report (2008a), it has been proved that the length of the growing season concerning various crop types across the European regions has changed. There are two ways to determine the growing season in temperate regions. The first, and more usual, is the calculation of the average number of days between the last frost in spring and the first severe frost in autumn. The second, depending on crops, is the calculation of the average number of days that the temperature rises high enough for a particular crop to sprout and grow (USEPA, 2012). As it can be seen from Figure 6-2, there is general tendency for lengthening of the growing season especially in the regions in northern latitudes (EAA, 2008a).



Note: The rate of change (number of days per year) of the duration of the growing season (defined as total number of frost-free days per year) as actually recorded during the period 1975–2007.

Source: MARS/STAT database (Genovese, 2004a, 2004b).

Figure 6-16: Rate of change of the duration of the growing season as actually recorded during the period 1975-2007

Source: EAA, 2008a

However in southern and warmer latitudes, the potential positive impacts on crop yields presented above are not of such a significant magnitude as are the potential negative impacts, which include reduced crop yields due to high temperatures, increased water demand for irrigation and reduced water availability due to periods of prolonged droughts, water scarcity, rainfall decrease and increased competition for water between sectors, which will in turn be much more intense (Behrens et al., 2010).

Scientific data provide evidence that the flowering and maturity phases of several types of plants currently take place two or three weeks earlier than in the past in Europe. Given the increasing trend of temperatures, the plant phases will shorten, especially in Western Europe and two or more cropping cycles may take place during the same season. On the other hand, high temperatures may hinder the efficiency of photosynthesis, thus leading to a gradual decrease of the reduction rate of these phenological phases (EEA, 2008a; IPCC, 2007).

Increased temperatures may accelerate the rate at which plants release CO_2 in the process of respiration, resulting in less than optimal conditions for net growth. In addition, when the optimal temperature for biological processes is exceeded, crops may be adversely affected with a steep drop in net growth and yield. Another important effect associated with high temperature is the acceleration of physiological development and subsequently of maturation resulting in reduced yields (GCRIO, 1995).

Reduced rainfall and increased temperatures result in increased demand for irrigation water with the subsequent negative impacts for the economy and the environment. Especially for the Mediterranean area, a deteriorating meteorological water deficit has been reported for the last 32 years. Furthermore, the annual number of rainy days is expected to decrease while the risk of summer drought is projected to increase. These areas are experiencing high competition for water between sectors and users (agriculture, tourism, energy etc.) (EEA, 2008a). The map illustrated in Figure 6-17 provides an estimation of the change in the volume of water needed for irrigation purposes so as not to inhibit crop growth. The rate of change of the *meteorological water balance* is expressed in “m^3 x ha^{-1} x year^{-1}”.

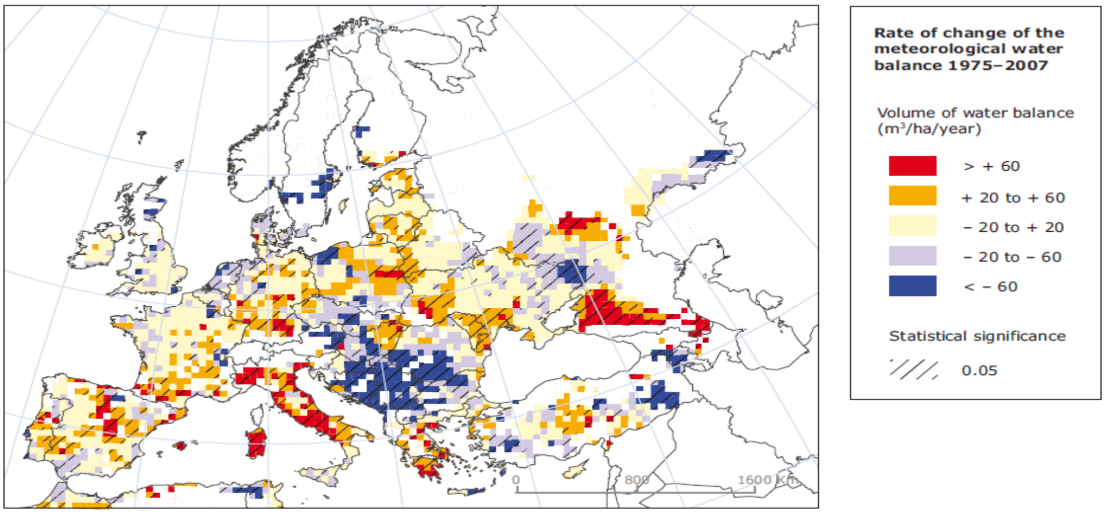


Figure 6-17: Rate of change of the meteorological water balance for the period 1975-2007

Source: EAA, 2008a

The occurrence of moisture stress during flowering, pollination and grain-filling is harmful to most crops. Increased evaporation from the soil and accelerated transpiration in the plants themselves will cause moisture stress. Subsequently, the demand for water for irrigation is projected to rise in a warmer climate, bringing increased competition between agriculture, which is already the largest water consumer in semi-arid regions, and other water users (GCRIO, 1995).

The case of Cyprus

Regarding the effects of elevated CO$_2$ on plant growth and yield in Cyprus, there are no available relevant research findings. As for the duration of the growing season in Cyprus, a lengthened crop growing season was estimated according to EAA (2008a) for the period 1975-2007 with a rate of change of 0.4-0.8 for the biggest part of the island (Figure 6-16).

In general, Cyprus, a region with already warm and dry conditions especially during summer, is likely to experience yield losses due to the increase in temperature and evapotranspiration and the decrease in precipitation, while the projected climate conditions will magnify the already intense water stress circumstances provoking crop failure. According to a recent study conducted by the Agricultural Research Institute of Cyprus, it was concluded that climate variability, high temperatures and low precipitation pose limits to crop production in Cyprus (Bruggeman et al., 2011c).

Moreover, Cyprus has encountered serious drought events and water shortage problems by now with the agricultural sector being the most severely affected and especially the areas that practice irrigated farming for hundreds of years as part of their tradition, as it is the first to receive water cuts during drought years, leading to a significant decrease of the lands covered with annual crops such as vegetables and potatoes.

The following figure shows the crop production in Cyprus during the period 1980-2008, according to data provided by the Statistical Service of Cyprus (CYSTAT, 2010). As it can be observed, there is a general decreasing trend which is however attributed to various other factors apart from climatic parameters, such as the development of the tertiary sector, the accession of Cyprus in the EU and others.

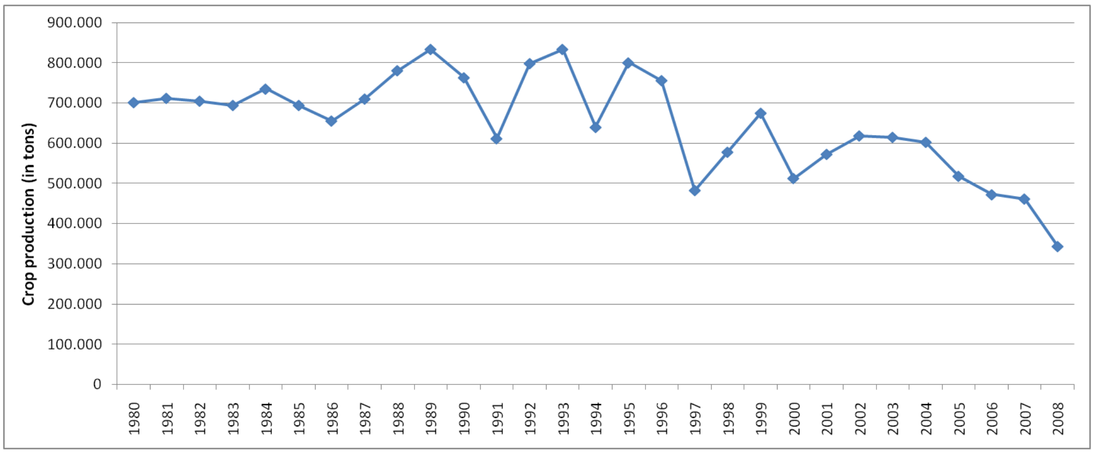


Figure 6-18: Production of main agricultural crops (in tons) in Cyprus, period 1980-2008 (CYPADAPT)

Source: CYSTAT, 2010

Next, the future climate changes in Cyprus for the period 2021-2050 that are considered to be associated with the impact of altered crop yields are presented in brief.

Although increases in temperature are expected to result in the lengthening of the growing season and increase crop yields, they also create less than optimal conditions for net growth due to increased rates of CO_2 plant release, increase moisture stress as well as the demand for irrigation water due to the increase in evapotranspiration rate and thus decrease crop yields. According to the PRECIS model, the mean change in annual average temperature in Cyprus with respect to the control period 1960-1990 will range from 1-2 ^{o}C on average.

In addition, high temperatures lead to reductions in crop yields due to the acceleration of plant maturation phase as well as due to the hindering of the photosynthesis process. PRECIS projections regarding future changes regarding the number of days with high temperatures, show that there will be an increase of 17-24 days per year in the average number of days with maximum temperature>30°C as well as an increase of 2-34 days per year in the average number of days with maximum temperature>35°C.

An increase in the length of the growing season and subsequently an increase in crop yields may also be deduced by a decrease in the number of frost days. For the case of Cyprus, a reduction in the mean number of frost days (temperature<0°C) per year is expected to decrease up to 8 days on average.

Furthermore, a decrease in rainfall and an increase in the drought periods are expected to decrease water availability for irrigation and to increase crop moisture stress and thus further decrease crop yields. PRECIS projections on annual average precipitation over the period 2021-2050 show minor changes or no changes at all. However, seasonal changes may be discerned, with winter and autumn precipitation presenting a decrease of 5-15 mm per year and a minor increase in summer and spring precipitation reaching up to 6-7 mm on average. The decrease in autumn precipitation when the sowing takes place is expected to have a negative impact especially on rainfed crops. In addition, the length of drought periods (precipitation <0.5mm) is projected to increase up to 13 days per year on average thus slightly magnifying water stress for agriculture.

6.3.2. Soil fertility alterations

The principal soil aspects that affect soil fertility and are susceptible to climate change are soil biodiversity, organic carbon content, available soil moisture, erosion, salinization and desertification.

Rising temperatures lead to loss of organic carbon from soils as the organic content is decomposed and mineralized with accelerated rate. Desertification phenomena cause the conversion of productive lands into non-productive.

Long dry periods along with regular strong seasonal winds are the main causes for wind erosion, while the force of raindrops, surface and subsurface runoff and river flooding are the main causes for rain water erosion (WMO, 2005).

Soil salinity is one of the most serious agricultural problems. The cause of this process is the accumulation of salts in soil capillaries leading to a sharp decrease in plant fertility. Salt concentration left in plant capillaries, with insufficient amount of nourishing substances leads to plants dying.

Moreover, climate change related factors, as for instance increasing temperatures have a significant influence on variations in timing, intensity and frequency of wildfire events. In case of serious and extended fire events, soil hydrophobicity can occur because of the decrease of hydraulic conductivity and runoff (Moss & Green, 1987). The reduction in quantity of surface cover caused by fires further exposes surface to erosive forces. The extended forest fires, affect the cultivation areas and put additional pressure on the agricultural sector (Behrens et al., 2010). On the other hand, fire affects nutrient cycling and the physical, chemical, and biological properties of soils since combustion of litter and soil organic matter increases the availability of some nutrients, while others are volatilized (for example, N, P, S).

Soil fertility in Cyprus experiences a declining trend. The phenomenon of erosion has affected the arable land in Cyprus and specifically the arable land and the land used for permanent crops. Indicatively it is mentioned that, during the period 1995 – 1999, 56% or 1130 km^2 of agricultural land, was eroded. However, it must be mentioned that, the available statistical figures denote that soil erosion has actually decreased in absolute values over time, while fluctuations are observed in the share of land that is affected (MANRE, 2007).

Table 6-7: Erosion trends observed on the agricultural land of Cyprus, 1980-1999

Period	Agricultural land		Arable land and land under permanent crops		Meadows and pastures	
	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%
1980 – 1984	1 305	56	1 285	73	20	51
1985 – 1989	1 230	58	1 210	77	20	44
1990 – 1994	1 215	49	1 200	77	15	42
1995 – 1999	1 130	56	1 120	78	10	76

Source: MANRE, 2007

It has been proved by a study assigned to I.A.C.O. Ltd (2007) by the Department of Environment of the Ministry of Agriculture, National Resources and Environment of Cyprus, that climate change can exacerbate desertification phenomena and loss of productive land in Cyprus, by deteriorating the quality of soil with the expansion of droughts. Regarding the fire risk in Cyprus, it is generally considered low but with some high rates of risk located in the forest areas (I.A.CO. Ltd, 2007; Iglesias et al., 2007).

Furthermore, soil salinization poses a threat to the fertility of Cyprus coastal agricultural land due the reduced water availability for irrigation from Government water supply schemes and the use of water from salinized coastal aquifers for irrigation, as many coastal aquifers have been affected by sea intrusion due to overexploitation (WDD, 2011a).

Next, the future climate changes in Cyprus for the period 2021-2050 that are considered to be associated with the impact of altered soil fertility are presented in brief.

Increasing temperatures may intensify the loss in soil organic carbon and soil moisture and increase wildfires and desertification. According to PRECIS projections for the future period 2021-2050, the average annual temperature in Cyprus is expected to increase by 1 - 2^{o}C with respect to the control period 1960-1990.

Reduced precipitation and increased drought periods reduce water availability and soil moisture. A reduction in surface water availability may lead to the overexploitation and depletion of aquifers which will result in sea intrusion to coastal aquifers. As also mentioned above, the irrigation with saline water may cause extended soil salinization. In addition, extended drought periods may intensify the phenomenon of soil erosion. PRECIS projections show that the annual average precipitation over the period 2021-2050 presents minor changes or no changes at all while the length of drought periods (precipitation <0.5mm) will increase up to 13 days per year on average. Thus, it considered that the impact of future climate changes on soil salinization and erosion will not be severe.

Finally, the increase in strong winds and in intense precipitation is reported to further magnify the phenomenon of erosion. However, no important impacts on soil erosion in the future are expected due to climate changes since PRECIS projections show that the highest mean wind speed in the future will present no changes at all or even minor decreases while the number of days with intense precipitation are expected to present a slight increase (2-5 mm) across the domain of the study.

For a more analytical presentation of climate change impacts on soil resources, on may refer to Chapter 3 “Soil resources”.

6.3.3. Increase in pests and diseases

Pest outbreaks, emergence of new pests and pathogens and an increase in the frequency of diseases, as secondary effects induced by higher temperatures and prolonged growing season will pose extra risk for crop production.

An additional point that should be taken into consideration is that weeds would undergo similar cycle acceleration as cultivated crops and would take advantage of the fertilization of CO_2. Given that the majority of weeds are classified as C3 plants, C3 species of weeds will become more competent and aggressive and may challenge the ability of crops to compete successfully (European Commission, 2007; Karki, 2008).

The case of Cyprus

There is no available and systemically organized information on pest and weed incidents concerning the agricultural crops and how their trends are correlated to climate change in

Cyprus. However, it is very likely that these factors along with the increased occurrence of diseases will exercise an additional pressure on the agricultural sector.

According to the PRECIS model, the mean change in annual average temperature in Cyprus with respect to the control period 1960-1990 will range from 1-2 ^{o}C on average. In addition, the growing season is expected to increase since the mean number of frost days (temperature<0^{o}C) is expected to decrease up to 8 days on average with respect to the control period 2021-2050 while the mean number of summer days (temperature >25^{o}C) per year in Cyprus is projected to increase by 19 - 32 days on average. The mean number of days per year with daily maximum temperature higher than 35°C (heatwave days) is expected to increase ranging from 2 to 34 days on average. Considering the above changes in future climate, it is expected the pests and diseases will increase in the future.

In order extract safe conclusions regarding the climate change impact of pests and diseases on the agriculture sector of Cyprus, the following are considered necessary:

- Data availability on pest/weed and diseases incidents from a long monitoring period
- Correlation with climatic conditions (high temperatures and frost days) and clear distinction of the effect from other factors influencing the occurrence of pests and diseases (e.g. farming practices)

6.3.4. Damages to crops from extreme weather events

There is evidence that from the beginning of the 21st century, damages to crops due to the occurrence of extreme weather phenomena (e.g. heat wave of 2003) show an increasing trend. These extreme events are likely to increase in frequency and magnitude, thus leading to a greater exposure of crop yields. In addition, the magnitude of damage caused to crops depends highly on the timing of the cycle of crops when extreme weather phenomena occur. Modifications concerning farming practices and sensible land use could counteract any resulting issues (EEA, 2008a; GCRIO, 1995; Bruggeman et al., 2011a).

More frequent occurrences of weather extremes, such as dry spells, heat waves, frost and hail incidents will potentially damage agriculture more than changes in the annual average temperature (Behrens et al., 2010).

The case of Cyprus

According to projections concerning the Mediterranean region, a rise of extreme weather events is already experienced and expected to continue in the future. For the case of Cyprus it is indicatively mentioned that, during the period from 1996 to 2005, it was observed that the number of hail events increased over time (Nicolaides et al., 2009).

From Figure 6-19 which presents the overall amounts of compensations provided to farmers during the period 1987-2007 for crop losses attributed to extreme weather events, based on data provided by the Agricultural Insurance Organization of Cyprus (AIO, 2008a), a slight increase in the amounts of compensations paid is observed which could imply an increase in the frequency and intensity of extreme weather events.

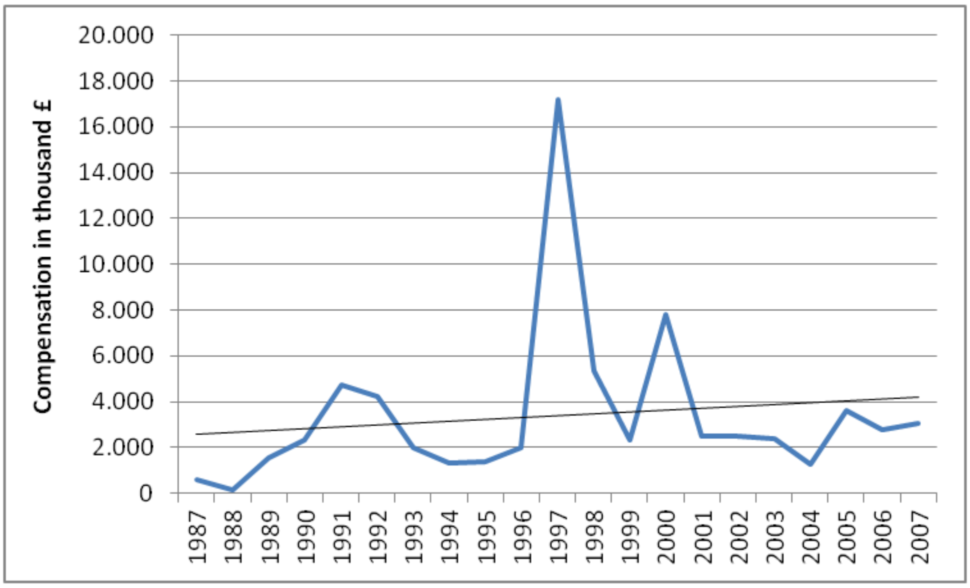


Figure 6-19: Compensation provided to farmers for damages caused to crops due extreme weather events in Cyprus (1987-2007) (CYPADAPT)

Source: AIO, 2008a

From Figure 6-20, which presents the amounts of compensations provided to farmers during the period 1978-2007 for each extreme weather event causing crop losses (AIO, 2008b), an increase in the amounts of compensation paid is observed, especially for crop damages caused by hail events.

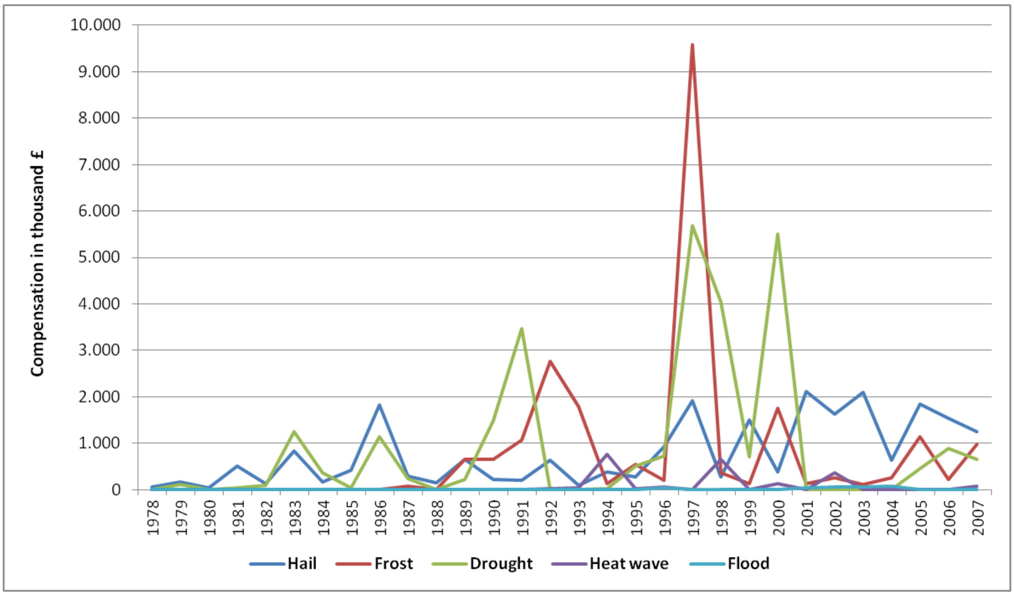


Figure 6-20: Compensation provided to farmers for damages caused to crops due extreme weather events in Cyprus, per event (1978-2007) (CYPADAPT)

Source: AIO, 2008b

Next, the future climate changes in Cyprus that are considered to be associated with the impact of damages to crops from extreme weather events are presented in brief.

According to PRECIS climate projections in Cyprus for the period 2021-2050, the length of drought periods (precipitation<0,5mm) is projected to increase up to 12days per year on average.

The mean number of heat wave days per year (temperature>35^{o}C) is expected to increase from +2 to +34 days per year. On the other hand, the mean number of frost nights per year (temperature<0^{o}C) is expected to decrease up to 8 days on average.

As for the heavy rainfall events which are associated with flooding events, the most relative indicator provided by PRECIS refers to the annual maximum total precipitation over one day. This indicator shows minor changes in the future period (2021-2050) ranging from 2 to 5 mm on average. However, this indicator alone is not sufficient for estimating future changes in the frequency and intensity of flooding events.

Considering the above, damages to crops due to extreme weather events in Cyprus are expected to be further intensified in the future, mainly due to the increase in the number of heat wave days and to a lesser extent due to the increase in drought periods while the damages to crops due to frosts are expected to be reduced.

6.3.5. Alterations in livestock productivity

Extended warm periods and heat waves are likely to adversely affect the livestock sector due to diseases outbreaks and heat stress suffered by animals which may result in reduction of the feed intake rate, the decline of growth and conception rates as well as in reduction of the productivity rates and can ultimately threat livestock life and lead to the extinction of species (Rowlinson, 2008).

In addition, warmer and drier climate conditions may reduce forage production resulting in shortage of animal feed which could modify animal diets and reduce growth and reproduction rates. Changes in precipitation patterns and in particular the increase in flooding events may also cause the spreading of animal diseases, thus putting additional constraints to livestock productivity (IFAD, 2009).

The case of Cyprus

The most important constraints of the livestock sector in Cyprus encompass the insufficient production of animal feed, as the limited water resources in Cyprus have also a negative effect on livestock feed production systems, as well as on fodder yields.

In the following figure, the meat and milk production in Cyprus during the period 1980-2008 is illustrated, based on the data provided by the Statistical Service of Cyprus (CYSTAT, 2010). As it can be seen, both meat and milk production follow a general increasing trend, while the years 2004-2007 are marked with a sudden reduction of production. However, in absence of sufficient data, this cannot be associated with climate changes, as there may be a number of other factors responsible for this reduction, such as market prices.

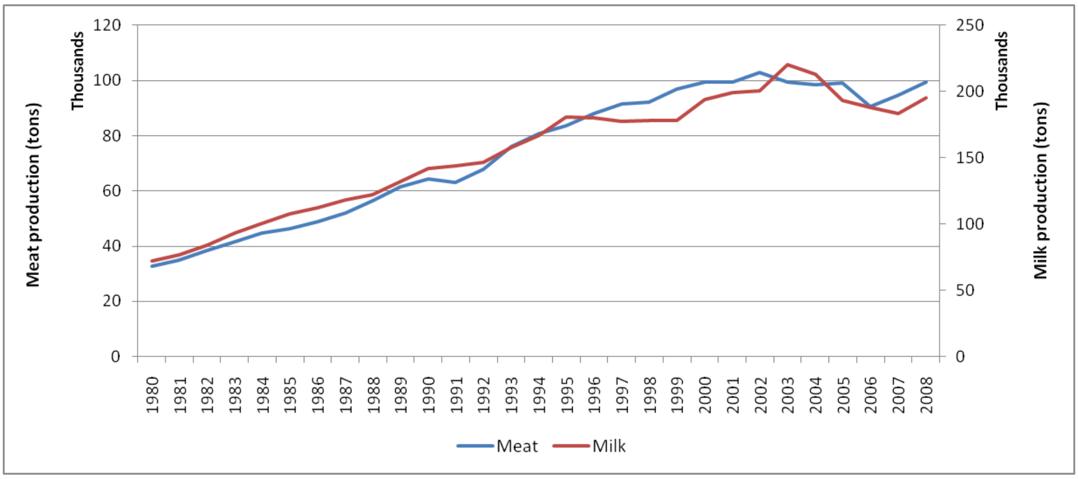


Figure 6-21 Meat and milk production in Cyprus, 1980-2008 (CYPADAPT)

Source: CYSTAT, 2010

In order to extract safe conclusions regarding the climate change impacts on livestock productivity in Cyprus, the following are considered necessary:

- Data availability on non-climatic factors affecting livestock production
- Correlation of livestock production with climatic conditions and clear distinction of the effect from other influential factors (e.g. market prices)

Next, the future climate changes in Cyprus for the period 2021-2050 that are considered to be associated with the impact of altered crop yields are presented in brief.

According to the PRECIS model, the mean number of hot days (temperature >30^{o}C) per year in Cyprus are projected to increase with respect to the control period 2021-2050 by 17 - 24 days on average. The mean number of days per year with daily maximum temperature higher than 35°C (heatwave days) is expected to increase ranging from 2 to 34 days on average. As previously mentioned, high temperatures and heatwaves are expected to reduce livestock productivity due to the increase in diseases outbreaks and the increase in animal heat stress as well as due to the reduction in the feed intake, conception, growth and productivity rates. In addition, high temperatures may lead to the reduction in forage production which could also affect livestock productivity.

Decreased precipitation and increased drought periods are also expected to reduce forage production given that they are mainly rainfed crops. However, PRECIS projections show that the annual average precipitation over the period 2021-2050 will present minor changes or no changes at all and that the length of drought periods (precipitation <0.5mm) will present a slight increase up to 12 days per year on average.

Increases in flooding events are also expected to increase diseases outbreaks and animal stress which could result in reduced livestock productivity. Nevertheless, it is projected that the number of days with intense precipitation which could also cause flooding events will present a slight increase (2-5 days) across the domain of the study.

6.3.6. Increase in costs for livestock catering

Reduced yields of forage crops due to increased temperatures and decreased rainfall in summer, increase costs for farmers for providing other sources of feeding. In addition, increased demand for irrigation of forage crops will further increase costs for farmers.

Increased risk for heat stress and unproductive grazing land during the summer months as well as the increase in extreme weather events may lead to increased housing requirements. Increased mechanical ventilation of both housing and transportation for livestock in order to reduce the risk of thermal discomfort in animals and the risk of spreading of diseases is also expected to increase the cost for livestock catering.

However, the risk associated with these problems is regarded as low (Iglesias et al., 2007).

The case of Cyprus

The livestock sector in Cyprus is constrained by the dependence on imports due to the insufficient production of animal feed. However, there is no sufficient information available in order to estimate the climate change impacts on the costs for livestock catering in Cyprus.

In order extract safe conclusions regarding the climate change impact on the costs for livestock catering in Cyprus, the following are considered necessary:

- Data availability on expenses made by farmers for importing animal feed, housing, ventilation etc.
- Correlation with climatic conditions and clear distinction of the effect from other factors

Next, the future climate changes in Cyprus for the period 2021-2050 that are considered to be associated with the impact of increased stocks for livestock catering are presented in brief.

According to the PRECIS model, the mean number of hot days (temperature >30^{o}C) per year in Cyprus are projected to increase with respect to the control period 2021-2050 by 17 - 24 days on average. In addition, the mean number of days per year with daily maximum temperature higher than 35°C (heatwave days) is expected to increase ranging from 2 to 34 days on average. The above mentioned changes are expected to increase housing requirements and relative costs in order to reduce thermal discomfort of livestock.

Increased temperatures together with decreased precipitation in summer will increase costs for farmers for irrigating forage crops or for providing other sources of animal feed. PRECIS projections show that the average summer maximum temperature over the period 2021-2050 will increase by 1.6-2.6^{o}C, while the change in average total summer precipitation will range from -2 to +6mm. Consequently, the overall impact however cannot be specified.

6.4. Future vulnerability assessment

In this section, the future vulnerability of the agricultural sector to climate change impacts is assessed in terms of its sensitivity, exposure and adaptive capacity, based on the available quantitative and qualitative data for Cyprus and the climate projections for the period 2021-2050. In particular, sensitivity is defined as the degree to which agriculture will be affected by climate changes, exposure is the degree to which agriculture will be exposed to climate changes and their impacts while the adaptive capacity is defined by the autonomous ability of agriculture to adapt to changing environmental conditions as well as by the effectiveness of the relative existing and planned adaptation measures.

For the assessment of future vulnerability, the same indicators used in the current vulnerability assessment (CYPADAPT, 2012) were used, wherever the necessary data were available. These indicators are summarized in Table 6-8.

Table 6-8: Indicators used for the vulnerability assessment of climate change impacts on the agricultural sector of Cyprus

Vulnerability Variable	Selected indicators
Crop yield	
Sensitivity	- Degree of sensitivity of C3 and C4 plants to CO_2 concentrations - Reduction in crop production during dry years - Degree of sensitivity of rainfed and irrigated crops to reduced precipitation - Water allocation for irrigation between permanent and temporary irrigated crops (%) - Degree of sensitivity of crops located at mountain areas - Degree of sensitivity of crops located at coastal areas
Exposure	- Areas covered with rainfed and irrigated crops - Contribution of rainfed and irrigated crops to the total crop production - Areas covered with permanent and temporary irrigated crops - Contribution of permanent and temporary irrigated crops to the total crop production - Percentage of unmet water demand for irrigation (water cuts) - Extension of areas with mountain crops - Extension of areas with crops located at the coastal regions - Future changes in average temperature - Future changes in the number of days with high temperature - Future changes in the number of frost days - Future changes in total annual and average precipitation - Future changes in the duration of droughts
Adaptive capacity	- Increase water availability from Government Water Works (increase storage capacity, use of desalinated water, treated effluent from WTTPs) - Increase water availability by applying on-farm practices (collection of rainwater)

Vulnerability Variable	Selected indicators
	- Increase water use efficiency in irrigation (redistribution of irrigated land, use of advanced irrigation systems, irrigation scheduling) - Reduce run-off - Use less water intensive crops - Increase crop productivity (crop rotation, fertilization, use of crops more resistant to hot and dry climates)
Soil fertility	
Sensitivity	- Degree of sensitivity of arable land to erosion - Degree of sensitivity of arable land to desertification - Degree of sensitivity of coastal agricultural land to soil salinization
Exposure	- Percentage of arable land subject to erosion - Salinization of coastal aquifers - Use of low quality (saline) groundwater for irrigation - Areas covered with coastal crops - Percentage of crops located in areas critical to desertification - Future changes in average temperature - Future changes in the number of days with intense precipitation - Future changes in highest mean wind speed - Future changes in total annual and average precipitation - Future changes in the duration of droughts
Adaptive capacity	- Substitution of the use of chemical products in agriculture (mechanical destruction of weeds, use of natural means for pest management, organic production) - Guidance and technical support to farmers regarding salinity and infiltration problems
Pests and diseases	
Sensitivity	- Plant species in competition with the agricultural crops* - Pest patterns* - Plant diseases favoured by the cypriot climatic conditions* - Crop types sensitive to diseases *
Exposure	- Number of pest outbreaks * - Areas covered by weeds * - Recorded incidents of diseases *
Adaptive capacity	- Promotion of indigenous and locally adapted plants and animals - Development of an integrated pest management strategy - Application of crop rotation - Resistance enhancement of existing plants and animals against pests and diseases - Use of pesticides
Damages to crops due to extreme weather events	

Vulnerability Variable	Selected indicators
Sensitivity	- Crops affected by extreme climatic events - Extreme climatic events affecting crops in Cyprus - Degree of sensitivity of crops to each extreme weather event
Exposure	- Frequency of extreme climatic events causing damages to crops in Cyprus - Future changes in the number of heat wave days - Future changes in the number of frost days - Future changes in the number of days with intense precipitation - Future changes in the duration of droughts
Adaptive capacity	- Increase water availability for irrigation and reduce run-off - Installation of windbreaks - Establishment of woodlands - Covering crops with nets for the protection from hail
Livestock productivity	
Sensitivity	- Animal species sensitive to increased temperatures and heat waves and percentage of their population over the total animal population in husbandry * - Degree of sensitivity of conception and production rates during extended warm periods *
Exposure	- Frequency of extended warm periods in Cyprus * - Reduction of the available animal feed * - Number of incidents of diseases outbreaks and heat stress on livestock * - Percentage of livestock with no housing and ventilation facilities *
Adaptive capacity	- Improve outdoor conditions (plantation of hedgerows of forest trees for increasing shade and decreasing wind force) - Improve indoor conditions (use of thermostats, cooling and ventilation systems within animal housing areas) - Establishment of a gene bank for animal species to protect genetic diversity - Improved breeding and management methods - Veterinary services for animal disease control and treatment - Enhancing local production of animal feed - Enhancing management skills of farmers
Costs for livestock catering	
Sensitivity	- Increase in costs for livestock catering during extended warm periods in Cyprus *
Exposure	- Deficit in local animal feed production * - Excess costs for importing animal feed, for providing housing, ventilation *

Vulnerability Variable	Selected indicators
Adaptive capacity	- Financial support provided by the Rural Development Programme of Cyprus for improving outdoor and indoor conditions for livestock

**There were no data available regarding this indicator*

The relationship between sensitivity, exposure and adaptive capacity is based on the following qualitative equation:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity * Exposure$$

Sensitivity, exposure and adaptive capacity are evaluated on a 7-degree qualitative scale ranging from “none” to “very high”.

In the sections that follow, the vulnerability is assessed for each of the impact categories presented in Section 6.3:

1. Crop yield
2. Soil fertility
3. Pests and diseases
4. Damages to crops from extreme weather events
5. Livestock productivity
6. Costs for livestock catering

It must be noted that, there are no sufficient scientific evidence and data to evaluate or correlate all impacts and indicators to future climate changes. Consequently, further research is required in order to provide concrete information for a more detailed and descriptive assessment of the future vulnerability of the sector. Nevertheless, an attempt was made to provide a preliminary assessment of the future vulnerability. In case additional data are provided by the competent authorities of Cyprus, the future vulnerability of the sector could be re-assessed.

6.4.1. Crop yield alterations

6.4.1.1. Assessment of sensitivity and exposure

In general, the plants which are quite sensitive to increased concentrations of CO_2 belong to the C3 physiological class. These plants account for 85-95% of all plant species. Corn, sorghum, sugarcane and millet belong to the C4 class which is less sensitive to elevated concentrations of carbon dioxide even though they possess a greater photosynthetical efficiency. On average, it is estimated that, compared to current atmospheric CO_2 concentrations, crop yields increase at 550 ppm CO_2 in the range of 10-20% for C3 crops and 0-10% for C4 crops (Easterling et al., 2007).

However, C3 plants are more sensitive to hot and dry conditions compared to C4 plants. C3 plants present accelerated rates of CO_2 release during the process of respiration, resulting in less photosynthetic efficiency and optimal conditions for net growth. On the other hand, the process of photosynthesis in C4 plants and CAM plants is faster than C3 plants under high light intensity and high temperatures and they present better water use efficiency adapted to arid conditions.

Considering the above, it is assumed that for hot and dry conditions as in Cyprus, the positive effect of increased CO_2 concentrations on the yield of C3 plants is counterbalanced by their decreased photosynthetic and water use efficiency in such climates.

In order to assess the sensitivity of crop production to precipitation, data on annual crop production from the Statistical Service of Cyprus (CYSTAT, 2010) were used in conjunction with data on precipitation provided by the Meteorological Service of Cyprus (MSC, 2012), for the period 1987/88-2007/2008. The data - illustrated also in Figure 6-22 - show that crop production is highly sensitive to precipitation as both rainfed and irrigated crops fluctuate over time in parallel to the fluctuations in precipitation, with rainfed crops being a little more sensitive than irrigated crops. Especially for the year 2008, a decline of 10.5 % in the gross output production was reported as a consequence of adverse weather conditions (Figure 6-5). The lack of water caused an extensive reduction of crop production, with rainfed crops such as cereals, straw and green fodder being mostly affected, presenting a reduction of 90%, 85% and 87.6% respectively. During the period 2002-2008 in Cyprus, rainfed crops covered on average 82% of the total crop area and irrigated crops the rest 18% on average while their contribution to the total crop production was 32% and 68% respectively (CYSTAT, 2010). Considering the percentage of rainfed crops in the total crop production, the exposure of crop yields regarding this indicator, is characterized as moderate.

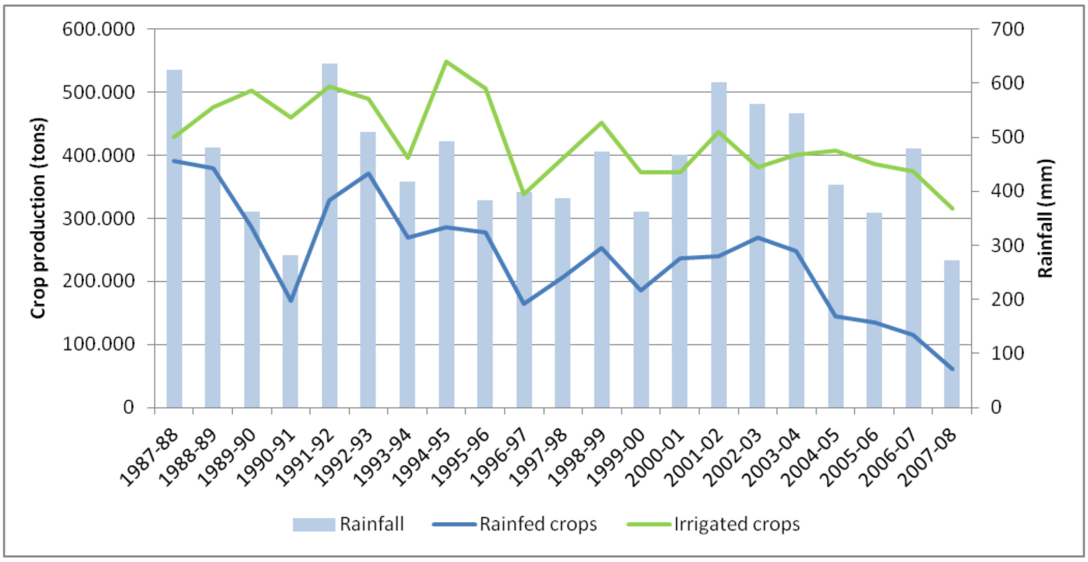


Figure 6-22: Rainfed and irrigated crop production and precipitation during the period 1987/88-2007/8 (CYPADAPT)

Source: CYSTAT, 2010; MSC, 2012

In addition, the sensitivity of crop production to water availability especially for irrigated crops depends on the water allocation policy of Cyprus under drought conditions (water rationing) and the prioritization of water uses. While the first priority is to satisfy the water demand of the domestic sector, the second priority is to maintain supplies to permanent crops at 80% of the recommended application levels and the last priority is to satisfy water requirements for temporary (vegetable) crops (WDD, 2011b). In general, water cuts in irrigation during the period 2000-2010 from the South Water Conveyor System, which is the water provider for the majority of the agricultural areas in Cyprus, ranged from 10% to 90% with the exception of 2004 where the water cuts were equal to zero (WDD, 2011b).

Consequently, irrigated temporary crops are more exposed to reduced water availability under drought conditions. During the period 2002-2008 in Cyprus, irrigated temporary crops covered on average 28% of the total crop area and produced 44% of the total production (CYSTAT, 2010). Considering the percentage of irrigated temporary crops in the total crop production, as well as the restrictions imposed to irrigation during drought periods, the exposure of crops to reduced water availability, is characterized as high to very high.

This is also shown in the study of Bruggeman et al. (2011c), which concluded that temporary crop production presents a fluctuation over time, following a similar trend to that of precipitation, i.e., in dry years the production decreases and vice versa while on the other hand, production of permanent crops presented a steady decrease with minor fluctuations over the past 29 years (see Figure 6-23).

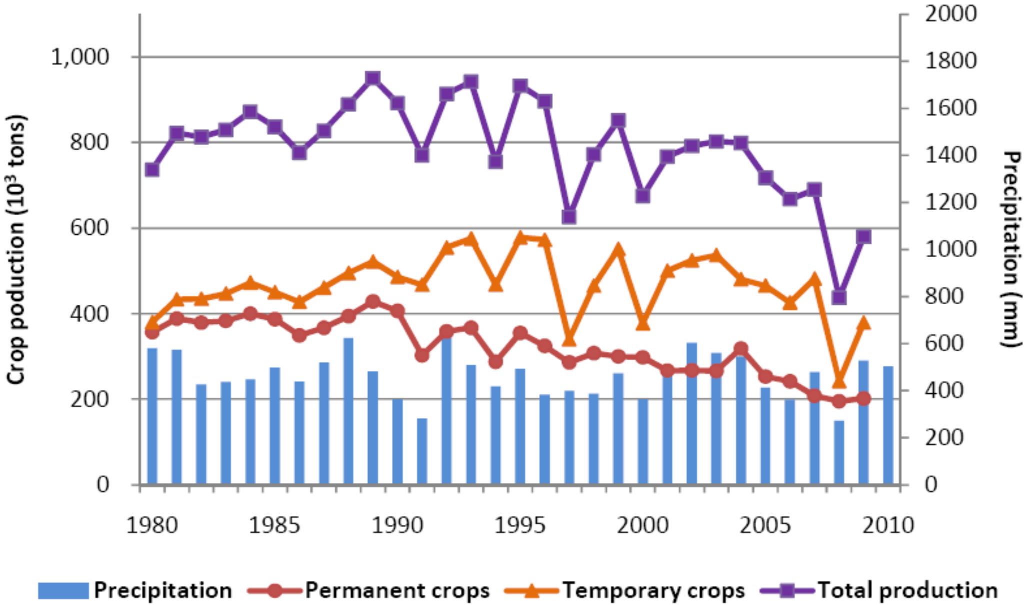


Figure 6-23: Crop production and precipitation during 1980/81-2009/10

Source: Bruggeman et al., 2011c

The study also concluded that the loss in irrigated production is mainly due to the reduction in irrigation water supply, whereas the loss in rain-fed production is both due to climate change and an overall decrease in agricultural land use (Bruggeman et al., 2011c).

The geographical distribution of crops is also linked with reduced water availability and crop yields under climate changes, as for example, the development of Government Water Works (dams, water conveyor systems, water treatment plants) in the steep mountain areas is impeded by technical difficulties thus rendering groundwater resources as the unique source of water for both drinking water and irrigation and leading to the overexploitation of the source. However, as the levels of groundwater resources depend on climate parameters such as precipitation and evapotranspiration as well as on climate-related parameters such as soil moisture and run-off, it is considered that groundwater resources and subsequently crops located in the mountain areas are very sensitive to climate changes, especially during prolonged drought periods (>1year). In addition, given that the main source of income of people residing in the mountain areas in Cyprus is agriculture, the sensitivity to this impact is magnified. However, it must be mentioned that there are limited crops located in the mountain areas (see Figure 6-24).

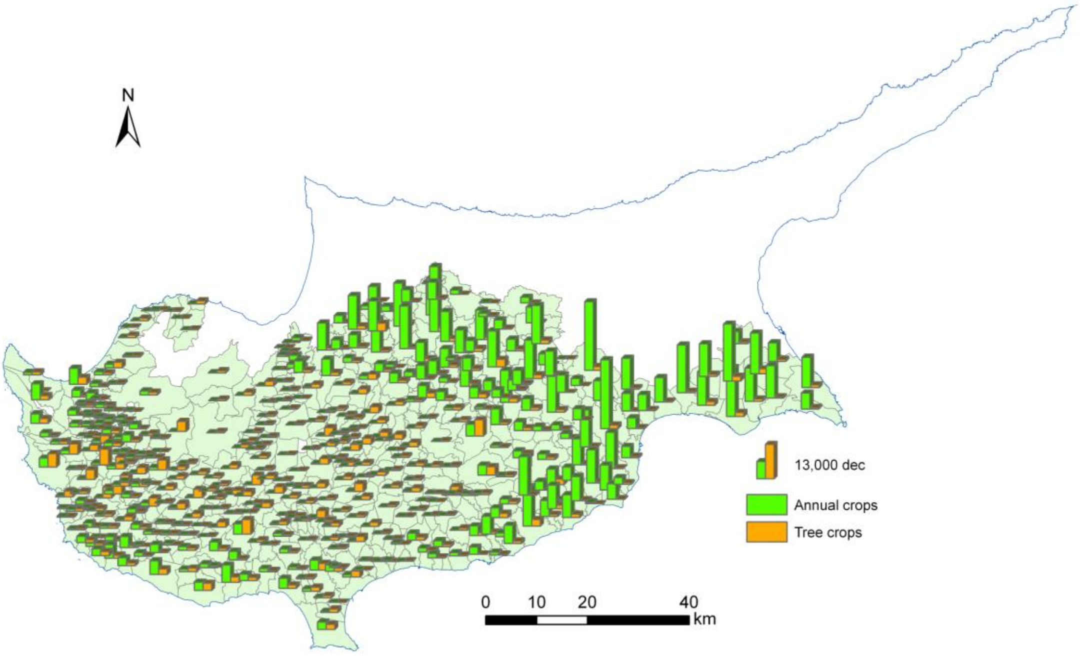


Figure 6-24: Distribution of the annual and tree crops

Source: Bruggeman et al., 2011d

On the other hand, although flat plain areas and coastal regions have less precipitation than mountainous regions, government irrigation schemes are usually found in the plains and coastal areas (see Figure 6-25). In addition, government water works in the coastal areas such as the Southern Conveyor Project or the Pafos Water Work are also connected to desalination plants which increase drinking water supply and reduce competition for water between water users, in this case between the domestic and the agricultural sector. On the other hand, the agricultural irrigated areas connected to the other government water works (e.g. the Pitsilia and the Chrysochou irrigation projects) are more exposed to reduced precipitation and to extended drought periods.

Figure 6-25: Major Government Water Works in Cyprus

It must be noted though that, crop yields in coastal areas that are irrigated with groundwater from private boreholes are adversely affected due to the irrigation of crops with low quality (saline) water, as a result of water scarcity and limited water availability for irrigation, overexploitation of groundwater resources and their subsequent decline which in turn caused sea intrusion and salinization of most coastal aquifers. With climate changes, the aforementioned effects on the crops located at the mountain and coastal areas are expected to be exacerbated, thus making them highly sensitive to climate changes.

Next, the projections for the main climate parameters associated with reduced crop yields due to reduced water availability are presented.

According to the PRECIS model, all north coasts and especially Karpasia peninsula are expected to receive less annual total precipitation in the future than that estimated for the recent past years 1961-1990. In all other parts of Cyprus, the annual total precipitation appears to have minor decreases or no changes at all with the exception of the area east from Paphos where an increase in total annual precipitation is noticed, minor though (up to 5mm). Concequently, the agricultural lands located at the area of Pafos and in particular the rainfed ones, are expected to be slightly benefited by the increase in precipitation.

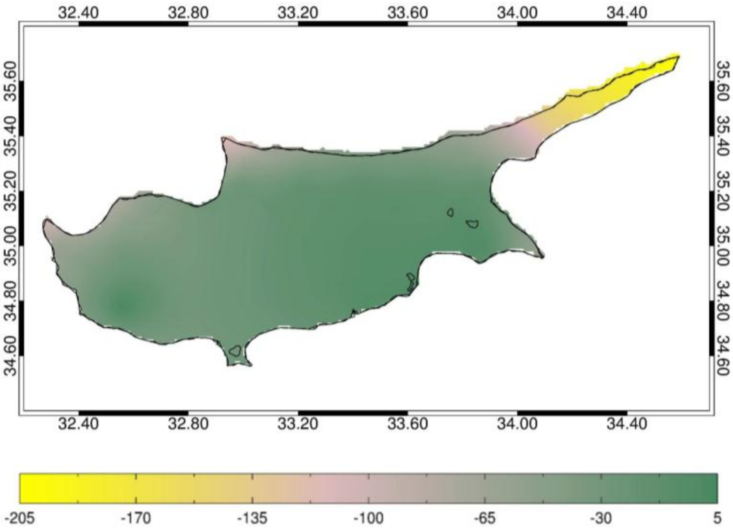


Figure 6-26: Changes in annual total precipitation between the future (2021-2050) and the control period (1961-1990)

Although a minor reduction in precipitation of 5% is estimated based on the PRECIS model for the areas where the main dams of Cyprus are located, this could lead to a 23% decrease in the future total dam inflow according to the relationship precipitation-dam inflow exhibited in the Chapter Water Resources, Section 2. However, it must be mentioned that this method does not take into account changes in evapotranspitation and runoff conditions in the future which could potentially further decrease inflow. To estimate the change in future groundwater availability, the current (1970-2000) water balance was adjusted based on the future dam inflows while the ratio between surface water, groundwater and losses to the sea was maintained. The available groundwater resources in the future, according to this water balance, are estimated to be reduced by approximately 29%.

As far as the length of drought periods in the future (2021-2050) is concerned, it is anticipated that the western coastal areas (Pafos agricultural areas) and higher elevation regions of Cyprus, as well as the area of Ayia Napa, will have slight decreases or no changes in the maximum length of dry spell. On the other hand, the central part of Cyprus will face an increase in the maximum length of dry spell. In particular, the increase of this index will be about 15 days/year in the continental agricultural areas near Nicosia, Kokkinochoria and Larnaca and approximately 20 days/year in the eastern part of Troodos (north from Limassol) (Figure 6-27). However, it must be mentioned that the continental irrigated agricultural areas are, to a large extent, provided with water from the Southern Conveyor Project which is more rainfall independent, while the irrigated crops located at the mountain areas which are supplied from other government water works which depend solely on precipitation and their water reserves during drought periods are very low, will be more exposed to the increased drought conditions. Nevertheless, as shown in Figure 6-24 mountain crops are limited.

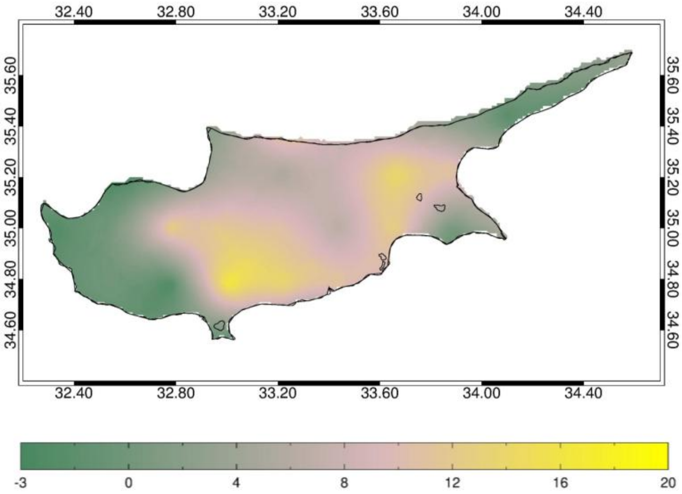


Figure 6-27: Changes in maximum length of dry spell (RR<0.5mm) between the future (2021-2050) and the control period (1961-1990)

At this point, it is considered essential to cite the results of the study of *Bruggeman et al., 2011c* which has among its aims to assess the effect of possible climate change scenarios and reduced irrigation water supply on crop production for the last seven seasons of this decade (2013/14-2019/20), based on climate change projections for Cyprus from an ensemble of six Regional Climate Models, under the medium A1B emission scenario of the UN Intergovernmental Panel on Climate Change (IPCC-SRES). The climate change projections indicated an increase in temperatures and highly variable but slightly lower precipitation amounts for the 2013/14-2019/20 seasons. However, *Bruggeman et al., 2011c* decided to use the observed daily data of the past to represent the future, as neither Global Circulation Models nor Regional Climate Models reproduce the past and present spatial and temporal distribution of daily precipitation very well (e.g., Dai, 2006; Boberg et al., 2009), especially in complex topographic environments such as Cyprus (Hadjinicolaou et al., 2010). In particular, based on two possible climate change scenarios, represented by more dry years, higher evaporative demand, and less irrigation water supply which resulted in a reduction of the 2010 irrigated area by 25%, a possible reduction of 41 to 43% in total national crop production for 2013/14-2019/2020 relative to 1980/81-2008/09 was projected. For the estimation of the changes in crop production in the future period under investigation in the framework of this study (2021-2050), it is recommended that a crop simulation model should be used in conjuction with the climate changes projected by PRECIS, in order to combine climatic, meteorologic, soil, phenology and cultivating data (Soussana et al., 2010).

The length of the growing season will be influenced mainly by the increase in temperatures in autumn and spring (Ainsworth and Long, 2005; Norby et al., 2003; Kimball et al., 2002; Jablonski et al., 2002) and the decrease in the number of frost days. According to the PRECIS model (Figure 6-28), the minimum increase in average autumn maximum temperature (1.0°C) is expected in the northern coasts (including the Chrysochou agricultural area), as well as in the southeastern area (near Kokkinochoria agricultural area). The continental lowland regions together with the southern coastal areas exhibit a moderate increase in autumn maximum temperature, while the highest increase (2.0°C) is located in the area around southern Troodos. The spring season is characterized by an average TX increase of 1.0°C at the northern coasts (including the Chrysochou agricultural area) and at the southeastern area (near Kokkinochoria agricultural area), while a larger TX change is observed in the southern coasts and continental lowlands. The higher elevation regions of Cyprus maintain the maximum increase of the spring average TX of 1.8°C (Figure 6-29).

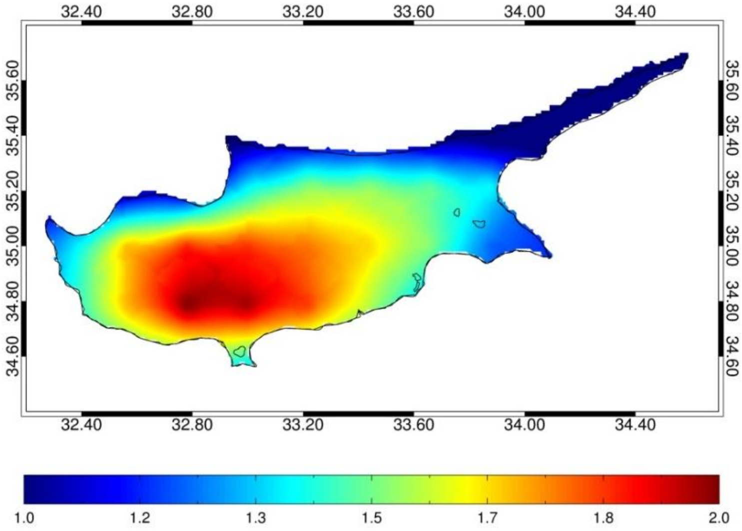


Figure 6-28: Changes in average autumn maximum temperature between the future (2021-2050) and the control period (1961-1990)

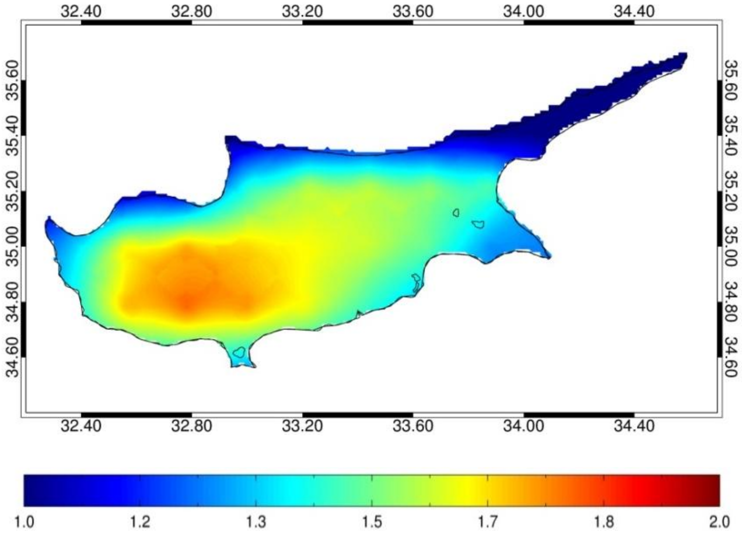


Figure 6-29: Changes in average spring maximum temperature between the future (2021-2050) and the control period (1961-1990)

As for the changes in the number of frost nights (temperature<0^{o}C), a decrease is anticipated of the order of 0-8 nights in Paphos, 2-8 nights in the Acrotiri agricultural areas

(Limassol), 4-7 nights in the continental lowland agricultural areas near Nicosia and 0-2 nights in the agricultural areas located in the coastal areas between Larnaca and Agia Napa. The model output shows that the highest decrease of frost nights reaches 6-9 days in the greater area around central and southern Troodos (Figure 6-36).

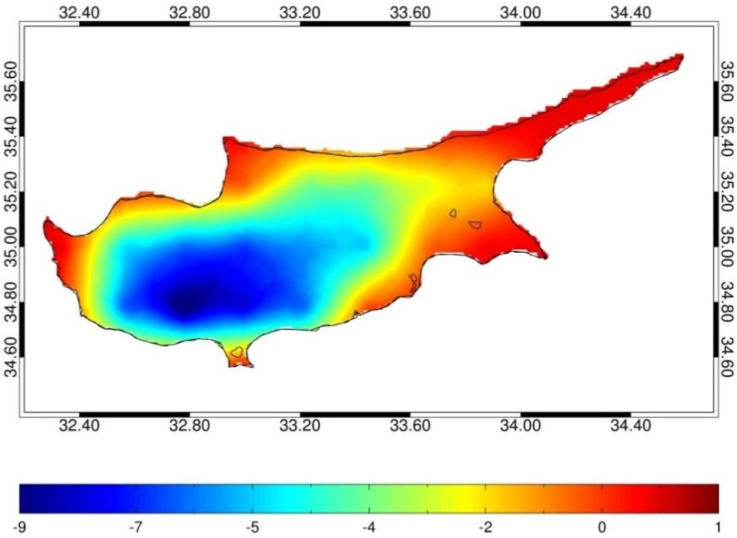


Figure 6-30: Changes in the annual number of frost nights (TN<0^{o}C) between the future (2021-2050) and the control period (1961-1990)

Considering that both autumn and spring temperature are expected to increase in the future as well as that the number of frost nights is expected to decrease, it is highly likely that the length of the growing season will be extended. In addition, since the most profound changes indicating lengthening of the growing season are located at mountain areas, mountain crops are expected to experience an increase in their yield due to the increase of the growing season.

Taking into consideration all the aforementioned indicators used for estimating the magnitude of the impact of climate changes on crop yields, the sensitivity to this impact is characterized as **very high** and the exposure as **high**.

However, it is highly recommended that for the projection of future crop yields based on climate changes, crop development models should be used which combine climatic, meteorologic, soil, phenology and cultivating data for the elimination of forecast errors (Soussana et al., 2010).

6.4.1.2. *Assessment of adaptive capacity*

The practices applied in Cyprus in order to reduce the impact of reduced crop yields are mainly associated with measures for (a) increasing water availability for irrigation, (b) reducing water demand for irrigation and (c) increasing crop productivity.

(a) Increase water availability for irrigation

The increase in water availability for irrigation is achieved through Government Water Works which aim in increasing water availability for all uses as well as through on-farm practices thus resulting in more water available for irrigation.

i) Increase water availability from Government Water Works

Increase water storage capacity by constructing numerous reservoirs, utilization of non conventional water resources such as such as desalinated water, treated water from Waste Water Treatment Plants (WTTPs). By increasing water availability with the use of desalinated water, drinking water requirements are satisfied thus allowing for more freshwater resources to be used for irrigation. Treated wastewater is used in agriculture for the irrigation of crops (excl. edible raw vegetables). However, the water demand of the agricultural sector is still not fully met due to the large amounts of water required (60% of total water demand in Cyprus) and the water scarcity characterizing the island.

ii) Increase water availability by applying on-farm practices

Farmers may explore other ways to supplement water supply and secure sufficient and continuous crop irrigation. This may be achieved by on-farm rainwater harvesting and establishing small-scale water reservoirs on farmland while ensuring the sustainable use of water resources and avoiding groundwater overexploitation. However, these practices do not find wide application in Cyprus. In order to promote such initiatives on farm level, the Rural Development Programme 2007-2013 of Cyprus, is providing incentives to farmers for the implementation of these measures.

(b) Reduce water demand for irrigation

The reduction in water demand for irrigation is achieved through (i) increasing water use efficiency in irrigation, (ii) reducing run-off and (iii) using less water intensive crops.

i) Increase water use efficiency in irrigation

- *Redistribution of irrigated land*. Land redistribution constitutes another measure which is directly linked with the decrease in water demand, through the reduction in the fragmentation of agricultural holdings, the opportunity for scale economies in irrigation works and the achievement of significant water savings. Since 1969, 62 out of 73 submitted redistribution plans referred in irrigated land and 3 in mixed, irrigated and rainfed land. In addition, another 12 plans are in progress and 27 under examination, both referring in irrigated land (WDD, 2011b).

- *Use of advanced irrigation systems*. A Water Use Improvement Project has been implemented by the Department of Agriculture since 1965. According to this project the government provided farmers with technical and financial assistance to turn from traditional surface irrigation methods to modern irrigation methods. Due to the relatively high installation costs, the drip method was initially used for irrigation of high value crops, such as greenhouse vegetables and flowers. At a later stage, the installation cost was reduced, and the use of drippers, mini sprinklers and low capacity sprinklers was expanded for irrigating trees and field vegetables. As a result, during the last decades farmers have extensively adopted modern irrigation systems. The new technology introduced is continuously being tested by the Agricultural Research Institute in order to evaluate the different systems under local conditions and select the appropriate irrigation method for each crop. The progress in the irrigation efficiency from less than 45% in 1960, reached 71% in 1980, 80% in 1990, 84% in 2000 and 90–95% in 2010. The on-farm irrigation systems comprise 90% micro-irrigation, 5% sprinkler irrigation and 5% surface irrigation (WDD, 2011b). Furthermore, the Agricultural Research Institute is conducting research for the design and application of hydroponics systems and the production of irrigation water through air condensation, in order for further savings in irrigation water to be achieved.

- *Irrigation scheduling*. Decisions on when and how much to irrigate are critical both to water use efficiency and to crop health. Irrigation scheduling aims at determining the exact amount of water to irrigate and the exact timing for application. Irrigation scheduling offers an opportunity for improving water efficiency at farm level and depend on private initiatives so its application cannot be considered wide. To further promote its application, the Rural Development Programme 2007-2013 of Cyprus is providing incentives to farmers for the implementation the application of integrated production management in the cultivation of potatoes and citrus, which inter alia foresees the sustainable use of water by following certain irrigation programmes and irrigation schedules.

ii) <u>Reduce run-off</u>

A number of practices applied in agriculture contribute to the reduction of run-off, such as terracing, contour plowing, installation of hedgerows, application of advanced irrigation systems and fire protection measures. The Good Agricultural and Environmental Conditions, a group of measures foreseen under the Cross Compliance[4] of the Rural Development Programme of Cyprus, include a number of standards for reducing run-off, which include:

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[4] Minimum requirements that farmers receiving direct payments must comply with

- *Minimum soil cover*: There should be a natural / plant vegetation for the cover of land with a slope greater than 10% during the period of rainfalls.
- *Minimum land management reflecting site-specific conditions*: In a land with a slope greater than 10%, contour plowing must be exercised. Soil cultivating during periods of heavy rain should be avoided, especially in clay and heavy soils.
- *Terracing*: Terraces / stone walls and natural slopes at the boundaries of the crop holdings should be maintained. The construction of terraces is also financially promoted through the Rural Development Programme.

However, the implementation of these practices are mandatory only for those farmers receiving direct payments from the RDP, while their independent implementation depends on private initiatives on farm level based on farmer's awareness on the issue and on the available methods for dealing with it.

iii) Use less water intensive crops

The existing crop patterns in Cyprus have been developed many years ago, when water availability was substantially higher. The decrease of water availability during the last years highlights the need to turn to less water intensive crops. However, this is a rather time-consuming process as most farmers have been adjusted to certain crops in terms of experience, know-how and equipment.

Among the proposed measures in the Programme of Measures of the Cyprus River Basin Management Plan (WDD, 2011a, - Annex III), the carrying of a study on the readjustment of crops towards a less water intensive crop mix in collaboration with the Department of Agriculture, the Agricultural Research Institute, the Ministry of Commerce, agricultural organizations, etc was proposed.

(c) Increase crop productivity

The increase in crop productivity is achieved through (i) the application of crop rotation, (ii) fertilization and (iii) using crops more resistant to hot and dry climates.

i) Crop rotation

The application of crop rotation and fallow on cultivated land is also associated with greater soil organic matter, soil structure and aggregation compared to simple rotations or mono-cropping. However, this practice entails that for at least one year there will be no revenues as there will be no crops cultivated. To compensate for these losses, the Rural Development Programme 2007-2013 of Cyprus is providing incentives to farmers for the implementation of crop rotation in crops of potatoes and arables.

ii) Fertilization

Management practices that enhance soil fertility apart from the use of chemical fertilizers and crop rotation, include the application of organic residues which are rich in nutrients (e.g. humus) to soil. The Good Agricultural and Environmental Conditions foreseen under the Cross Compliance[5] of the Rural Development Programme of Cyprus, include a set of standards for managing crop residues and suggest that depending on weather conditions, producers may use plant residues as soil cover or integrate them in the soil for annual crops.

It must be mentioned that the common practice in Cyprus for increasing crop productivity is the use of chemical fertilizers. Fertilization with chemical products although significantly contributes to the enhancement of soil fertility, is not considered a sustainable practice as it results in the pollution of water with the leaching of nitrates and is restricted by law on stressed areas.

iii) Use crops more resistant to hot and dry climates

Crop productivity under adverse climatic conditions may be ensured by the genetic improvement of plants in order to increase their resistance to those conditions and reinforce their adaptive capacity to climate change. The Agricultural Research Institute of Cyprus is conducting a research on the genetic improvement of plants for adaptation to climate change. Specific objectives of this research are the increase in crop yields, the increase of the resistance to abiotic and biotic stresses and the genetic improvement of a local variety of beans (*louvi*) and barley for increased adaptability to the warm and dry environment of Cyprus. These varieties were selected due to their substantial economic importance for Cyprus.

Considering the number of measures applied in Cyprus that contribute to the enhancement of the adaptive capacity of crop productivity to climate changes as well as the level of their adoption, their integration into farm practices and their effectiveness, it is estimated that the adaptive capacity towards this impact is **limited to moderate**.

Following, additional recommended adaptation measures (Shoukri & Zachariadis, 2012) that are considered to further enhance adaptive capacity towards this impact are presented indicatively. Nevertheless, their assessment and final selection for implementation will be made through the use of the Multicriteria Analysis (MCA) tool which will be developed and implemented in the framework of Actions 4 and 5 of the CYPADAPT project.

- Changing land use in areas that are more susceptible to drought
- Adjust cropping calendar (sowing-planting) - earlier planting, so that maturation occurs before the summer when temperatures are higher
- Increase rainwater harvesting and use in agriculture
- Increase the use of recycled water in agriculture
- Irrigating at night when evapotranspiration is reduced

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[5] Minimum requirements that farmers receiving direct payments must comply with

6.4.2. Soil fertility alterations

6.4.2.1. *Assessment of sensitivity and exposure*

Soil fertility is sensitive to increasing temperatures as they intensify the loss in soil organic carbon and soil moisture and increase wildfires and desertification. According to the PRECIS model, the change in average annual maximum temperature (TX) for the period 2021-2050 will range from an increase of 1.0 – 1.5 °C at the eastern coastal agricultural area of Kokkinochoria (Famagusta) and the western coastal agricultural area of Chrysochou to +2.0°C in higher elevation areas and especially at the southwestern side of Troodos. The lowland and continental agricultural areas in the central part of the country (greater area of Nicosia) present also notable changes in the average annual TX (mainly more than +1.5°C), followed by the western and southern coastal agricultural areas with a temperature increase limited to 1.3-1.7°C (Figure 6-31). To sum up, all agricultural areas are expected to be exposed to increased temperatures and especially the mountain areas, followed by the continental lowland agricultural areas and the coastal agricultural areas.

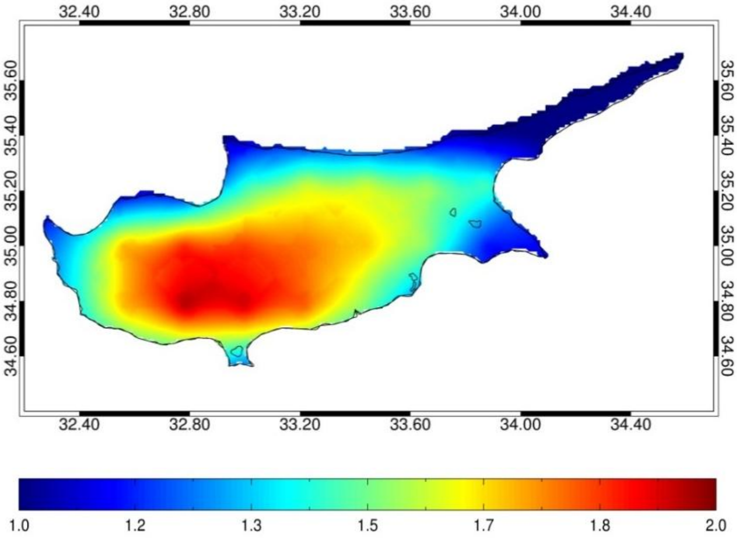

Figure 6-31: Changes in average annual maximum TX between the future (2021-2050) and the control period (1961-1990)

Soils are sensitive to long dry periods along with regular strong seasonal winds as they causes wind erosion. In addition soil erosion by rain is caused by intense precipitation and river flooding. However, the agricultural land in Cyprus and especially arable land and land used for permanent crops which constitutes approximately 70% of the total agricultural land, is sensitive to erosion mainly due to the intensive cultivation and overexploitation of land resources, which overburden the soil and reduce its productivity. The current exposure of agricultural land to erosion is considered as very high, as during the period 1980 – 1999, on average 55% or 1,220 km^2 of agricultural land was eroded from which 99% (1,200 km^2)

was arable land and land used for permanent crops and 1% was meadows and pastures (see Table 6-7) (MANRE, 2007).

As for the future changes in droughts and strong winds affecting the exposure of soils to wind erosion, these are presented next. In particular, the length of drought periods in the future (2021-2050) is expected to have slight decreases or no changes at all at the western coastal areas (Pafos agricultural areas) and higher elevation regions of Cyprus, as well as at the area of Ayia Napa. On the other hand, the central part of Cyprus will face an increase in the maximum length of dry spell. In particular, the increase of this index will be about 15 days/year in the continental agricultural areas near Nicosia, Kokkinochoria and Larnaca and approximately 20 days/year in the eastern part of Troodos (north from Limassol) (Figure 6-32).

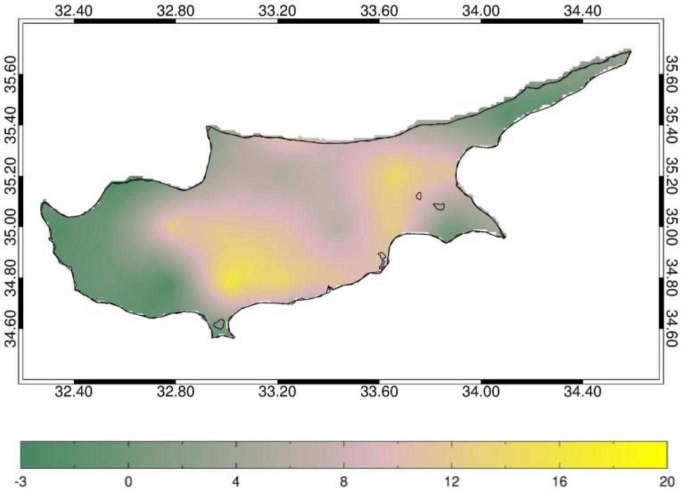

Figure 6-32: Changes in maximum length of dry spell (RR<0.5mm) between the future (2021-2050) and the control period (1961-1990)

Concerning future changes of extreme wind events, it is expected according to PRECIS that the number of days with mean wind speed greater than 5 m/s will decrease about 12 days in the western, southeastern and inland areas while in mountain areas the decrease varies from 5 days to 10 days depending on the elevation. Also southern areas will present a slight decrease of about 5 days (Figure 6-33). In general, all agricultural areas are characterized by decreases in strong winds.

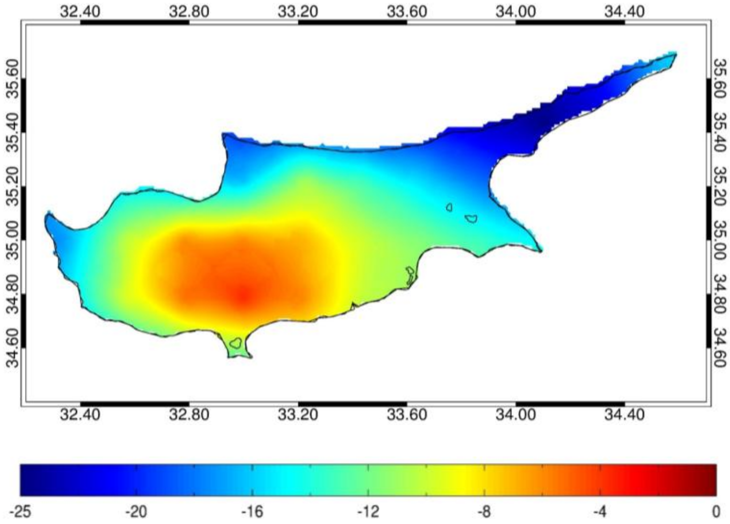

Figure 6-33: Changes in the number of days with mean wind speed > 5m/s between the future (2021-2050) and the control period (1961-1990)

Considering the above changes in climate, it is expected that the exposure to soil erosion by wind in the future due to climate changes will not further intensify.

As regards the future exposure of agricultural land to erosion by rain, the future changes in the maximum amount of rainwater that falls in a short period of time (1 day in this case) within the year is used. PRECIS projections show that a slight increase of about 2-4 mm is anticipated in western, inland and mountain regions. Additionally, southern and southeastern areas present an even minor increase of about 1 mm in annual max total rainfall over 1 day (Figure 6-34). Considering that the change in the future towards this indicator is of minor importance, it is expected that the exposure to soil erosion by rain in the future due to climate changes will not further intensify.

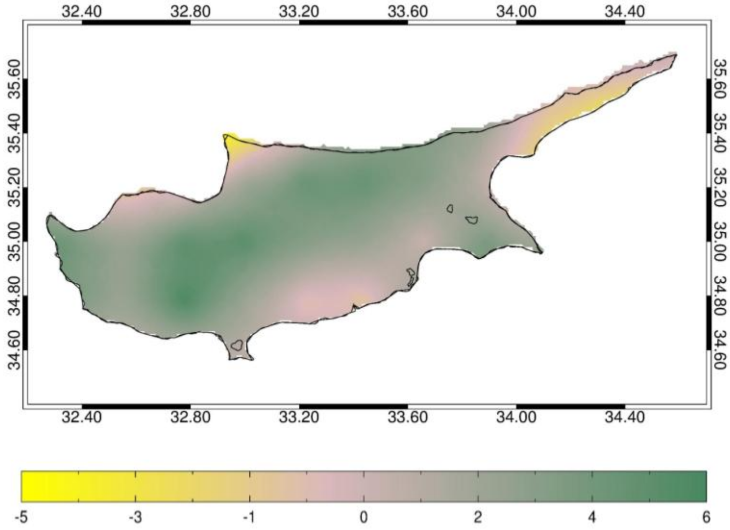

Figure 6-34: Changes in annual maximum total precipitation over 1 day between the future (2021-2050) and the control period (1961-1990)

Overexploitation has in many cases led to depletion of aquifers and, often to salinization of groundwater due to sea intrusion in coastal aquifers (see Figure 6-18). The agricultural land located at the coasts is sensitive to soil salinization under a potential long-term use of these waters for irrigation due to the degradation of the colloidal phase of the soils, the high build-up of salinity and the high concentration of toxic elements which will inevitably affect commercial growing plants. As shown in Figure 6-24, the majority of crops in coastal areas are located in the south - eastern part of Cyprus. It must be noted that, the main source of irrigation in coastal areas, during periods of sufficient water availability, is Government Water Works which is characterized by good quality water and to a lesser extent groundwater, while during drought periods the water supply for irrigation by Government Water Works is restricted in order to meet water demand for the domestic sector first, and thus, more groundwater is drilled from private boreholes in order to meet the demand for irrigation.

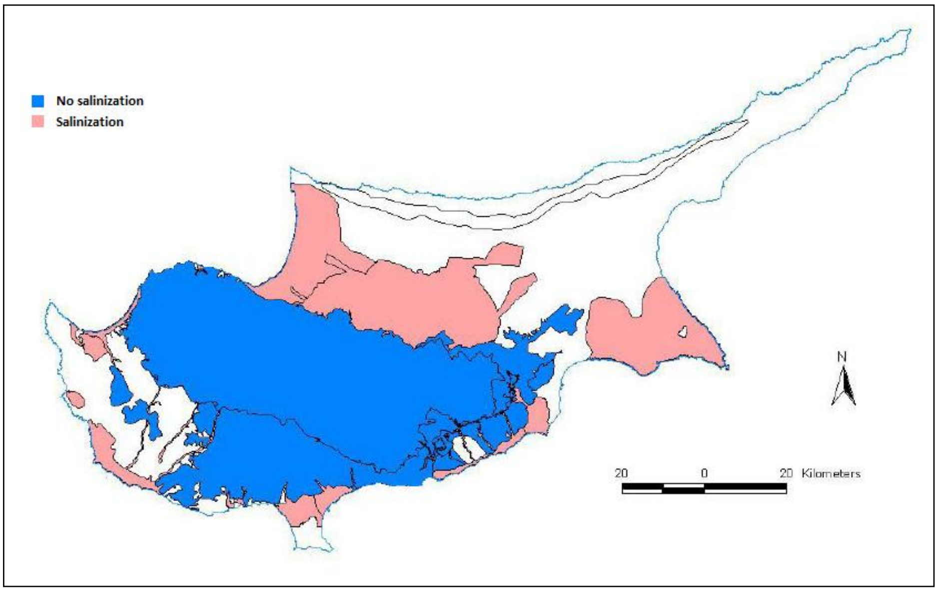

Figure 6-35: Salinization in the groundwater bodies of Cyprus

Source: Water Development Department, 2008

Next the future changes in precipitation and in the periods of drought which are considered to be associated with the salinization of coastal agricultural land are presented. According to the PRECIS model projections on average annual precipitation, all north coasts and especially Karpasia peninsula are expected to receive less annual total precipitation in the future than that estimated for the recent past years 1961-1990. In all other parts of Cyprus, the annual total precipitation appears to have minor decreases or no changes at all with the exception of the area east from Paphos where an increase in total annual precipitation is noticed, minor though (up to 5mm) (Figure 6-36).

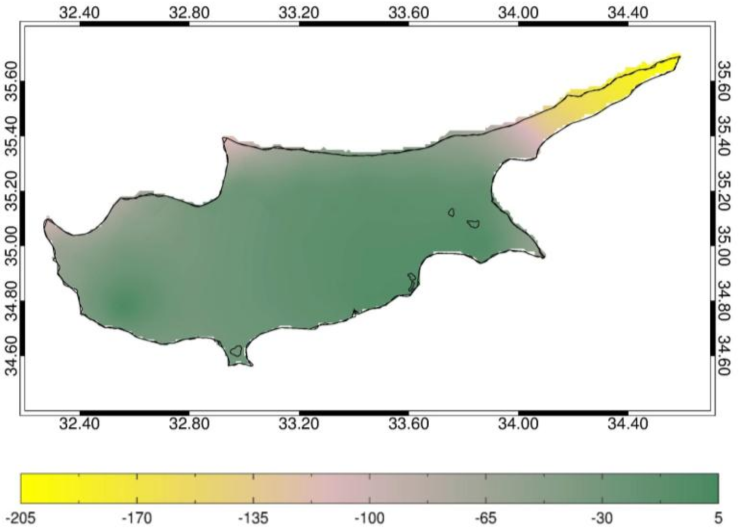

Figure 6-36: Changes in annual total precipitation between the future (2021-2050) and the control period (1961-1990)

As far as the length of drought periods in the future (2021-2050) is concerned, it is anticipated that the western coastal regions of Cyprus as well as the area of Ayia Napa, will have slight decreases or no changes in the maximum length of dry spell. In addition, an increase of about 12-15 days/year in the coastal agricultural areas near Kokkinochoria, Larnaca is also projected (Figure 6-37).

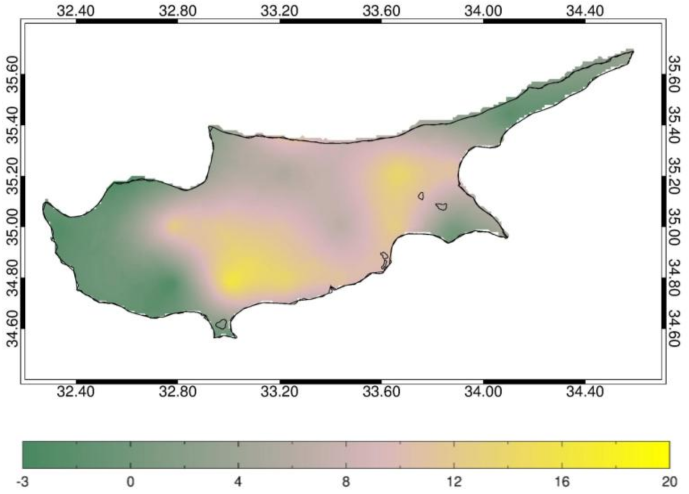

Figure 6-37: Changes in maximum length of dry spell (RR<0.5mm) between the future (2021-2050) and the control period (1961-1990)

To sum up, considering that the future climate changes affecting soil salinization are minor, are not expected to significantly increase future exposure. Taking into account the current exposure to salinization as well as the relative future climate changes, it is expected that the future exposure of crops to the risk of soil salinization is moderate.

Desertification is a result of erosion by wind and rain, reduced soil moisture and chemical degradation of land (e.g. salinization) (I.A.CO, 2007).The combined evaluation of Figure 6-38 and Figure 6-24, showed that the majority of crops cultivated in Cyprus are located in areas which are considered as fragile or critical to desertification, and therefore their current exposure to desertification is characterized as high.

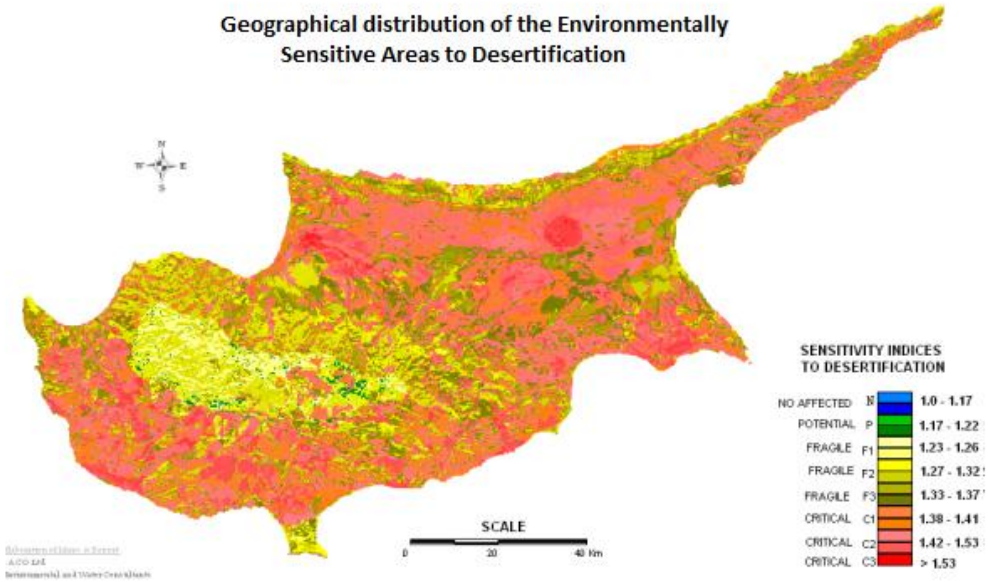

Figure 6-38: Geographical distribution of the Environmentally Sensitive Areas to Desertification

Source: I.A.CO, 2007

Considering the abovementioned climate change impact indicators for soil fertility, it is concluded that the agricultural sector of Cyprus has **moderate** sensitivity and **high** exposure to climate changes.

6.4.2.2. Assessment of adaptive capacity

In order to address degradation of arable land caused by intensive cultivation and overexploitation of land resources in Cyprus, the substitution of the use of chemical products in agriculture is encouraged with the provision of economic incentives for the application of the following eligible activities under the Rural Development Programme of Cyprus (2007-2013): (i) mechanical instead of chemical destruction of weeds, (ii) integrated production management and (iii) organic production.

i) The mechanical destruction of weeds is promoted through certain measures foreseen under the RDP, which refer to the cultivation of wine / table grapes and citrus.
ii) The integrated production management which involves inter alia the application of integrated pest management with the use of pheromones, traps, natural predators

instead of chemical pesticides is promoted through certain measures of the RDP which refer to the cultivation of potatoes and citrus.

iii) The organic production which involves inter alia the production of agricultural products, without the use of chemical fertilizers and pesticides, in accordance with the provisions of Regulations 2092/91 is promoted through the RDP.

Additionally, guidance and technical support is provided to farmers regarding salinity and infiltration problems, and irrigation management methods for overcoming them, as well as guidelines and indicative concentration limit values for crops.

Even though there is a plethora of measures and different approaches which could be employed by farmers for mitigating risk of reduced soil fertility, their implementation are mandatory only for those farmers who have undertaken the commitment to implement those measures, while their independent implementation is rather costly and depends on private initiatives on farm level based on farmer’s awareness on the issue and on the available methods for dealing with it. Thus, the current adaptive capacity of Cyprus’ agriculture towards this impact is considered as **limited to moderate**.

6.4.3. Increase in pests and diseases

6.4.3.1. Assessment of sensitivity and exposure

Some indicators which could be investigated in order to evaluate sensitivity towards this impact, are the identification of plant species that are in competition with the agricultural crops, pest outbreak patterns, diseases favoured by the Cypriot climatic conditions as well as the crops which are sensitive to diseases. Moreover, the magnitude of the exposure could be estimated by gathering information regarding the number of pest outbreaks, the areas covered by weeds, the recorded incidents of plant diseases as well as the exposure of crops to climate changes that favour the presence of pests and diseases such as the increase in temperature. However, due to limited data availability for the determination of the above mentioned indicators, no assessment of the sensitivity and exposure of the agriculture in Cyprus to pests and diseases due to climate changes will be made.

6.4.3.2. Assessment of adaptive capacity

The measures that have been undertaken in Cyprus to support farmers in order to reduce the proliferation of new pests and diseases are categorized into four groups: (a) promotion of indigenous and locally adapted plants and animals, (b) development of an Integrated Pest Management Strategy, (c) application of crop rotation and (d) resistance enhancement of existing plants and animals against pests and diseases. The four groups are presented in detail below.

(a) Promote indigenous and locally adapted plants

The concept of this measure in relation to climate change adaptation lies on the fact that indigenous and locally-adapted plants and animals of Cyprus are more resistant to the climatic conditions of Cyprus and therefore they are less likely to be susceptible to infestations. Relative measures undertaken in Cyprus are the provision of financial support to farmers under the Rural Development Programme for the cultivation of traditional wine grapes and, on research level, the identification and promotion of endemic flora species for cultivation.

(b) Develop an Integrated Pest Management Strategy

The role of an Integrated Pest Management Strategy towards the reduction of pests is mainly preventive, as it includes measures for the prevention of infestation by promoting plant varieties which best adapt to local growing conditions, as well as for the monitoring of pests patterns to prevent damages. Although no such strategy has yet been enforced in Cyprus, the Agricultural Research Institute of Cyprus has undertaken a research project for the integrated and biological treatment of insects and mites in annual and perennial crops.

(c) Apply crop rotation

Pest and pathogens may also be reduced by applying crop rotation on cultivated land, as the changing of crops in a sequence disrupts the pest (weeds and insects) and pathogen life cycles. Thus, the build-up of pest and pathogen populations is obstructed. As mentioned also above, the Rural Development Programme 2007-2013 of Cyprus is providing economic incentives to farmers for the implementation of crop rotation on the cultivation of potatoes and arables.

(d) Reinforce resistance of existing plants against pests and diseases

The resistance of plants against pests and diseases can be reinforced by the application of biotechnology for the plant health improvement and their strengthening against future health risks. On this direction, the Agricultural Research Institute of Cyprus is investigating the local production of healthy propagating material of various cultivars which will enable inter alia the elimination of infestations. For that reason, an *in vitro* Seed Bank has been created for the preservation of healthy propagating material.

It must be mentioned that the common practice in Cyprus for dealing with pests and diseases is the use of chemical products (e.g. pesticides) for their destruction. Although it constitutes an effective method for the temporary solution of the problem, the intensive use of pesticides increases the resistance of pests to pesticides and reduces the plant self-resistant capacity, thus reducing their long-term effectiveness. Furthermore, the application of chemical products is not considered as an acceptable and sustainable method due to the degradation it creates to the quality of soils and water.

However, in absence of data on the magnitude of the impact of climate changes on pests and diseases on crops, the adaptive capacity towards this impact cannot be evaluated.

6.4.4. Damages to crops from extreme weather events

6.4.4.1. Assessment of sensitivity and exposure

The sensitivity of crops to extreme weather events is evaluated based on the extent of the damage caused to them categorized by crop species and by type of extreme event while the exposure is assessed based on the current and future frequency of the extreme climatic events causing damages to crops in Cyprus.

The lion's share in compensations provided by the Agricultural Insurance Organization (AIO) of Cyprus for losses to crops caused by extreme climatic events for the period 1978-2009 is possessed by cereal and dry fodder crops, with a percentage of 41.5% (€65 million) of total compensations granted during that period. However, it must be mentioned that the amount of compensations paid for cereals and fodder crops is high mainly due to the large area of arable land covered for the cultivation of these crops (63% of the total crop area, see also Figure 6-2) and not due to the severity of the effect of extreme events on these crops. The second place is occupied by potato crops with a percentage of 28% (€44 million) of total compensations followed by deciduous crops with 13.5% (€21 million), vines with 9.2% (€14.5 million) and citrus with 7% (€11 million) (Ioannou, 2010). In the following figure, the contribution of each crop to the total compensations provided by the AIO in Cyprus during the period 1987-2007, is illustrated.

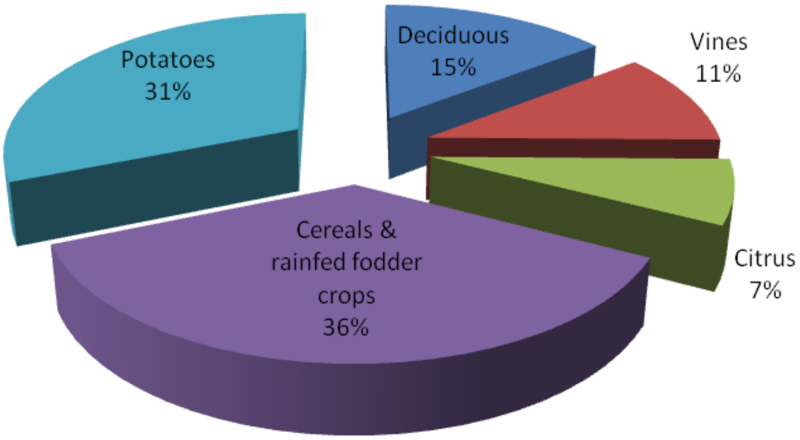

Figure 6-39: Contribution of the compensations paid to main crops affected to the total compensations provided in Cyprus during the period 1987-2007 (CYPADAPT)

Source: AIO, 2008a

The extreme weather event causing the majority of damages to crops during the period 1978-2009 and which was mostly compensated for, is drought in cereals and dry fodder crops (€62.5 million). However, it must be mentioned once more that the damaging effects of drought are not so intense, considering that the compensations paid for cereals and fodder crops are high mainly due to the fact that they cover a large area of arable land (63% of the total crop area, see also Figure 6-2). Hail and frost are the second most damaging extreme weather event in Cyprus with quite high compensations provided for the damages caused to almost all crops (€42 million each), while heat waves which are in the third place have been considerably less compensated for (€3.5 million), with damages caused mainly to vines. With regard to the rest of extreme weather events, the total compensation provided for the damages that caused to crops was significantly lower (€6 million in total) (Ioannou, 2010).

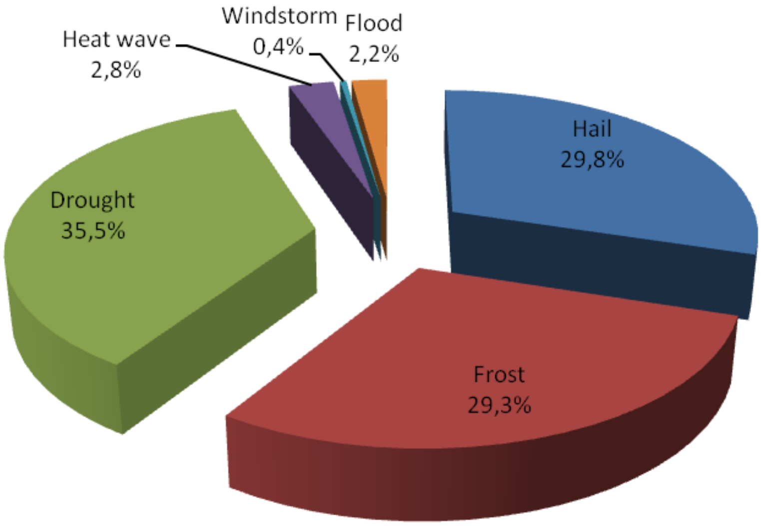

Figure 6-40: Contribution of compensations paid for the main extreme weather events to the total compensations provided in Cyprus during the period 1987-2007 (CYPADAPT)

Source: AIO, 2008b

The common damaging extreme climatic event is hail, since when it occurs almost all crops are affected with extensive damages (Ioannou, 2010). Hail was found to be the most damaging factor to deciduous plantations. Mountainous plantations whose contribution to the total compensation is the greatest, like deciduous trees and vines, are primarily affected by thermal instability hail events, while frontal instability hail events are responsible for the high compensation for plantations of potatoes (Nicolaides et al., 2009).

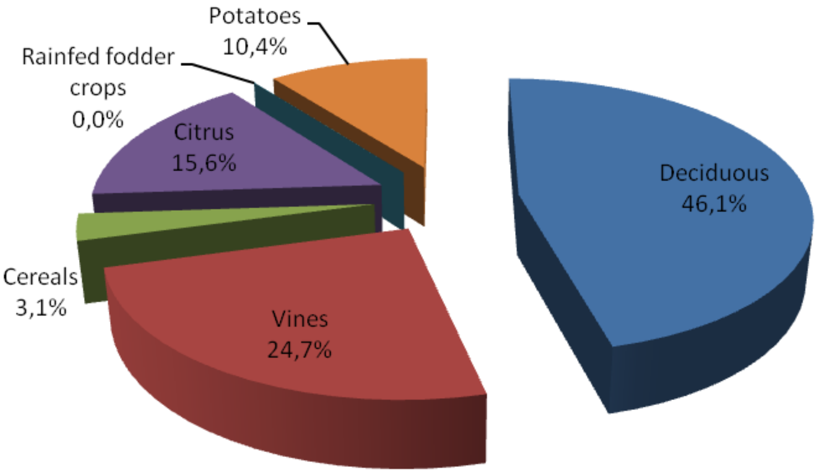

Figure 6-41: Compensations provided to farmers for damages caused to crops by hail events, 1978-2007 (CYPADAPT)

Source: AIO, 2008b

Therefore, it is estimated that the sensitivity of crops cultivated in Cyprus to extreme climatic events is **high**.

With regard to exposure, from the statistical analysis of the data provided by the AIO (2008b), it was observed that compensations for damages by hail events were paid every year from the establishment of the AIO in 1978 until 2007 with a frequency of occurrence 100%, followed by compensations for frosts with a frequency of occurrence 83%, droughts with 70%, heatwaves and windstorms with 53% each and floods with 47%.

Regarding the future changes in the frequency of extreme weather events in Cyprus as these were estimated by the PRECIS mode, both negative and positive changes are noted.

Frost nights (temperature below 0°C) cause serious damage to agricultural areas, especially where sensitive crops exist, such as orange and lemon groves. PRECIS projections (Figure 6-43) show that sensitive crops may benefit in future from climate warming since a decrease is anticipated in the number of frost nights of the order of 0-8 nights in Paphos, 2-8 nights in Limassol, 4-7 nights in Nicosia and 0-2 nights in Larnaca Districts. The model output shows that the highest decrease of frost nights reaches 6-9 days in the greater area around central and southern Troodos. As a result frost nights below 0°C are anticipated to reach 10-15 in Limassol and Paphos areas in contrast with the current period where they are approximately 20-25 (Figure 6-42).

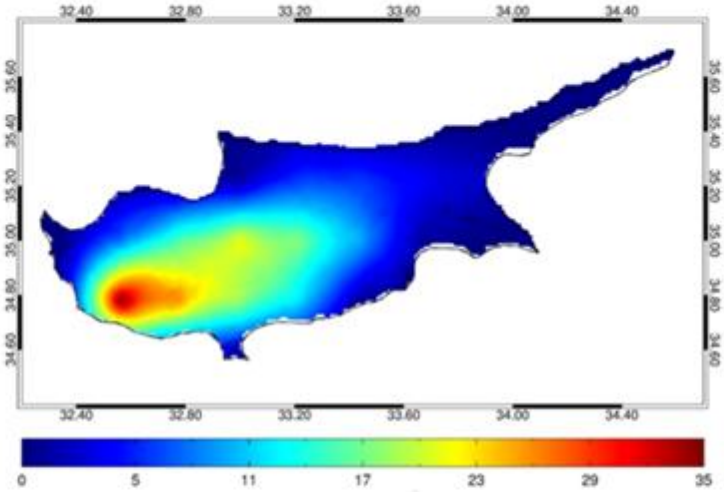

Figure 6-42: Annual number of frost nights (TN<0^{o}C) for the control period (1961-1990)

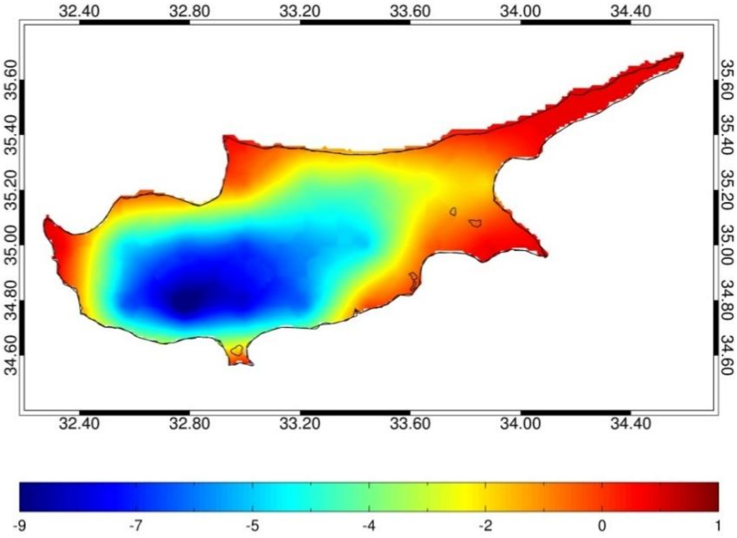

Figure 6-43: Changes in the annual number of frost nights (TN<0°C) between the future (2021-2050) and the control period (1961-1990)

Dry spells highly influence sensitive plants to soil moisture content. Figure 6-45 depicts that the areas of Nicosia and Larnaca reveal increases of about 10 days and Limassol presents an increase of about 12 days, while the western area of Paphos shows no increases. As a result, the maximum length of dry spell is expected to reach 110 days in Larnaca and Nicocia Districts and 80 days in Limassol District in contrast with the control period where the maximum length of dry spell is 100 days and 70 days respectively (Figure 6-44).

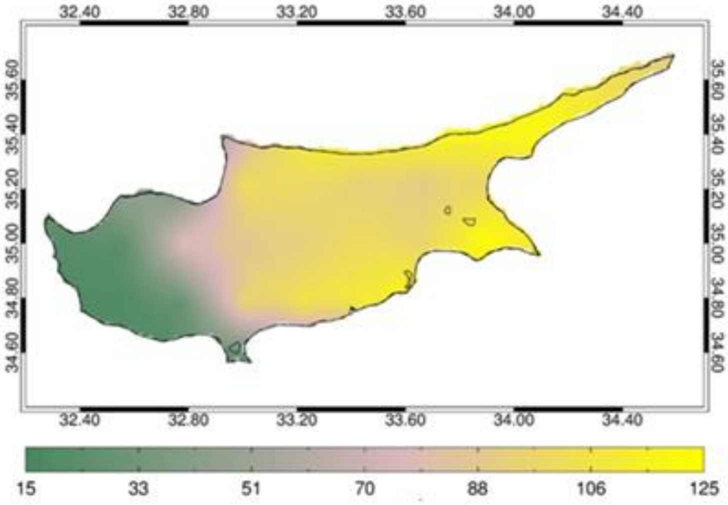

Figure 6-44: Maximum length of dry spell (RR<0.5mm), control period (1961-1990)

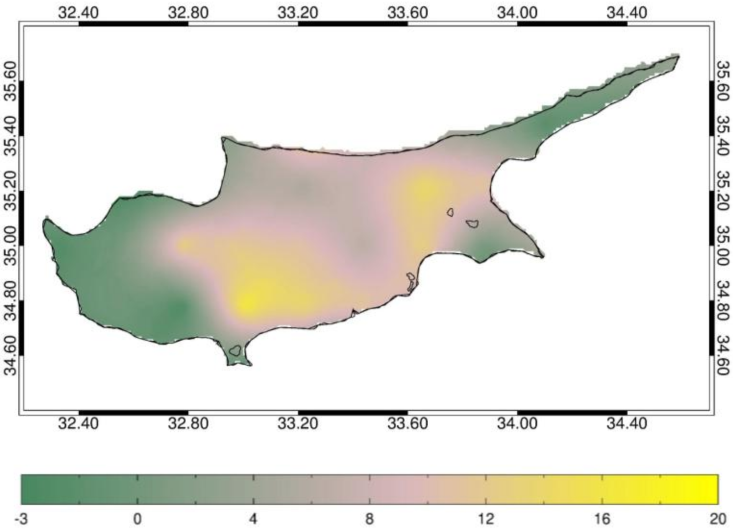

Figure 6-45: Changes in maximum length of dry spell (RR<0.5mm) between the future (2021-2050) and the control period (1961-1990)

Figure 6-47 illustrates potential future changes in the number of days, where maximum temperature exceeds 35°C. Under such temperature conditions, the productive stage of crops may be unfavourably affected. As PRECIS results testify, an increase of about 30 days is expected for the agricultural areas of Nicosia, Larnaca and Limassol Districts and 10 days for areas of Paphos District. Consequently, the number of heatwave days over 35°C may reach in future 70 days in Nicosia, 60 days in Larnaca, 55 days in Limassol and 20 days in Paphos in contrast with current period where heatwave days are approximately 40, 30, 25 and 10 respectively (Figure 6-46).

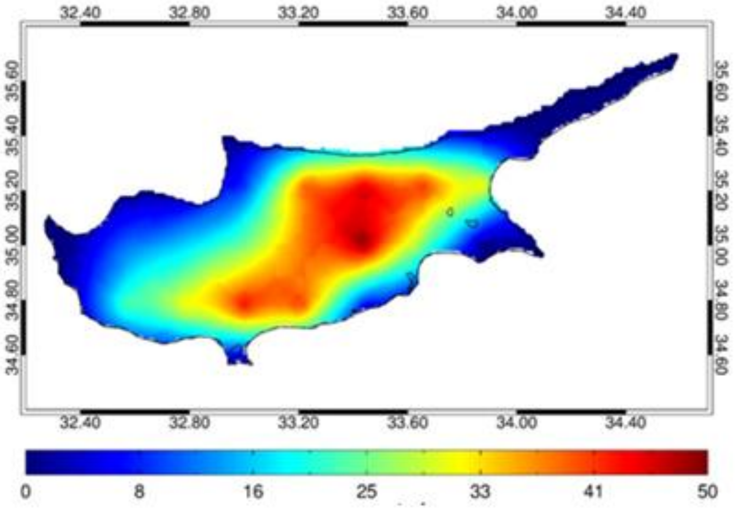

Figure 6-46: Average annual number of heat wave days (T>35^{o}C), control period (1961-1990)

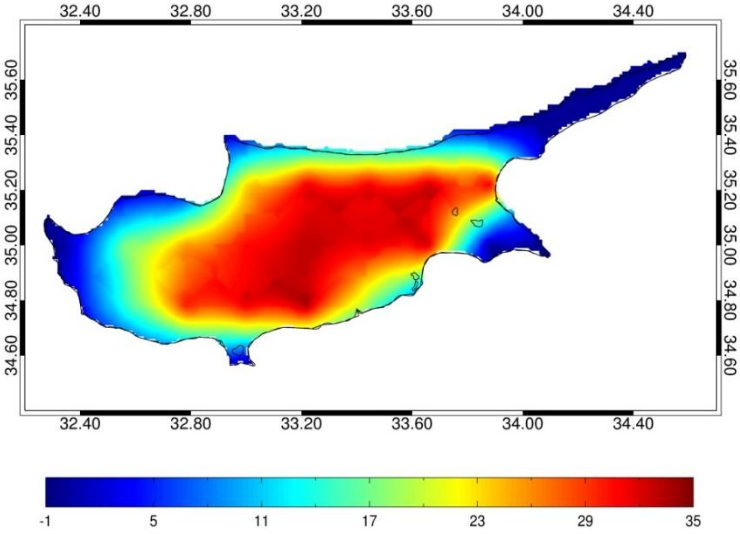

Figure 6-47: Changes in the average annual number of heat wave days (T>35°C) between the future (2021-2050) and the control period (1961-1990)

Extreme wind events are also associated with wind storms and damages to crops. Concerning future changes of extreme wind events according to PRECIS projections on the number of days with mean wind speed greater than 5 m/s, it is anticipated that in western, southeastern and inland areas a decrease of about 12 days will be noticed while in mountain areas the decrease will vary from 5 days to 10 days depending on the elevation. Also southern areas present a slight decrease of about 5 days. Consequently, the damages to crops due to extreme wind events are expected to decrease.

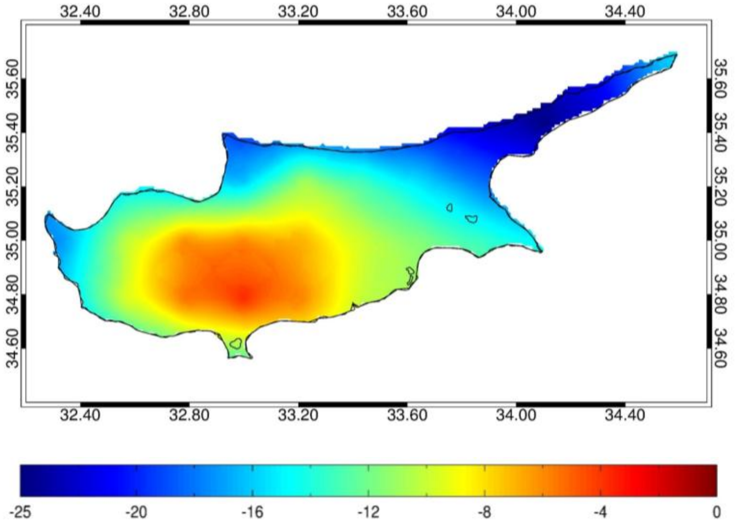

Figure 6-48: Changes in the number of days with mean wind speed > 5m/s between the future (2021-2050) and the control period (1961-1990)

Another important parameter associated with damages to agricultural crops is flooding. To get some insight into this threat, the maximum amount of rainwater that falls in a short period of time (1 day in this case) within the year is calculated. PRECIS projections show that a slight increase of about 2-5 mm is anticipated in western, inland and mountain regions. Additionally, southern and southeastern areas present an even minor increase of about 1 mm in annual max total rainfall over 1 day. It must be noted though that this indicator alone is not sufficient for estimating flood risk since other factors play an important role as well.

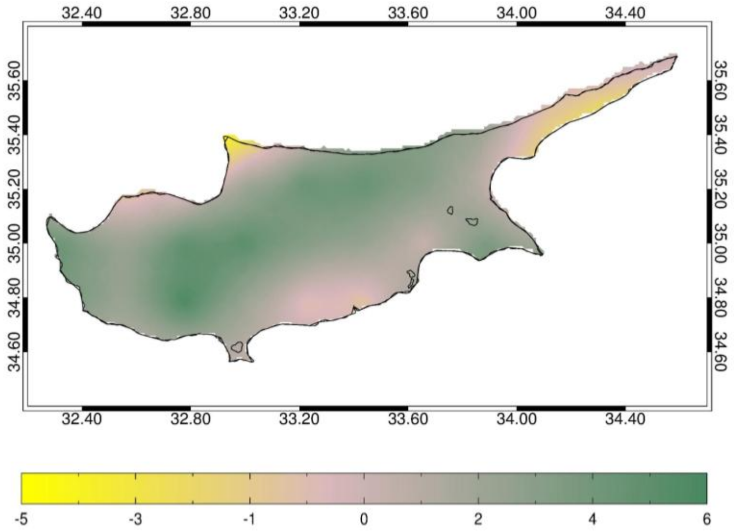

Figure 6-49: Changes in annual maximum total precipitation over 1 day between the future (2021-2050) and the control period (1961-1990)

Considering the above, the exposure of the agricultural sector of Cyprus to extreme climatic events is characterized as **moderate to high.**

6.4.4.2. Assessment of adaptive capacity

For the protection of crops against droughts, a plethora of measures have been undertaken or promoted in order to increase water availability for irrigation and reduce run-off, as also described in Section 6.4.1.2. However, in spite of the measures, water demand for irrigation during drought events is not fully met in most cases, and thus the adaptive capacity of crops to droughts is considered limited to moderate.

Plantations of hedgerows of shrubs or trees help protect agricultural crops from external factors such as floods, winds and frosts, thereby reducing damage to crops while improving the quality and quantity of agricultural production. To promote the implementation of such measures, financial support is provided through the Rural Development Programme 2007-2013 of Cyprus for the installation of windbreaks, which are actually hedgerows of forest trees, around agricultural crops. In addition, irrigation with sprinklers protects from frosts. The installation of advanced irrigation systems such as sprinklers, is also financially supported by the Government.

Furthermore, woodlands help buffer peak rainfall events, prevent flooding and waterlogging by slowing the movement of water from soil to watercourses. To promote the implementation of such measures, financial support is provided through the Rural Development Programme 2007-2013 of Cyprus for the establishment of woodlands.

The destructive effects of hails to crops may be prevented by covering crops with nets, however it requires the timely forecast of the event and the rapid response of farmers for the placement of the net. Finally, the options for the protection of crops from heatwaves are limited.

In general, the abovementioned measures for the protection of crops from extreme events, are applied on farm level and hence their implementation depends on the private initiative of farmers. Considering the above the adaptive capacity to this impact is characterized as **limited to moderate**.

Following, additional recommended adaptation measures (Shoukri & Zachariadis, 2012) that are considered to further enhance adaptive capacity towards this impact are presented indicatively. Nevertheless, their assessment and final selection for implementation will be made through the use of the Multicriteria Analysis (MCA) tool which will be developed and implemented in the framework of Actions 4 and 5 of the CYPADAPT project.

- Provide incentives through the measures of agri-environmental commitments to encourage farmers to maintain floodplain lands with appropriate compensation.
- Recommending farmers to move crops and stock from fields vulnerable to waterlogging in order to reduce consequent impacts on stock health and crop yields.
- Coordination of efforts in planning measures / projects to reduce risks from flooding
- Installation of thermostats and cooling systems in greenhouses
- Changing land use in areas that are more susceptible to drought
- Use of new crops more tolerant of drought and heat
- Use of new drought and heat resistant cultivars of current crops

6.4.5. Alterations in livestock productivity

6.4.5.1. Assessment of sensitivity and exposure

There are no available data for the determination of the sensitivity and exposure of livestock productivity in Cyprus to climate changes. However, some indicative indicators which could be investigated in order to evaluate sensitivity towards this impact, are the animal species which are more sensitive to increased temperatures and heat waves and the percentage of their population over the total animal population in husbandry, as well as the sensitivity of conception and production rates during extended warm periods. The exposure can be estimated based on the assessment of data on the frequency of extended warm periods in

Cyprus, on the reduction of the available animal feed, on the incidents of diseases outbreaks and heat stress on livestock and on the percentage of livestock with no housing and ventilation facilities.

6.4.5.2. Assessment of adaptive capacity

Catering for animal welfare under adverse weather conditions can be enhanced by increasing the amount of shade and shelter or by keeping livestock indoors.

Shelterbelts provide protection from heat and wind for livestock. Planting tall, fast-growing, trees on the southern edge of pastures is one method of increasing shade. The implementation of this measure is promoted through the Rural Development Programme with the provision of economic incentives for the plantation of hedgerows of forest trees.

In addition, the use of thermostats, cooling and ventilation systems within animal housing areas may be used to maintain temperature in acceptable levels and thus reduce heat stress and disease outbreaks. The implementation of this measure is promoted through the Rural Development Programme 2007-2013 of Cyprus which provides financial support to farmers for the installation of ventilation systems in animal housing areas.

Another measure adopted which also contributes to the increase of the sector’s adaptive capacity is the establishment of a gene bank for animal species in order to protect genetic diversity.

Furthermore, the Ministry of Agriculture, Natural Resources and Environment of Cyprus in order to support the efforts made by Cypriot farmers, focuses on the increasing of animal productivity by promoting improved breeding and management methods, improving veterinary services for animal disease control and treatment, local production of animal feed, and upgrading of farm units through mechanization and enhancing the management skills of farmers.

However, in absence of data on the magnitude of the impact of climate changes on livestock productivity, the adaptive capacity towards this impact cannot be evaluated.

6.4.6. Increase in costs for livestock catering

6.4.6.1. Assessment of sensitivity and exposure

There are no available data for the determination of the sensitivity and exposure of costs for livestock catering in Cyprus to climate changes. However, some indicative indicators which could be investigated in order to evaluate sensitivity and exposure towards this impact, are the increase in costs for livestock catering during extended warm periods in Cyprus, the deficit in local animal feed production and the excess costs for importing animal feed, for providing housing, ventilation, etc.

6.4.6.2. Assessment of adaptive capacity

The measures for enhancing adaptive capacity to increased costs for livestock catering are related mainly to the financial support provided by the Rural Development Programme of Cyprus for improving outdoor and indoor conditions for livestock.

However, in absence of data on the magnitude of the impact of climate changes on the costs for livestock catering, the adaptive capacity towards this impact cannot be evaluated.

6.4.7. Assessment of overall vulnerability

The principal aim of this chapter is to identify the key vulnerabilities of the agricultural sector of Cyprus to future climate changes, as well as to assess the magnitude of these vulnerabilities. However, it must be noted that, as there were no sufficient data to evaluate all indicators further research is required.

In order to quantify the vulnerability potential of the agricultural sector against a climatic change impact, the values of sensitivity, exposure, adaptive capacity and vulnerability are quantified as follows:

Degree of sensitivity, exposure & adaptive capacity		Degree of vulnerability		Legend
None	0	None	V≤0	
Limited	1	Limited	0<V≤1	🟩
Limited to Moderate	2	Limited to Moderate	1<V≤2	🟨
Moderate	3	Moderate	2<V≤3	🟨
Moderate to High	4	Moderate to High	3<V≤4	🟧
High	5	High	4<V≤5	🟧
High to Very high	6	High to Very high	5<V≤6	🟥
Very high	7	Very high	6<V≤7	🟥
Not evaluated	-	Not evaluated	-	⬜

Since vulnerability is defined by the following formula:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity * Exposure$$

“Impacts” and “Adaptive capacity” should be evaluated on the same scale (1-7). For this to be achieved, the square root of “Sensitivity x Exposure” is used.

The results of the vulnerability assessment for the agricultural sector in Cyprus are summarized in Table 6-9.

Table 6-9: Overall vulnerability assessment of the agricultural sector in Cyprus to climate changes

Impact	Sensitivity	Exposure	Adaptive Capacity	Vulnerability
Crop yield alterations	Very high (7)	High (5)	Limited to Moderate (2)	Moderate to High (3.9)
Soil fertility alterations	Moderate (3)	High (5)	Limited to Moderate (2)	Limited to Moderate (1.9)
Increase in pests and diseases	Not evaluated	Not evaluated	Not evaluated	-
Damages to crops from extreme weather events	High (5)	Moderate to High (4)	Limited to Moderate (2)	Moderate (2.5)
Alterations in livestock productivity	Not evaluated	Not evaluated	Not evaluated	-
Increase in costs for livestock catering	Not evaluated	Not evaluated	Not evaluated	-

As it may be observed from the table above, the first vulnerability priority of the sector is the impact of climate changes on crop yield, as the latter is expected to be significantly reduced as a result of adverse climate conditions which impede crop productivity. The second priority of the sector regarding its vulnerability to climate changes is related to the damages caused to crops due to extreme weather events, taking into consideration their devastating effect and the magnitude of their effect on crops as well as the fact that climate changes are expected to increase the frequency and intensity especially of droughts and heat waves. The last priority refers to the impact of climate changes on soil fertility, whose condition is already deteriorated while climate changes are expected to magnify the impact. For the rest of the identified impacts, no evaluation took place due to lack of sufficient data.

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7 FORESTS

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Abbreviations and Acronyms

CIAM	Centre for Integrated Assessment Modelling
CYSTAT	Statistical Service of Cyprus
EEA	European Environment Agency
EMEP	European Monitoring and Evaluation Programme
EU	European Union
FWI	Fire Weather Index
FAO	Food and Agriculture Organization of the United Nations
FRA	Forest Resources Assessment Programme
FWI	Fire Weather Index
GDP	Gross Domestic Product
ICP-Forests	International Co-operative Program on the Assessment and Monitoring of Air Pollution Effects on Forests
IPCC	Intergovernmental Panel on Climate Change
LTRAP	Long-range Transmission of Air Pollutants in Europe
MCA	Multi Criteria Analysis
MANRE	Ministry of Agriculture, Natural Resources and Environment
NFP	National Forest Programme
ODS	Ozone Depleting Substances
OWL	Other Wooded Land
PRECIS	Providing Regional Climates for Impact Studies
RCM	Regional Climate Change
UNECE	United Nations Economic Commission for Europe

7.1 Climate change and forests

The forest areas in Cyprus are classified in forests and other wooded land. The two groups account for 390,944 ha. High forests comprise 44.2% of the total forest area, though maquis and lower vegetation such as scrub and phrygana account for 55.8%. The total cover of forest & OWL areas in Cyprus (42.3%) is close to the average of the EU (44%), whereas the forest cover only (excl. OWL) (18.7%) is about half of the average of the EU (36,4%). Almost all forest areas are either natural (primary-undisturbed by man) or semi-natural.

The forest sector is highly dependent on climate. Direct impacts of climate change on Cyprus forests arise mainly from decreased rainfall and increased temperature, droughts, fluctuations in intensified precipitation and changes in fire regimes.

The impact, vulnerability and adaptive measures for the forest sector in Cyprus regarding climatic changes was assessed in Deliverable 1.2. The main vulnerability priority for the forests of Cyprus was found to be the impact of climate changes on the dieback of tree species, due to insect attacks and diseases since a significant part of Cyprus' forests has already been affected. The second priority regarding the vulnerability of forests to climate changes was found to be related with the effect of increased frequency and intensity of forest fires, since fires cause severe and extended damages on forests. Finally, it was considered that the forests of Cyprus are not vulnerable at all to floods mainly due to the fact that they are located at mountains where the risk for floods is limited, while the vulnerability of forest growth to climate changes was not evaluated due to lack of sufficient data.

Future climate change impact, vulnerability and adaptation measures in the sector of forestry will be reassessed for the case of Cyprus, in the framework of this study, in order for the future vulnerability potential of forestry against climatic change impact to be quantified. Future vulnerability priorities for the forest sector will be identified in order appropriate adaptation measures to be implemented.

Each climatic parameter (temperature, precipitation, heat waves and dry spell) was analyzed for the future situation with the use of the PRECIS regional climate model through comparison between a control period (1961–1990) and a future period (2021–2050). Regional Climate Models of the ENSEMBLES project have also been used. The results of models were used as an ensemble mean for testing and comparing the respective results of PRECIS. Detailed information is available in Deliverable 3.2 while the main model used in this report is the PRECIS (Providing Regional Climates for Impact Studies) regional climate model. The reason is that while, in the other simulations models, Cyprus is placed in the south-eastern part of the domain in PRECIS simulations, Cyprus lies at the center of the study domain. The future period 2021-2050 has been chosen specifically for the needs of stakeholders and policy makers to assist their planning in the near future, instead of the end of the twenty-first century as frequently used in other climate impact studies

7.2 Baseline situation

Two are the major classifications of the forest areas in Cyprus: a) forests and b) other wooded land, OWL (incl. maquis and garique) which are either of state or private ownership.

The Cypriot forests are natural with the main forest species of Turkish pine (*Pinus brutia*) as well as Black pine (*Pinus nigra*), which mainly covers the higher parts of Troodos Mountain. Also found many endemic species most well-known are the Golden oak (*Quercus alnifolia*) and Cyprus cedar (*Cedrus brevifolia) species.* Other native tree species in Cyprus are Pinus brutia, Pinus nigra ssp. pallasiana, Cedrus brervifolia, Cupressus sempervirens, Juniperus phoetidissima, Juniperus excela, Platanus orientalis, Alnus orientalis, Quercus infectoria ssp. Veneris (Department of Forests, 2011a).

The geographic distribution of forest, garigue and maquis vegetation areas in Cyprus is illustrated in the following Figure 7-1. Mountain areas of Cyprus are mainly covered by forests.

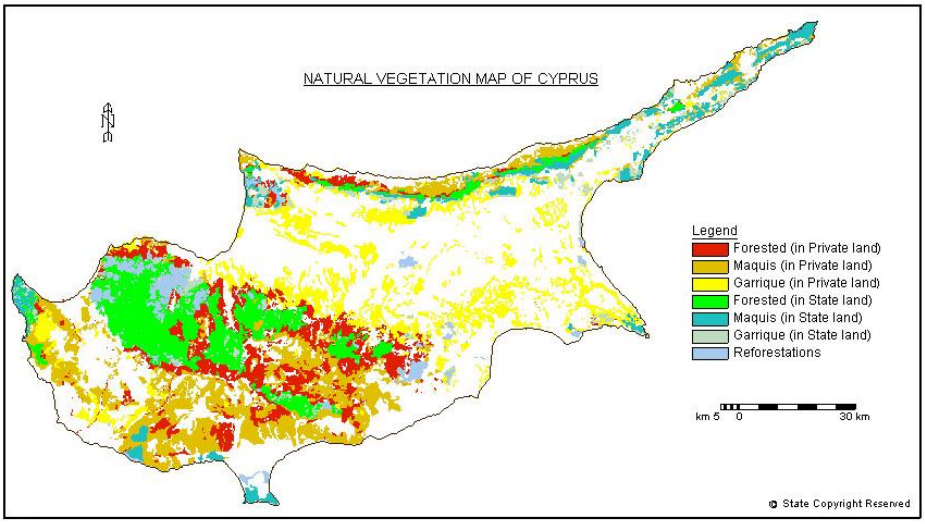


Figure 7-1: Natural vegetation of Cyprus

Source: Department of Forests, 2011a

In the context of the forest law, State Forests are categorized into two categories "Main" and "Minor" State Forests. Their allocation is presented in the following map (Figure 7-2).

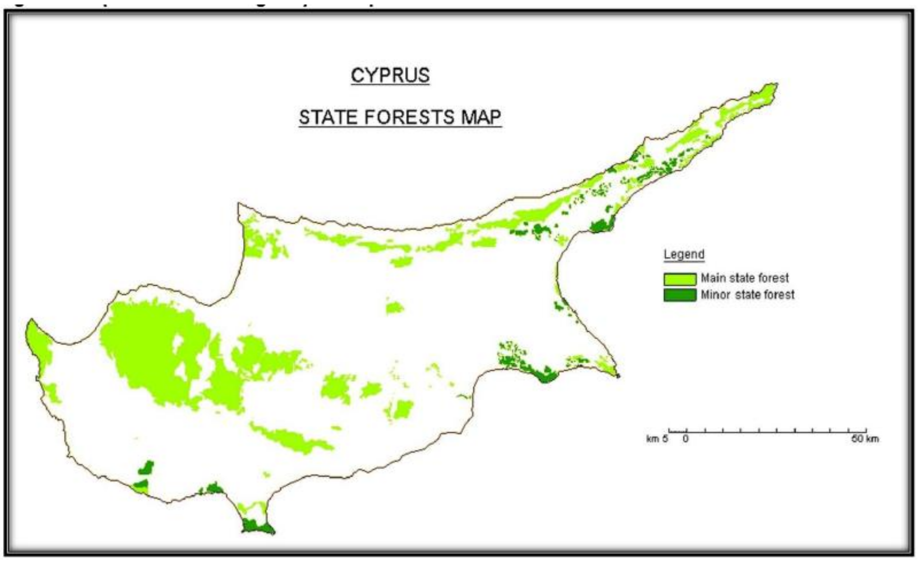


Figure 7-2: State Forests of Cyprus

The GDP share of the forestry sector in Cyprus is generally low, presenting a declining trend over the last decade. Based on data collected from the Department of Forests (2006), the annual contribution of forestry in the economy is negligible. In 2001, the contribution of forests in the total GDP was 0.026% while this of timber based industries (sawmilling, wood based panels and wooden pallets) as well as wooden furniture manufacturing was more significant. That contribution was accounted for 1.1% of the total GDP. Additionally, the national annual wood production estimated at 8000 m^3/year, an amount which is not sufficient to support the primary wood processing industries of the island. The national timber production accounts for only 8% of the total consumption compared to the imported timber and timber products necessitating the import of final products (Department of Forests, 2006).

The main commercial value species of Cyprus forests is Pinus brutia (native tree species) that constitutes about 90% of the growing stock. This is the only species that is actively managed for timber production constituting about 60% of the State Forests. The particular species is utilized as solid wood products and fuels for energy production (Department of Forests, 2011).

Cyprus forests, like all forests, are threatened by a variety of agents, both abiotic and biotic as well as human induced ones. As already mentioned main climatic pressure on Cyprus forests are decreased rainfall and increased temperature, droughts, fluctuations in intense precipitation events and changes in fire regimes. Non climate related pressures are mainly associated with (i) unsustainable timber harvesting, (ii) overgazing which causes degradation not only on the vegetation but also on the soil and water regime of the island and (iii) land development especially for tourism development and construction of holiday dwellings. Any future increase in those pressures, if suppression measures are not implemented, will deteriorate their effect on forest areas. Furthermore intensive tourism development that is desirable for economy sector in the future can cause further degradation in State Forest land, soil erosion and compaction, pressure on sensitive flora and fauna species, water quantity and quality and further increase of pollution.

The need to manage the forest of Cyprus for multiple purposes has been clearly set out, right from the first official forest policy declaration in 1950. However, the emphasis previously given to timber production and meeting domestic requirements for wood products is no longer appropriate and a new balance is emerging (Christodoulou, 2003).

Cyprus has formulated a forest policy and a National Forest Programme, while starting a process of updating its forest legislation, laying the stress on environmental services and recreation rather than wood production. The national strategy for forests of Cyprus has two main thrusts: multiple use (protection, recreation and trade) and sustainability (ecological, economic and social). A participatory approach to forest management and its planning is introduced in the proposed new legislation, strategy and policy (FAO, 2010). The management of the State Forests is controlled by the forest law, which has been amended several times since its first enactment in 1879.

The National Forest Programme (NFP) of Cyprus covered the ten-year period 2001-2009. The NFP consists of a complex set of activities and related projects, which are designed to achieve the aims of the strategy. These sub-programmes deal with the following groups of activities (Christodoulou, 2003):

- Afforestation and silviculture
- Production of timber and non-wood products
- Protection against fires and other hazards
- Conservation of ecosystems, flora, fauna and heritage
- Water
- Local plans and village development
- Institutional reform, modernization and capacity building

During 2010, the first preliminary drafts of a new Forest Policy were developed while within the first quarter of 2011, these drafts were forwarded to the Council of Ministers for approval and to the House of Representatives for voting. The Department of Forests within the first half of 2011 and after finalizing the relevant texts proceeded with public consultation (Department of Forests, 2011a).

The Department of Forests of the Cyprus Republic is also participating in many other plans, including the Standing Forestry Committee of the European Commission which is currently working on the Climate Change mitigation. In addition, it is participating in the “Echoes Cost Action” which has as main objectives to mobilize and integrate the existing scientific knowledge for European forest policymakers and managers. The Action begun at 2008 and has a duration of 4 years. There are three working groups: Impacts, Adaptation and Mitigation (Weiskel, 2009).

7.3 Future impact assessment

The direct impacts of climate change on Cyprus' forests arise mainly from temperature and precipitation changes as well as fires. Indirect impacts come from the interactions between changes in climatic variables and several abiotic and biotic factors (Lindner *et al.,* 2008).

The impacts of climate change on Cyprus's forests are similar to the ones identified in Deliverable 1.2, however as climate change factors are expected to intensified, the magnitude of the impacts is expected to increase. According to PRECIS projections for the future period 2021-2050, the average annual temperature in Cyprus is expected to increase by 1-2°C with respect to the control period 1960-1990, while precipitation is expected to decrease in seasonal level and in minor degree in annual level. In addition, the maximum length of dry spells (precipitation<0.5mm) is expected to increase 10 to 13 days on average while heat wave days (temperature >35°C) will be increased averagely about 10-30 days on annual basis. Concerning future changes of annual max total rainfall over 1 day, PRECIS projections show that a slight increase of about 1-4 mm is anticipated. Finally, regarding the highest annual total precipitation, falling in 3 consecutive days, a negligible increase of about 1-2 mm of rainfall is expected.

In this section the climate impacts on the forest sector, as these have been identified in Deliverable 1.2 will be reviewed in light of the climate projections for the future (2021-2050). In the context of the future impact assessment the indicators presented in Table 7-1 summarize the potential impacts of climate change on Cyprus' forests.

Table 7-1: Relationship between potential climate changes and impacts on the forest sector

Potential climate change in Cyprus	Potential Forest impacts	
	Direct Impacts	Indirect Impacts
Drought	– Insect attacks – Dieback of trees – Pressure on fauna species – Biodiversity loss – Desertification	– Reduction of forestry regeneration and growth – Degradation of forest, impacts on forests' health and vitality – Increase in number and severity of forest fires – Soil erosion – Increase of dust in the atmosphere – Negative effect on reforestations and natural stands
Higher mean annual temperatures – Hot spells	– Insect attacks – Dieback of trees – Pressure on fauna species – Biodiversity loss – Desertification	– Increase in number and severity of forest fires – Photosynthesis decrease – Decrease of biomass growth and yield – Decrease of forests' productivity

Potential climate change in Cyprus	Potential Forest impacts	
	Direct Impacts	**Indirect Impacts**
		– Decrease of wood production – Effect on carbon sequestration rates and net carbon balance
Decreased rainfall	– Change in competition among -plant species – Nutrient availability in soils – Deficiency in water for fauna	
Increase of extreme events (floods, wind throws and storm damages)	– Injuries – Inhibition of seed germination – Changes in plant anatomy – Promotion of early senescence and mortality – Nutrient availability in soils	
Atmospheric CO_2 increase	– Increase in photosynthesis rates (varying with plant nitrogen status and species) – Effects on forest growth, tree physiology – Insect attacks	
Increase in atmospheric nitrogen, ozone		

The main direct and indirect impacts presented in the table above were grouped in the following impact categories:

- Dieback of tree species, insect attacks and diseases leading to desertification
- Fires
- Floods, wind throws and storm damages
- Forest growth

7.3.1 Dieback of tree species, insect attacks and diseases

Climate change has an effect on insect development and diseases, which are the main harmful forest organisms in Cyprus forests. Faster development of insects due to rising temperature and low levels of soil moisture due to drought can lead to further necrosis of trees.

The typical Mediterranean climate with mild winters and hot, dry summers favors the breeding of harmful forest organisms in large populations (Department of Forests). Anticipated rising temperatures and droughts will deteriorate negative impact of insects and diseases in forest species.

As presented in the following there is an anticipated increase in temperature in the island and decrease in rainfall. This climatic change except from dieback of the tree species due to thermal stress has secondary results such as increase in the severity of future insect attacks. The warm and dry climate conditions make pine stands in the forests of Cyprus vulnerable to pests such as the pine processionary caterpillar and bark beetle. Further research is required concerning exact impact of changes in temperature and precipitation in dieback of the tree species. Thus it is important to refer to anticipated changes of temperature and precipitation in the future period (2021-2050) in the following as an input for further research.

Analytical description of anticipated climatic changes and impact on forest dieback follows. Winter minimum and summer maximum temperature projections for areas of particular concern are presented for the future period (2021-2050) as the most extreme seasonal cases. Furthermore winter and autumn rainfall have the most significant changes in seasonal precipitation for the future period and thus future precipitation is presented for these periods. All seasonal future (2021-2050) changes are presented analytically in Deliverable 2.3.

7.3.1.1 Future rising temperature and impact on forest dieback

The anticipated increase in average winter minimum and summer maximum temperature will have a negative impact on forest organisms in Cyprus forests. Furthermore except from increase in temperature there are anticipated changes in events that are related to temperature increase and have an impact on forest dieback such as heat wave days and maximum length of dry spell. More specific information follows.

Average winter minimum and summer maximum temperature

Projections of PRECIS regional climate model make evident that all forested areas of Cyprus will experience, in the near future, a warming of about 0.8 – 1.1°C. In specific, in the near future, winter minimum temperature is anticipated to reach 6°C in Troodos Mountain and Paphos Forest and 7-9°C in forested area of Larnaca District in contrast with control period where the respective temperatures is 5°C and 6-8°C respectively. Furthermore forested regions of Troodos Mountain will experience a significant warming of about 2.0 – 2.7°C reaching summer maximum temperatures of about 32 – 35.7°C in comparison with the current situation (control period).

As a conclusion rising temperature may enable some insect species to develop faster and endanger thus the forest growth. In this frame the predicted increase in winter minimum and summer maximum temperature in the future period can worsen current situation of dieback of tree species.

Maximum length of dry spell

Increases in maximum length of dry spell can affect negatively forest species sensitive to soil moisture content. Areas of Nicosia and Larnaca and Troodos mountain will have increases of about 10 days. Conversely, western area of Paphos shows no increases. As a result, the maximum length of dry spell reaches 110 days in Larnaca and Nicocia Districts and 70 days in Paphos and Troodos District.

Dry spell has an impact on soil moisture. Increase in length of dry spell can decrease soil moisture. Low level of soil moisture has a negative impact on the intense stress of forest ecosystems, particularly those found in lowland and hilly areas. Furthermore low soil moisture can cause the necrosis of trees due to the possibility development of secondary insects attack is highly possible. In Cyprus, the lack of soil moisture, apart from its effects on the drying of trees, has secondary impacts on them since it enhances the activity of insects such as the Orthotomicus erosus and Bursaphelenchus leoni which attack stressed trees due to lack of moisture and dry them up altogether. The necrosis of a significant number of pines and cypress in Stavrovouni forest occurred due to the impact of insects during the dry period 2005 – 2008 (Department of Forests, 2011b; Cyprus Institute, 2011).

Number of Heatwave days

Under temperature that exceeds 35°C, forests may be unfavourably affected. As PRECIS results testify, an increase of about 20-30 days is expected for mountain regions and conversely 10 days for areas of Paphos District. Consequently, number of heatwaves days over 35°C may reach in future 40-60 days in Troodos forest and 20 days in Paphos in contrast with current period where heatwaves days are approximately 20-30 and 10 respectively.

Number of heatwaves days is a very important factor since in combination with the length of dry period can cause “thermal stress” to trees leading to extended necrosis mainly during the long hot summer period.

7.3.1.2 Precipitation changes and impact on forests dieback

Concerning ordinary annual rainfall no increase is anticipated in the future period (2021-2050).However, PRECIS model projections, depict decreases in seasonal precipitation. In winter total rainfall a decrease of about 20 mm is anticipated for all the domain of study. Decrease in rainfall except from dieback of the tree species due to thermal stress has secondary results such as increase in the severity of future insect attacks.

Changes in the hydrological regime may also have serious implications for the forests’ sustainability. Decreased soil moisture is known to largely affect forestry species such as Pinus brutia the predominant species of Cypriot forests. For Troodos Mountain and Paphos District is anticipated a winter total rainfall of about 210 mm and for Larnaca District 70 mm in comparison with present-day climate where precipitation is 230 mm and 90 mm respectively.

A similar pattern to winter is evident for autumn precipitation regarding PRECIS plots. A decrease in the amount of rainfall of about 15 mm is projected for the near future throughout the domain of study. Future amounts of autumn rainfall will reach 55 mm for Larnaca District, 95 mm for Troodos Mountain and 135 mm for Paphos District comparing with current amounts which are 70 mm, 110 mm and 150 mm respectively.

7.3.2 Fires

Forests of Cyprus are vulnerable to fire, primarily due to the long, hot and dry summers, mild winters, strong winds, intense relief and flammable xerophytic vegetation. These natural factors are further exacerbated by changing climatic conditions, which favor prolonged periods of drought and extreme weather events. Also, the accumulation of biomass due to the abandonment of rural areas and the increasing tourism and exodus of city residents to forested areas, are also important factors which contribute to an increased fire risk, especially during summer months.

Mediterranean Europe, in general, has been identified as likely to suffer potentially increased fire risk. The contribution of meteorological factors to fire risk is simulated using various non-dimensional indices of fire risk. Viegas et al. (1999) validated a number of fire indices in the Mediterranean against observed fire occurrence, and the Canadian Fire Weather Index (FWI, van Wagner, 1987) was among the best performers. Viegas et al. (2001) demonstrated that in summer, the slow response of live fine fuel moisture content to meteorological conditions is well described by the Drought Code sub-component of the FWI system. In addition, FWI is one of the most widely used indices of fire risk. Therefore, output from climate model simulations of the coming decades was used to examine potential changes in fire risk for Cyprus.

The Canadian Fire Weather Index system is described in detail in van Wagner (1987). Briefly, it consists of six components that account for the effects of fuel moisture and wind on fire behavior. These include numeric ratings of the moisture content of litter and other fine fuels, the average moisture content of loosely compacted organic layers of moderate depth, and the average moisture content of deep, compact organic layers. The remaining components are fire behavior indices, which represent the rate of fire spread, the fuel available for combustion, and the frontal fire intensity; their values rise as the fire danger increases. Although FWI has been developed for Canadian forests, several studies have shown its suitability for the Mediterranean basin (Moriondo et al. 2006; Good et al. 2008). FWI is divided into four fire danger classes:

Low 0 – 7
Medium 8 – 16
High 17 – 31
Extreme >32

In addition, as already mentioned above, forest fires are highly sensitive to climate change because fire behavior responds immediately to fuel moisture (Weber and Flannigan 1997; Stocks et al. 2001), which is affected by precipitation, relative humidity, air temperature and wind speed. Thus, the projected increase in temperature will increase fuel dryness and reduce relative humidity and this effect will worsen in those regions where rainfall decreases. Accordingly, increases in climate extreme events are expected to have a great impact on forest fire vulnerability (Beniston 2003; Körner et al. 2005).

Maximum length of dry spell

In the climatic parameters with implication on fire risk, is examined the maximum length of dry spell (amount of rainfall less than 0.5 mm) because it is a parameter which not only increases fire risk but also highly influence forest species due to their sensitivity to soil moisture content. As regards PRECIS results on maximum length of dry spell, Troodos Mountain and Larnaca District anticipate an increase of 12 days and 8 days respectively. Conversely, Paphos District shows no increases. As a result, the maximum length of dry spell reaches 108 days for Larnaca District and 82 in Troodos Mountain in contrast with the control period in which the maximum length of dry spell reaches 100 and 70 days respectively.

Fire Weather Index (FWI)

Continuing with Fire Weather Index (FWI) the index simulating the fire risk, it is obvious that the FWI shows the highest values during summer and more specifically during months July and August. Regarding PRECIS results, FWI reaches extremely high values in forested areas of about 50 (extreme high risk) in the control period, during July. Districts that present these excessive values are Limassol, Nicosia and Larnaca where FWI varies from 40 to 50. In Paphos District, FWI presents lower values of about 10 in Akamas peninsula, where National Park of Akamas is located, and 20-30 in Paphos Forest in the northwestern part of Troodos Mountain. As far as PRECIS near future projections are concerned, shows a small increase of FWI all over the Troodos Mountain of about 1-2 in low altitudes and 3-5 in high altitudes is anticipated.

August FWI reveals comparable values compared with those in July. Similarly, FWI reaches extremely high values, mainly in the forested areas of Cyprus, of about 50 in Troodos Mountain parts of Limassol and Nicosia Districts. Lower values are evident in Larnaca forested areas (Stavrovouni and Rizoelia Forests) of around 40 and even more low values shows Paphos District where FWI varies from 10 in Akamas peninsula to 30 in Paphos Forest. Regarding future projections, PRECIS shows a small increase in FWI of about 2 in forested areas of Limassol, Nicosia and Larnaca Districts. Also, no increase is projected for Paphos District.

However, fire risk is not confined during the summer period. Due to the increase in temperature and the decrease in precipitation, which may intensify in the near future, there is elevated fire risk in late spring and early autumn. To study fire risk before and after summer, April average FWI and October average FWI plots were carried out. In the current period climate FWI reaches 20 (high risk) in the forested areas of Larnaca District, 10-15 in Troodos Mountain and 7 in forested areas of Paphos District. As far as future changes are concerned, a small increase of about 2 degrees is projected by PRECIS for Troodos Mountain as well as for forested areas of Larnaca District while Paphos District shows no increase.

A relatively similar pattern is evident for the October FWI average. Larnaca and Nicosia areas present a high fire risk with FWI varying from 17 to 20. Additionally, the southern parts of Troodos Mountain (Limassol District) as well, present a high fire risk with FWI values varying from 20 to 22. As far as future changes are concerned, PRECIS projections show a small FWI increase of about 1-2 in Troodos Mountain and no increase in Larnaca and Paphos District.

In analyzing fire risk it is very important to investigate the number of days during the year, with an increased fire risk, in other words, with an increased FWI. In our study we examined two parameters: the number of days with FWI>15 i.e. days with moderate fire risk and the number of days with FWI>30 i.e. days with extreme fire risk. As evidenced by PRECIS results for the control period there are approximately 200 days with FWI>15 in the forested area of Larnaca District and approximately 160 days in Troodos Mountain. The fewest days with FWI>15, approximately 60, are shown in Akamas National Park. As far as future changes are concerned, Troodos shows an important increase of about 15 days while forested areas of Paphos District present an increase of about 5. Also, Larnaca District shows no increase.

Finally, forested areas of Larnaca District as well as Troodos Mountain region of Nicosia and Limassol Districts present 120 days with extreme fire risk, in the present-day climate (PRECIS). Also, the northwestern part of the Troodos Mountain (Paphos District) and Akamas National Park present 55 and 15 days respectively. As far as future changes are concerned, PRECIS projections testify a small increase of the order of 8-10 days for Troodos Mountain whereas for the remaining forested areas of Cyprus projections show negligible changes in extreme fire risk occurrence.

The Future Weather Index both for present-day climate and potential near future changes due to climate change. More analytic information is presented in the following Table 7-2 and Table 7-3.

Table 7-2: Values of indices with particular relevance to forest fire risk.

	Western Regions	Mountain Regions	Inland Regions	Southern Regions	Southeastern Regions
	PRECIS	PRECIS	PRECIS	PRECIS	PRECIS
July average FWI	10-30	30-50	45	45	45
August average FWI	10-30	25-50	40	45	40
April average FWI	7	10-15	20	17	20
October average FWI	10	15-22	17	21	20
Nb of days with fire risk (FWI>15)	60	160	175	170	200
Nb of days with extreme fire risk (FWI>30)	30	120	120	100	120

Table 7-3: Potential future changes in indices with particular relevance to forest fire risk.

	Western Regions	Mountain Regions	Inland Regions	Southern Regions	Southeastern Regions
	PRECIS	PRECIS	PRECIS	PRECIS	PRECIS

July average FWI	(+) 0-1	(+) 1-5	(+) 2	(+) 1	0
August average FWI	0	(+) 2	(+) 2	(+) 2	(+) 2
April average FWI	0	(+) 2	(+) 2	(+) 2	(+) 2
October average FWI	0	(+) 1-2	(+) 1	(+) 1	0
Nb of days with fire risk (FWI>15)	(+) 5	(+) 15	(+) 10	(+) 15	0
Nb of days with extreme fire risk (FWI>30)	(+) 1	(+) 8-10	(+) 5	(+) 2	1

7.3.3 Floods, wind throws and storm damages

Forest damage by wind and snow are a continuing cause of economic loss in forestry throughout Europe and Cyprus (Lindner *et al.,* 2008) because of reduction in the yield of recoverable timber, increased costs of unscheduled thinning and clear-cutting, and resulting problems in forestry planning. Despite the great severity of the particular climate change impact on forests, there are no available data for future estimation of wind throws and storm damages in Cyprus.

Flooding is harmful especially if it occurs during the growing season (Lindner et al., 2008). Extreme flooding events are expected to occur more frequently as a consequence of climate change. Global circulation models predict that it is very likely that higher amounts of precipitation will occur in northern Europe, especially during winter and spring, considerably increasing the risk of flooding in Central and Northern Europe.

Changes in rainfall and anticipated heavy rain events may a significant influence on flooding. While the number of rain days is projected to decrease the number of days with heavy rain events is projected to increase. More specifically future changes of annual max total rainfall over 1 day, PRECIS projections show that a slight increase of about 5mm is anticipated for forested areas and 2-4 mm is anticipated in western and inland regions. Additionally, southern and southeastern areas present an increase of about 1 mm in annual max total rainfall over 1 day. Furthermore the highest annual total precipitation, falling in 3 consecutive days (mm) present a negligible increase of about 1-2 mm in the future period (2021-2050) for the whole domain of study.

Nevertheless as a result of the topography and the sleepy slopes in the forest areas anticipated increase in heavy rain events will not pose a flooding threat to Cyprus forests.

7.3.4 Forest growth

Forest growth and productivity may be affected by projected climate change aspects such as increases in temperature, changes in precipitation and increases in air pollution.

Further research is required concerning impact of changes in temperature, precipitation and air pollution in forest growth. Thus it is important to refer to anticipated changes of in the future period (2021-2050). More specifically all forested areas of Cyprus will experience, in the near future, a warming of about 0.8 – 1.1°C. Anticipated annual total precipitation in the future period presents minor decreases or no changes at all. The only region with an increase in total annual precipitation, minor though (up to 5mm), is the area around Orites Forest, east from Paphos. Finally increases in air pollution should be under further research as well.

During hot spells (Higher mean annual temperatures), photosynthesis decreases and biomass growth and yield are expected to decline. Even drought-adapted ecosystems are influenced by increased heat which can lead to reduced plant growth and primary productivity as well as to altered plant recruitment (Linder *et al.,* 2010).

The growing season of forests can be lengthened along with rising temperatures. On the other hand rising temperatures can cause shifting of the geographic ranges of some tree species northward or to higher altitudes or could even cause their extinction if conditions in their current geographic range are no longer suitable. For example, species that currently exist only on mountaintops may die out as the climate warms since they cannot move to a higher altitude (EPA, 2012).

Future changes in precipitation will have a significant effect on forests' growth. Plant growth and forest cover in particular will be affected by changes in frequency and availability of precipitation. The anticipated decrease in precipitation may inhibit forest growth and limit forest cover.

Changes in the hydrological regime may also have serious implications for the forests' sustainability. Decreased soil moisture is known to largely affect forestry species such as *Pinus brutia* the predominant species of Cypriot forests. Regarding PRECIS model projections, decreases are expected in winter total rainfall of about 20 mm for all the domain of study. As a result, for Troodos Mountain and Paphos District is anticipated precipitation of about 210 mm and for Larnaca District 70 mm in comparison with present-day climate where precipitation is 230 mm and 90 mm respectively.

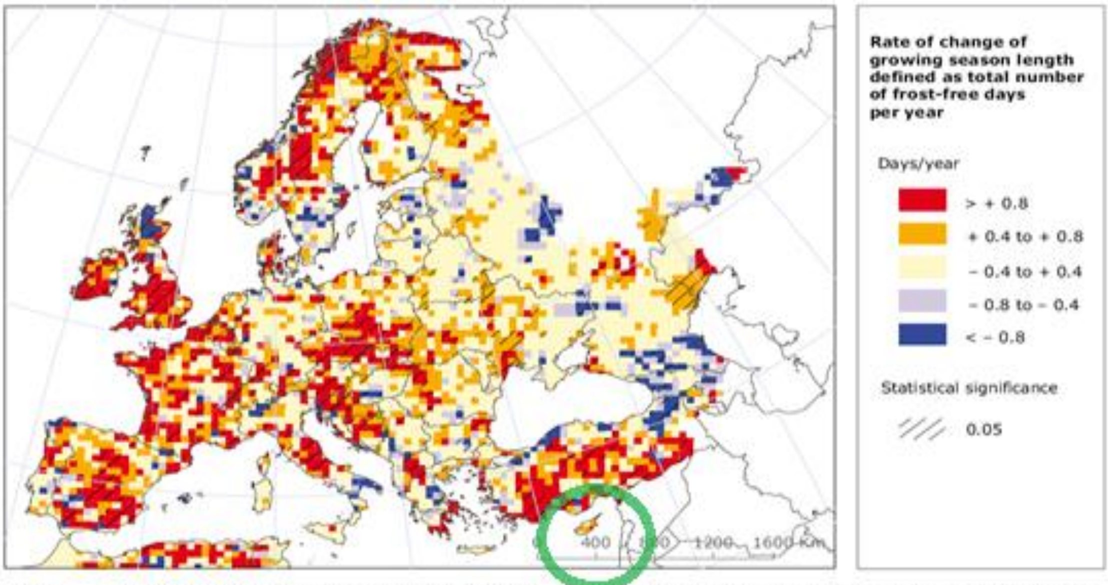
A similar pattern to winter is evident for autumn precipitation regarding PRECIS plots. A decrease in the amount of rainfall of about 15 mm is projected for the near future throughout the whole domain of study. Future amounts of autumn rainfall will reach 55 mm for Larnaca District, 95 mm for Troodos Mountain and 135 mm for Paphos District comparing with current amounts which are 70 mm, 110 mm and 150 mm respectively.

7.3.4.1 Future levels of atmospheric CO2 and impact on forest growth

It is recognized that increases in ambient CO_2 have positive impacts on plant growth. Atmospheric CO_2 is a substrate for plant photosynthesis. Therefore, rising concentrations of CO_2 in the atmosphere is believed to act as a fertilizer and increase photosynthesis rate (Lindner *et al.,* 2008). Furthermore ozone and nitrogen deposition affect tree physiology, carbon allocation and plant interactions, resulting in complex interactions with other climatic impact factors such as drought (Lindner *et al.,* 2008).

The length of growing season is regarded as a simple but important indicator of the climate change impacts at local level (EAA, 2008a; Brinkmann, 1979). A prolonged growing season increases plant growth as it strongly assists the optimum use of the available thermal energy, sunlight and water resources and facilitates the presence of new species in certain areas which was limited before because of unfavourable conditions. Nevertheless, a shortening of the growth period could also help prevent harsh summer stress conditions in regions that face drought problems.

According to the EEA's assessment report (2008a), it has been proved that the length of the growing season concerning various crop types across the European regions has changed. There are two ways to determine the growing season in temperate regions. The first, and more usual, is the calculation of the average number of days between the last frost in spring and the first severe frost in autumn. The second, depending on crops, is the calculation of the average number of days that the temperature rises high enough for a particular crop to sprout and grow (USEPA, 2012). As it can be seen from Figure 7-3 there is general tendency for lengthening of the growing season especially in the regions in northern latitudes (EAA, 2008a).



Note: The rate of change (number of days per year) of the duration of the growing season (defined as total number of frost-free days per year) as actually recorded during the period 1975–2007.

Source: MARS/STAT database (Genovese, 2004a, 2004b).

Figure 7-3: Rate of change of the duration of the growing season as actually recorded during the period 1975-2007

Source: EAA, 2008a

Scientific data provide evidence that the flowering and maturity phases of several types of plants currently take place two or three weeks earlier than in the past in Europe. Given the increasing trend of temperatures, the plant phases will shorten, especially in Western Europe and two or more cropping cycles may take place during the same season. On the other hand, high temperatures may hinder the efficiency of photosynthesis, thus leading to a gradual decrease of the reduction rate of these phenological phases (EEA, 2008a; IPCC, 2007).

Increased temperatures may accelerate the rate at which plants release CO_2 in the process of respiration, resulting in less than optimal conditions for net growth. In addition, when the optimal temperature for biological processes is exceeded, crops may be adversely affected with a steep drop in net growth and yield. Another important effect associated with high temperature is the acceleration of physiological development and subsequently of maturation resulting in reduced yields (GCRIO, 1995).

Reduced rainfall and increased temperatures result decrease in water abundance with the subsequent negative impacts for the environment. Especially for the Mediterranean area, a deteriorating meteorological water deficit has been reported for the last 32 years. Furthermore, the annual number of rainy days is expected to decrease while the risk of summer drought is projected to increase. These areas are experiencing high competition for water between sectors and users (agriculture, tourism, energy etc.) (EEA, 2008a). The map illustrated in Figure 7-4 provides an estimation of the change in the volume of water needed for irrigation purposes so as not to inhibit crop growth. The rate of change of the *meteorological water balance* is expressed in “m^3 x ha^{-1} x year^{-1}”.

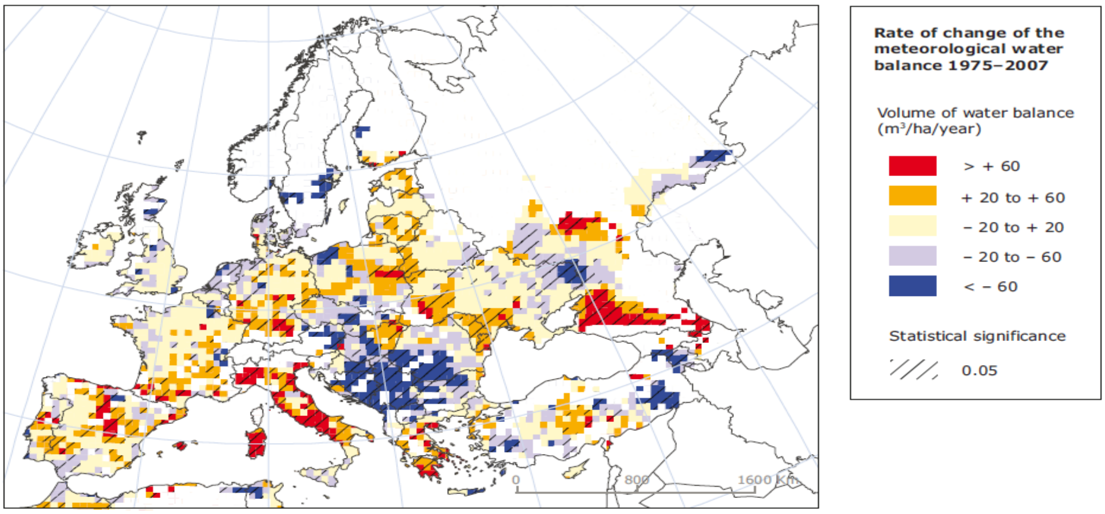


Figure 7-4: Rate of change of the meteorological water balance for the period 1975-2007

Source: EAA, 2008a

The occurrence of moisture stress during flowering, pollination and grain-filling is harmful to most crops. Increased evaporation from the soil and accelerated transpiration in the plants themselves will cause moisture stress. Subsequently, the demand for water for irrigation is projected to rise in a warmer climate, bringing increased competition between agriculture, which is already the largest water consumer in semi-arid regions, and other water users (GCRIO, 1995).

Regarding the effects of elevated CO2 on plant growth and yield in Cyprus, there are no available relevant research findings. Cyprus, has recently joined the ICP international program on the assessment and monitoring of air pollution effects on forests from which more concrete data are expected to be provided. The first findings of this project show that rising atmospheric CO2 levels have positive effects on photosynthesis and water-use efficiency and thus on forest growth but it is unclear how persistent this 'CO2-effect' will be in the long-term. The applied model projects that with increasing CO2, growth across Europe and across different tree species will increase. Under constant CO2-levels the changes are much smaller and become negative particularly for plots in the south and some regions of central Europe. Coniferous stands mostly show increasing productivity. This effect is, however, because coniferous stands dominate in northern regions and at higher altitudes where climate change is assumed to have more growth-stimulating effects. In contrast, net primary productivity of broadleaved tree species is projected to decrease under constant CO2 on a majority of the studied forests, particularly in the south (Figure 7-5).

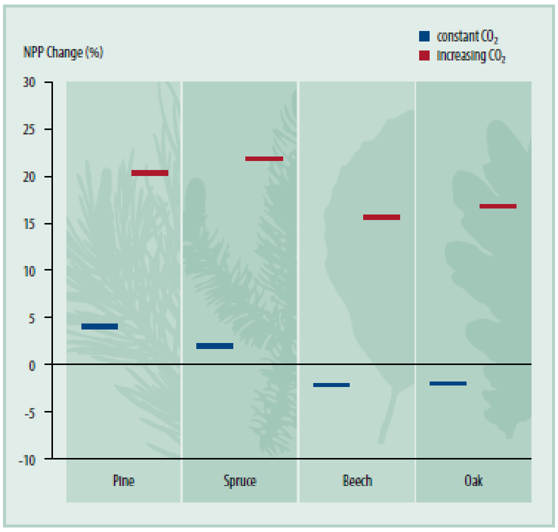


Figure 7-5: Projected change in net primary productivity (NPP) for four main tree species in the period 2061–2090 relative to 1971–2000 under constant and increasing CO2 concentrations. Means of six modelled climate change scenarios are depicted.

As a result of clean air policies, under the Convention on Long-range Transboundary Air Pollution and EU legislation future projections depict a decreasing sulphur deposition, while mean nitrogen inputs have shown only a minor decrease. The evaluations reveal nutrient imbalances specifically in areas with high nitrogen deposition loads. There is clearly a need for more emissions reductions in this field.

In general, Cyprus, a region with already warm and dry conditions especially during summer, is likely to experience decrease in forest growth due to the increase in temperature and the decrease in precipitation, while the projected climate conditions will magnify the already intense water stress circumstances provoking forest growth failure.

Although increases in temperature are expected to result in the lengthening of the growing season and increase forest growth, they also create less than optimal conditions due to increased rates of CO2 plant release, increase moisture stress and water demand According to the PRECIS model, the mean change in annual average temperature in Cyprus with respect to the control period 1960-1990 will range from 1-2 ^{o}C on average.

7.4 Future vulnerability assessement

In this section, the vulnerability of forests to the future climatic changes is assessed in terms of their sensitivity, exposure and adaptive capacity based on the available quantitative and qualitative data for Cyprus and the climate projections for the period 2021-2050. In particular, sensitivity is defined as the degree to which forests will be affected by climate changes, exposure is the degree to which forests will be exposed to future climate changes and their impacts while the adaptive capacity is defined by the ability of forests to adapt to changing environmental conditions which is also enhanced by the measures implemented in Cyprus in order to mitigate the adverse impacts of climate change on the sector.

The same indicators are used for the assessment of sensitivity, exposure and adaptive capacity of Cyprus forests to future climate change impacts, with those used for the assessment of current vulnerability of forests. Indicators to be used for the future vulnerability assessment of climate change impacts on the forests of Cyprus are summarized in Table 7-4.

Table 7-4: Indicators used for the future vulnerability assessment of climate change impacts on the forests of Cyprus

Future Vulnerability Variable	Selected Indicators
Dieback of tree species, insects attacks and diseases	
Sensitivity	– Species affected by drought – Species affected by pest and diseases – Proportion of trees with insect occurrence – Pests affecting tree species – Area with drought problems and distress – % of species within Cyprus threatened – Distribution of threatened species
Exposure	– Forest areas exposed to increased temperatures – Forest areas exposed to decreased precipitation – Frequency and intensity of droughts
Adaptive capacity	– Monitoring – Dead trees removal – Control of insect populations – Irrigation – Thinning – Restriction of afforestation/refostation – Limit timber
Fires	
Sensitivity	– Climatic factors (temperature, wind, humidity) – Presence of flammable vegetation – Topography – Urbanization factor

Future Vulnerability Variable	Selected Indicators
	– Fire risk in Cyprus – % of species within Cyprus threatened – Distribution of threatened species
Exposure	– Number of fires, burnt areas, fire size – Fire Weather Index – Fire season (months) – Dry spells – Forest area
Adaptive capacity	– Fire Prevention measures – Fire Pre-suppression measures – Suppression measures – Increase water supply points – Early Warning System – Increase Alert and Readiness – Restoration of burnt areas
Floods, wind throws and storm damages	
Sensitivity	– Age of species – Slopes – Height of vegetation
Exposure	– Forest areas with risk to be exposed or exposed to floods
Adaptive capacity	– Flood Risk Management Plans in progress – Need for adaptation measures
Forest growth and air pollution	
Sensitivity	– Sensitive species to air pollution (ozon, nutrient nitrogen, acidity etc) * – Sensitive species to increased temperature and decreased precipitation *
Exposure	– Concentration of ozone and CO2 in forest areas – Exceedances of critical loads of nutrient nitrogen and acidity – Forest areas exposed to increased temperatures – Forest areas exposed to decreased precipitation – Frequency and intensity of dry spells – Frequency of extreme events

Future Vulnerability Variable	Selected Indicators
Adaptive capacity	– Monitoring of the effect of air pollution to forest growth

*There were no data regarding this indicator

The relationship between sensitivity, exposure and adaptive capacity is based on the following qualitative equation:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity\ *\ Exposure$$

Sensitivity, exposure and adaptive capacity are evaluated on a 7-degree qualitative scale ranging from “none” to “very high”.

The vulnerability is assessed for each of the impact categories presented in Section 8.2:

1. Dieback of tree species, insect attacks and diseases
2. Fires
3. Floods, wind throws and storm damages
4. Forest growth

The future vulnerability of forest ecosystems is anticipated to vary substantially as it will be related to the different rate and magnitude of climate change in different parts of Cyprus such as level of air pollution levels, temperature, rainfall variations and meteorological conditions (e.g. wind, moisture).

It must be noted that, there are no sufficient scientific evidence and data to evaluate or correlate all impacts and indicators to future climate changes. Consequently, further research is required in order to provide concrete information for a more detailed and descriptive assessment of the future vulnerability of the sector. Nevertheless, an attempt was made to provide a preliminary assessment of the future vulnerability. Additional data and further research is required for a more comprehensive evaluation for the vulnerability of the sector.

7.4.1 Dieback of tree species, insects attacks and diseases

7.4.1.1 Assessment of sensitivity and exposure

Sensitivity

Increase in temperature is significant for the health of the forest ecosystem. Studies showed that the increased incidents of dieback of forest species in Cyprus are attributed to the adverse environmental conditions that prevailed and particularly the decrease in rainfall and increase in air temperature (Christou et al., 2001). An increase of the temperature only of 1-2 °C might be the end of the species of Pinus nigra at the top of Troodos mountains. Furthermore a drought period can result the necrosis of pines and cypress -which are very demanding in soil moisture-, as already happened in Stavrovouni forest in Larnaca and in several trees of the Stone Pine species (Pinus pinea) –in the Rizoelia National Forest Park.

The study on the dieback of Cedrus brevifolia growing in Cyprus which is limited to the Tripylos area (Cedars valley), in the Paphos forest, showed that the increased incidents of dieback during the period 1998-2001 are attributed to the adverse environmental conditions that prevailed in Cyprus and particularly the decrease in rainfall and the increase in air temperature (Christou et al., 2001).

According to Table 7-5, the dieback incidents of trees during the period 2007-2008 were more intense in the forest regions of Nicosia, Larnaca and Famagusta (16%) and in Troodos (7%).

Table 7-5: Dieback Inventory Summary at state forests of Cyprus (period 2007-2008)

Forest Region	Total Forest Covered Area (ha)	Area with Serious drought Problems (ha)	Area with Serious Distress and low drought (ha)	Total Forest Area with Problems (columns 3+4) (ha)	Percentage (%)
Paphos	69,386	70	1,307	1,377	1.98
Troodos	33,760	453	1,835	2,287	6.78
Nicosia, Larnaca, Famagusta	18,422	1,479	1,474	2,953	16.03
Forestry College (Limassol)	2,342	0	16	16	0.68
Total	**123,911**	**2,002**	**4,631**	**6,633**	**6.37**

Source: Department of Forests, 2009a

A large number of tree species are affected by indigenous insects. The dominant forest pests affecting both naturally regenerating forests and planted forests in Cyprus are presented in Table 7-6. The anticipated increase in temperature and heat-wave days as well as the decrease in rainfall is possible to increase this proportion if further measures are not adopted.

Table 7-6: Forest pests (indigenous insects) which affect natural regenerating and planted forests of Cyprus

Insects	Affected tree species
Lymantria dispar Linnaeus	Broadleaved trees, oak (Quercus infectoria ssp. Veneris), golden oak (Quercus alnifolia), strawberry tree (Arbutus andrachne), terebinth (Pistacia terebinthus)
Orthotomicus erosus	Calabrian pine (Pinus brutia), Black pine (Pinus Nigra ssp. Pallasiana)
Phloeosinus armatus	Cypress tree (Cupressus Sempervirens), Gold crest or Monterey Cypress (Cupressus macrocarpa Hartw)
Thaumetopoea wilkinsoni	Calabrian pine (Pinus brutia), P. Canariensis, P. Halepensis And the hybrid P. Brutia x P. Halepensis.Thaumetopoea wilkinsonii
Tomicus destruens	Pinus brutia
Tomicus piniperda	Calabrian pine (Pinus brutia)
Tomicus minor Hartig	Pinus brutia, Pinus nigra Var. Caramanica

Source: FAO, 2008

In 2010, the proportion of trees in Cyprus with insect occurrence was at most cases 75-100%, as shown in Figure 7-6.

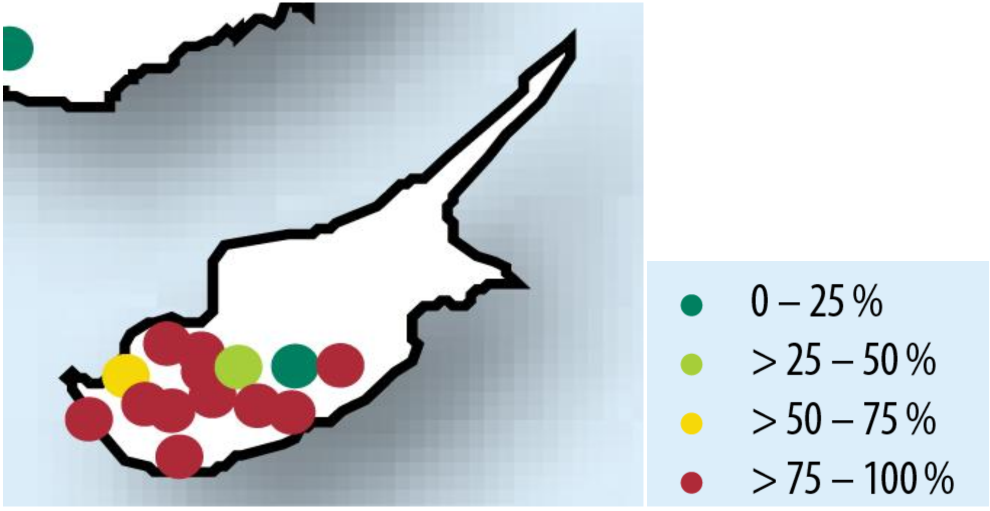


Figure 7-6: Proportion of trees per plot with insect occurrence in 2010

Source: LRTAP/EWF, 2011

The recorded outbreaks of insects that affected Pinus bruttia's health and vitality are shown on Table 7-7.

Table 7-7: Impacts of insect outbreaks to Pinus bruttia

Description / name	Tree species or genera affected (scientific name)	Year(s) of latest outbreak	Area affected (1000 hectares)	If cyclic, approx. cycle (years)
Thaumetopoea wilkinsonii	*Pinus brutia*	2007	8.1	Every year
Leucaspis knemion	*Pinus brutia*	2006 2007	0.2 0.2	x

Source: FRA, 2010

In Table 7-8, the area, density and distribution of the main tree and other woody forest species threatened by drought, desertification, pests and diseases as well as the range of threat within Cyprus, are presented.

Table 7-8: Main tree and other woody forest species considered to be threaten by drought, desertification and pests in all or part of their range in Cyprus

Species (scientific names)	Area (ha) of species, natural distribution	Average number of tree per hectare	Distribution in Cyprus	Type of threat	Threat Category*		
					High	Medium	Low
Cedrus brevifolia (tree)	367	75	Local	Drought & desertification Pests and diseases		X	
Juniperus excels (tree)	643	32	Local	Drought & desertification		X	
Pinus nigra ssp. pallasiana (tree)	4,970	n.a.	Local	Pests and diseases		X	
Juniperus foetidissima (tree)	72.7	n.a.	Local	Drought & desertification		X	
Quercus infectoria ssp. veneris (tree)	354.7	n.a.	Widespread	Drought & desertification Pests and diseases	X		

Species (scientific names)	Area (ha) of species, natural distribution	Average number of tree per hectare	Distribution in Cyprus	Type of threat	Threat Category*		
					High	Medium	Low
Cupressus sempervirens (tree)	450	n.a.	Widespread	Drought & desertification Pests and diseases			X
Arbutus unedo (shrub)	1.5	53	Local	Drought & desertification	X		
Phillyrea latifolia (shrub)	596	8.4	Rare	Drought & desertification	X		
Viburnum tinus ssp. tinus (shrub)	17	60	Local	Drought & desertification	X		

**Threat categories: High – threatened throughout species range within Cyprus, Medium – threatened in at least 50% of range within country, Low-threatened in less than 50% of range within country.*

Source: Department of Forests, 2011a

Currently four out of nine main forest trees and shrubs are considered highly threatened by drought, desertification, pests and diseases and this situation can be negatively affected with the future estimations in climatic parameters.

Summer maximum temperature is anticipated to increase about 2-2.7 °C in forested regions reaching 30-32 °C. This might be the end of some species in Troodos forest and the dieback of other species. This temperature increase may also lead to extinction of certain species in their current geographical range. Furthermore PRECIS predicts duplication of heat wave days in forested areas for the future period reaching 40-60 days.

To sum up, taking into account the combination of temperature increase and the increase in heatwave days in Troodos and Paphos forest, sensitivity of Cyprus' forests to increased diebacks and insect outbreaks is expected to be **very high**.

Exposure

Precipitation changes: For the current period and past period rainfall has been geographically unevenly distributed, with maximum precipitation falling on the island's two mountainous masses where the two main state forests are found whereas minimum precipitation is observed in the eastern plain and the coastal areas. The main bulk of precipitation (about 80% of the total) falls during November and March, while the period from May to September is a biologically dry period. The areas most exposed to low precipitation, high temperatures and drought conditions especially during summer are the coastal areas (such as Paphos, Limassol, Larnaca and Famagusta) while the mountain areas (Troodos) are characterized by higher precipitation and lower temperature. However, it must be mentioned that the area of Troodos mountains where major state forests are located is featured by higher annual precipitation decreases for the period of 1917 to 2000 comparatively to the rest free part of Cyprus. Anticipated changes in climatic parameters will affect dieback of species and may cause further necrosis of forest areas. Projections are presented analytically in the following.

Decrease in rainfall except from dieback of the tree species due to thermal stress has secondary results such as decreased soil moisture which is known to largely affect forestry species. The overall decrease in precipitation for the future period is not significant. However it is most evident for winter and autumn seasons. More specifically for Troodos Mountain and Paphos District is anticipated a winter total rainfall of about 210 mm while for Larnaca District 70 mm in comparison with present-day climate where precipitation is 230 mm and 90 mm respectively (Figure 7-7).

As a result the decrease of about 20mm in winter precipitation in combination with higher predicted temperatures in all forested areas may enhance the dieback of forest species.

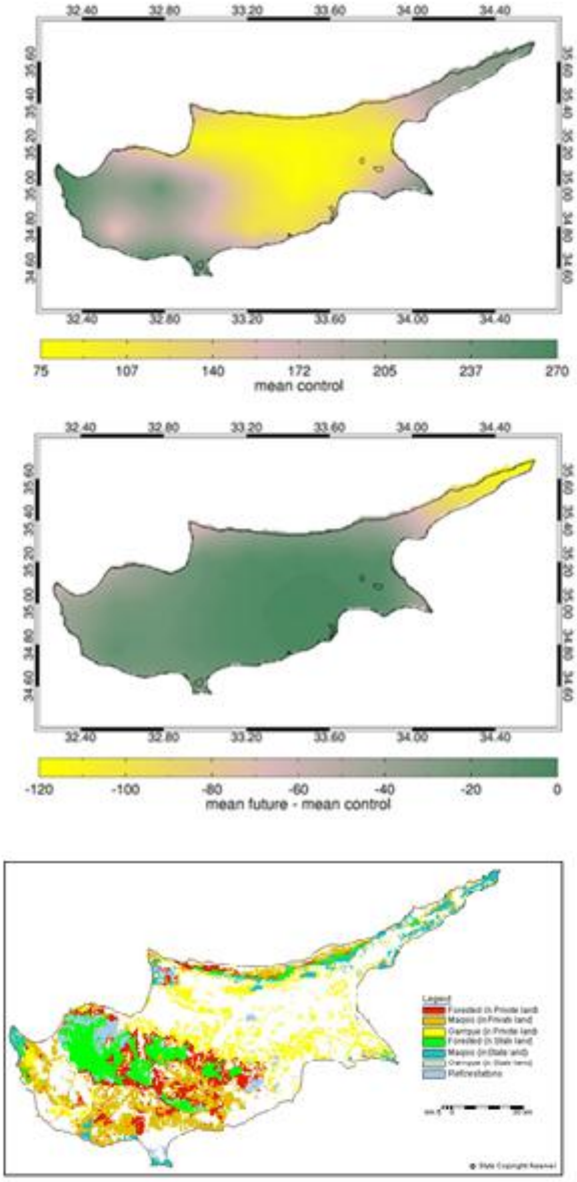


Figure 7-7: Winter total precipitation (mm) for control period using PRECIS RCM model (a) Changes in winter total precipitation in the near future (Future – Control period) using PRECIS RCM model (b) and Natural vegetation of Cyprus (c)

A similar pattern to winter is evident for autumn precipitation regarding PRECIS plots. Figure 7-8 shows that a decrease in the amount of rainfall of about 15 mm is projected for the near future throughout the domain of study. Future amounts of autumn rainfall will reach 55 mm for Larnaca District, 95 mm for Troodos Mountain and 135 mm for Paphos District compared with current amounts which are 70 mm, 110 mm and 150 mm respectively.

The decrease in autumn precipitation which follows the prolong summer period will result an additive stress in the dieback of forest species.

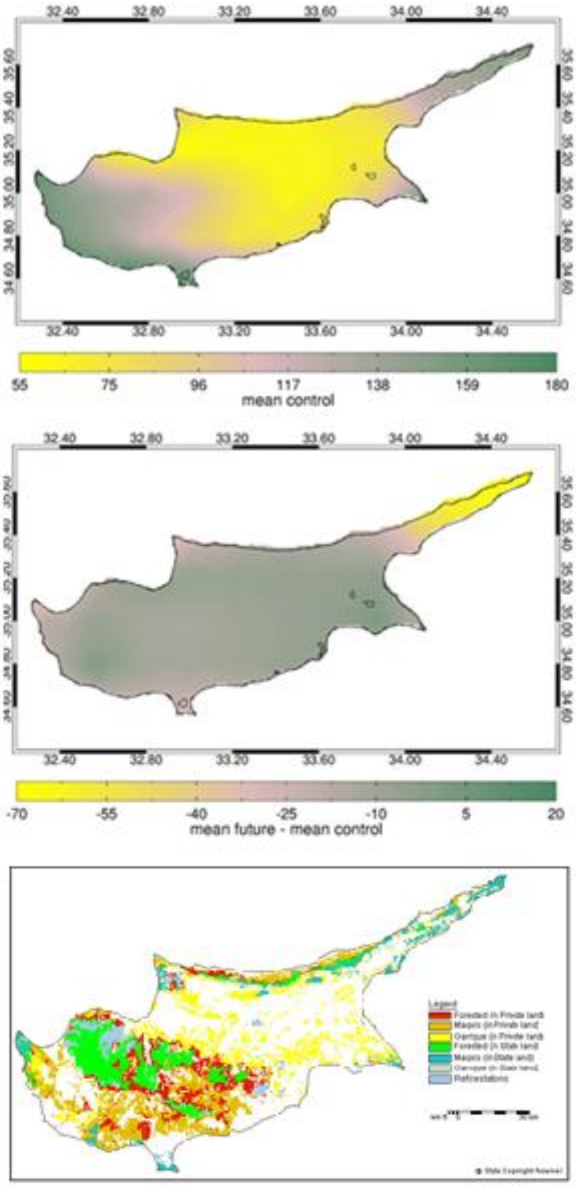


Figure 7-8: Autumn total precipitation (mm) for control period using PRECIS RCM model (a) and Changes in autumn total precipitation in the near future (Future – Control period) using PRECIS RCM model (b) and Natural vegetation of Cyprus (c)

<u>Maximum length of dry spell</u>

Dry spell has an impact on soil moisture. Increase in length of dry spell can decrease soil moisture. Low level of soil moisture has a negative impact on the intense stress of forest ecosystems, particularly those found in lowland and hilly areas. Furthermore low soil moisture can cause the necrosis of trees due to the possibility development of secondary insects attack is highly possible. In Cyprus, the lack of soil moisture, apart from its effects on the drying of trees, has secondary impacts on them since it enhances the activity of insects such as the Orthotomicus erosus and Bursaphelenchus leoni which attack stressed trees due to lack of moisture and dry them up altogether. The necrosis of a significant number of pines and cypress in Stavrovouni forest occurred due to the impact of insects during the dry period 2005 – 2008 (Department of Forests, 2011b; Cyprus Institute, 2011).

Increases in maximum length of dry spell can affect negatively forest species sensitive to soil moisture content. In the current period maximum length of dry spell in forested regions of Troodos is about 60 days and in Paphos Forest is 15 days. Figure 7-9c depicts that areas of Nicosia and Larnaca and Troodos forest reveal increases of about 10 days. Conversely, western regions that include a major part of Paphos forest show no increases. As a result increases in maximum length of dry spell will affect mostly forested areas situated in the central part of Cyprus and less the western areas.

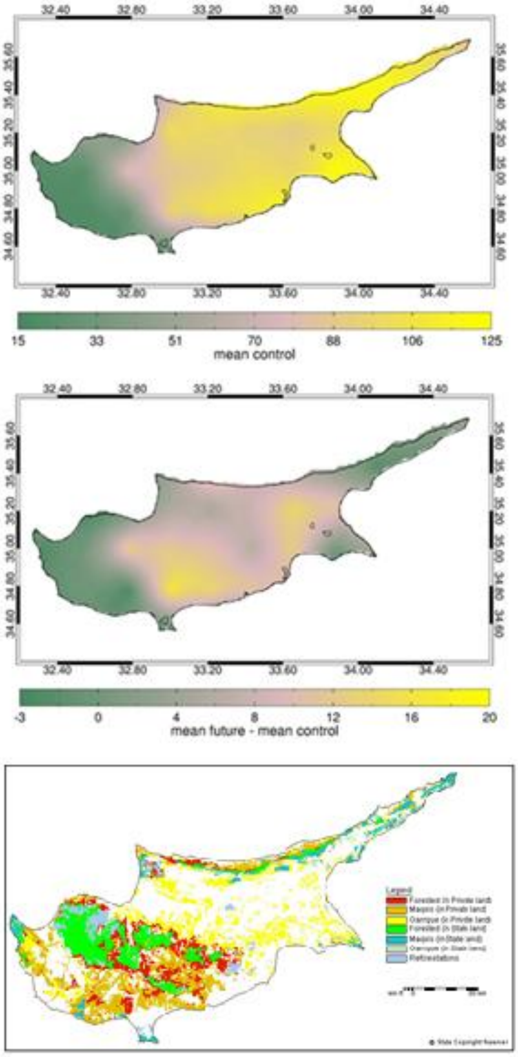


Figure 7-9: Maximum length of dry spell for control period using PRECIS RCM model (a) Changes in maximum length of dry spell in the near future (Future – Control period) using PRECIS RCM model (b) and Natural vegetation of Cyprus (c)

Consequently future increase in maximum length of dry spell will affect the central part of Cyprus and more significantly Troodos forest increasing the existing risk of dieback of tree species in this area.

The Standardized Precipitation Index, which provides a quantitative definition of drought, was computed for the case of Cyprus for the period 1970/71 - 2010/2011. The past 40 years have been marked by three extreme drought years, with an SPI below -2 (1972/73, 1990/91, 2007/08). There were also three years of moderate droughts (1989/90, 1999/00, 2005/06 and 12 years of mild drought (Cyprus Institute, 2011). From the SPI values it can be seen that drought events appear in Cyprus with great frequency while there are some years of quite intense droughts. Further research is required for calculation of the future Standardized Precipitation Index.

Temperature changes: The anticipated increase in average temperature affects tree species in Cyprus. Specific information is provided for anticipated winter minimum and summer maximum temperatures in the various forested areas as the seasons with the most significant changes. Furthermore increase in the number of heat wave days is presented.

Average winter minimum and summer maximum temperature

Rising temperature may enable some insect species to develop faster and endanger thus the forest growth. In this frame the predicted increase in winter minimum and summer maximum temperature in the future period can worsen current situation in dieback of tree spieces.

In comparison with the natural vegetation map of Cyprus projections of PRECIS regional climate model make evident that all forested areas of Cyprus will experience, in the near future, a warming of about 0.8 – 1.1°C. Winter minimum temperature is anticipated to reach 6°C in Troodos and Paphos Forest and 7-9°C in forested area of Larnaca District in contrast with control period where the respective temperatures is 5°C and 6-8°C respectively. The most significant increases of about 1.1°C are anticipated for Paphos forest and southern non forested region (Maquis in Private and state land) while for the rest of the areas changes are expected to be less significant. Especially in the northern Cyprus changes in winter minimum temperature are anticipated to be minor.

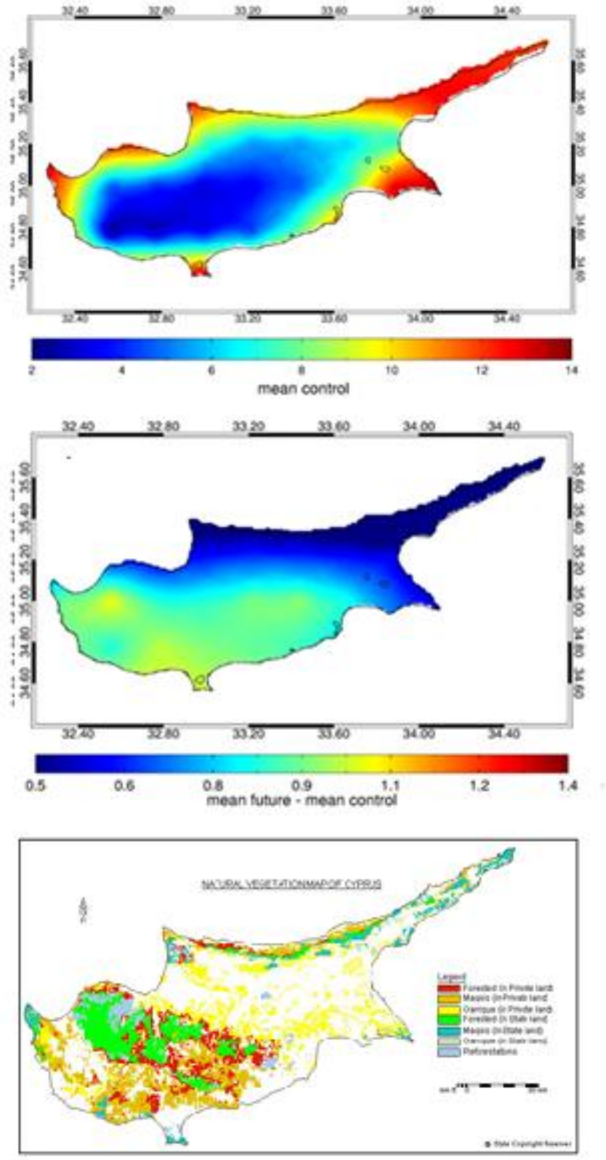


Figure 7-10: Average winter minimum temperature for control period using PRECIS RCM model (a) Changes in average winter minimum temperature in the near future (Future – Control period) using PRECIS RCM model (b) Natural vegetation of Cyprus (c)

Figure 7-11 shows average summer maximum temperatures for the control period as well as projected future changes. According to Figure 8-4c forested regions of Troodos Mountain (Troodos and Paphos forest) will experience a significant warming of about 2.0 – 2.7°C reaching temperatures of about 32 – 35.7°C which are unfavorable for forests. As it presented in the following figure increases in summer maximum temperatures are more significant for forested mountain regions and inland regions in comparison with coastal areas that are either non covered by vegetation or Maquis. In reforestation areas summer maximum temperatures will increase about 1°C, less than all other areas.

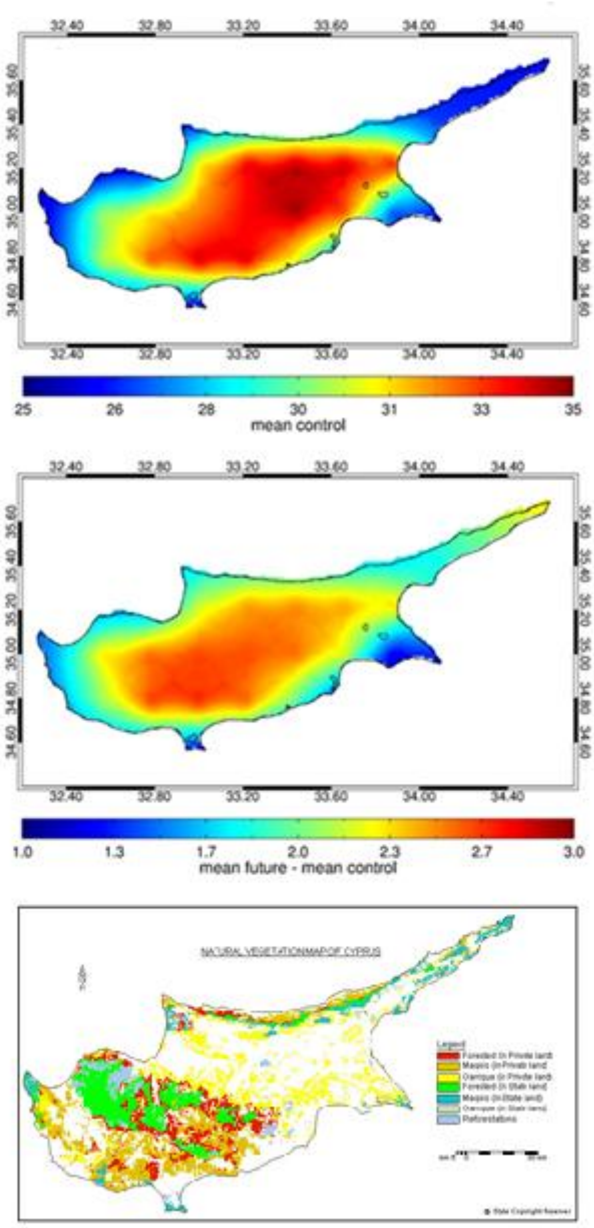


Figure 7-11: Average summer maximum temperatures for control period using PRECIS RCM model (a) Changes in average summer maximum temperature in the near future (Future – Control period) using PRECIS RCM model (b) Natural vegetation of Cyprus (c)

Future increase in average winter minimum temperature is affecting the biggest part of Cyprus and more significantly forested areas. Nevertheless this may not increase the risk of dieback of tree species during winter period.

Number of Heatwave days

Number of heatwaves days is a very important factor since in combination with the length of dry period can cause "thermal stress" to trees leading to extended necrosis mainly during the long hot summer period.

Figure 7-12 illustrates potential future changes in the number of days, where maximum temperature exceeds 35°C. Under such temperature conditions, forests may be unfavourably affected. As PRECIS predictions show, an increase of about 20-30 days is expected for Troodos mountain regions and conversely 10 days for western areas. In specific, number of heatwaves days over 35°C may reach in future 40-60 days in Troodos forest and 20 days in Paphos forest in contrast with current period where heatwaves days are approximately 20-30 and 8-10 respectively (Figure 7-12). As a result Troodos forest is affected more than Paphos forest while southwestern regions covered mainly by Maquis will be affected even less.

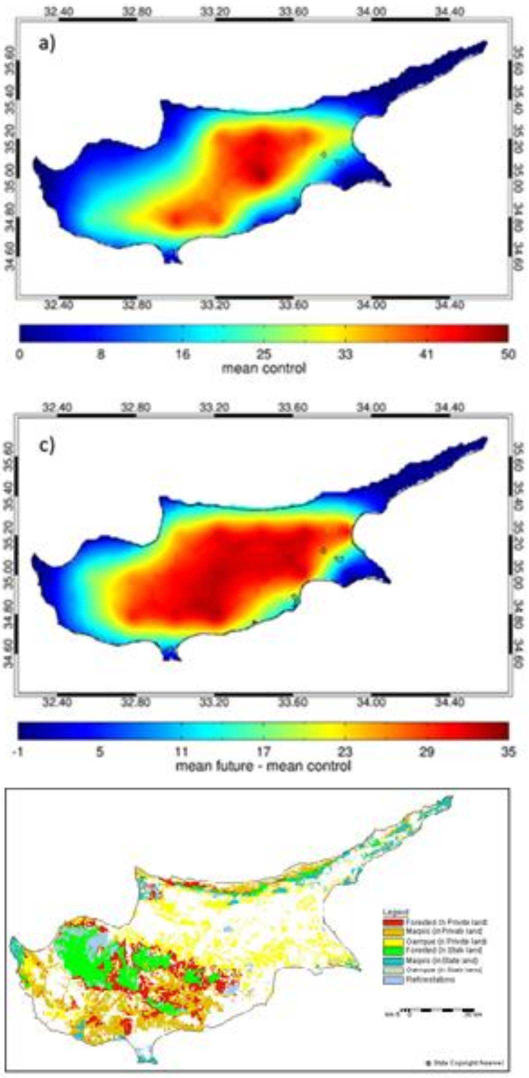


Figure 7-12: Number of heatwaves days for control period using PRECIS RCM model (a) Number of heatwaves days in the near future (Future – Control period) using PRECIS RCM model (b) and Natural vegetation of Cyprus (c)

The most significant increase in number of heat wave days appears in the central part of Cyprus affecting significantly Troodos forest and increasing in this area the risk of dieback of tree species. However is Paphos forest and southeastern forested areas the increase is less intense but still very significant. The predicted increase of (100%) in heat wave days in Paphos may also put at high risk the dieback of tree species.

Considering the above, future increase of temperatures will significantly affect all forested areas of Cyprus. Decreased precipitation specifically in Autumn period as well as increase in dry spell periods will alleviate the dieback and insect outbreak of all major forested areas. Thus exposure is characterized as **very high**.

7.4.1.2 Assessment of adaptive capacity

The Department of Forests in Cyprus has taken action considering the implications of droughts and high temperatures and prepared a "Short-term Action Plan for the Confrontation of the Implications of Drought in Cyprus state forests (2009-2010)". The measures and actions of the Plan address the dieback of tree species, insect attacks, biodiversity loss as well as fires. The Plan has flexibility and can be adjusted depending on the progress of drought and the new data that may arise. Also, some of the actions will be implemented gradually until 2013 (Department of Forests, 2009b).

Despite the numerous measures that are implemented in Cyprus for combating dieback of forests and insect attacks as well as for the protection of biodiversity, the effect can only be alleviated but not eliminated. Additional recommended adaptation measures that are considered to further enhance adaptive capacity towards this impact are presented indicatively. Nevertheless, their assessment and final selection for implementation will be made through the use of the Multicriteria Analysis (MCA) tool which will be developed and implemented in the framework of Actions 4 and 5 of the CYPADAPT project.

- Further increase forest areas through afforestation of bare lands and reforestation of abandoned agricultural lands
- Use of species with higher carbon sequestration ability (for plantations) and well adapted to hard climatic conditions
- Minimize tillage and associated practices
- Prevent non forest uses to state forest land, with the exception of specific cases and only for the public interest
- Preparation of management plans for all state forests within 10 years, taking into account national needs, climate changes and the provisions of relevant EU directives
- Meeting the requirements in timber of wood industries and at the same time establishing annual quantity of timber harvested well below the annual increment, in order to improve the quality and land cover of forests
- Creation of a permanent committee with the responsibility of identifying suitable land for the expansion of forests
- Research, data collection and monitoring of biotic and abiotic parameters

- Identification and promotion of micro- climatic benefits and environmental services of trees and forests
- Stricter control on grazing in the Akamas and other forest areas. Grazing in the remaining forest covered areas, outside the State Forests, should be limited to the least possible
- Control of land use change in private forests with relevant incentives and reimbursements
- Purchase by the State private forest areas enclosed or wedging into state forests
- Inclusion of the private forest covered areas in the fire fighting schemes of the Department of Forests

In the future further measures can increase adaptive capacity Thus, the adaptive capacity of Cyprus is characterized as **moderate.**

7.4.2 Fires

7.4.2.1 Assessment of sensitivity and exposure

Sensitivity

Forests in Cyprus are sensitive to fires because of their composition which is dominated by flammable vegetation and the topography of the forested areas, which is mostly mountainous. Moreover, urbanization increases the fire hazard because of the increase of flammable forest vegetation and decrease of human activity in the countryside as well as the availability of human and water resources in case of fires (Department of Forests).

In all the areas that main forests of Cyprus exist, such as Troodos and Pentadactylos the fire risk is "very high" while at maquis and garique vegetation areas found at Troodos and Pentadactylos as well as southern of Troodos the fire risk is high.

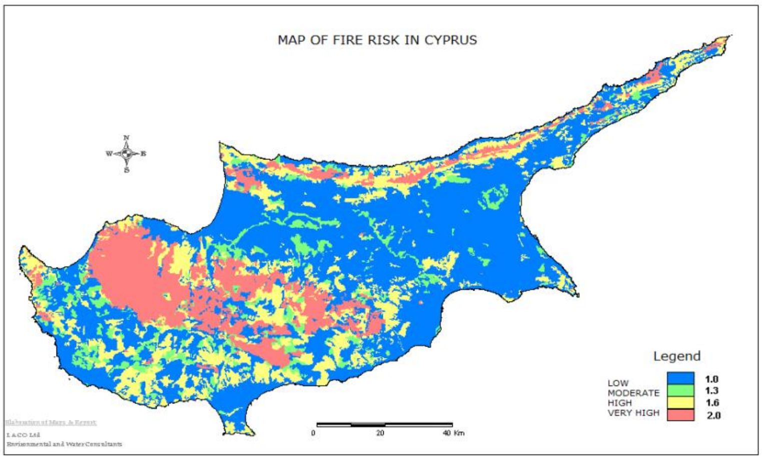


Figure 7-13: Map of fire risk in Cyprus

Source: Environment Service, 2007

The area, density and distribution of the main forest tree and shrub species that are threatened by forest fires as well as the range of threat within Cyprus, are presented in Table 7-9.

Table 7-9: Main tree and other woody forest species considered to be threatened by forest fires in all or part of their range in Cyprus

Species (scientific names)	Area (ha) of species, natural distribution	Average number of tree per hectare	Distribution in Cyprus	Threat Category*		
				High	Medium	Low
Cedrus brevifolia (tree)	367	75	Local		X	
Juniperus excels (tree)	643	32	Local		X	
Pinus nigra ssp. pallasiana (tree)	4,970	n.a.	Local		X	
Juniperus foetidissima (tree)	72.7	n.a.	Local		X	
Quercus infectoria ssp. veneris (tree)	354.7	n.a.	Widespread	X		
Cupressus sempervirens (tree)	450	n.a.	Widespread			X
Arbutus unedo (shrub)	1.5	53	Local	X		
Phillyrea latifolia (shrub)	596	8.4	Rare	X		
Viburnum tinus ssp. tinus (shrub)	17	60	Local	X		

**Threat categories: High – threatened throughout species range within Cyprus, Medium – threatened in at least 50% of range within country, Low-threatened in less than 50% of range within country.*

Source: Department of Forests, 2011a

In Cyprus for the future period it is expected to have increase in temperature, decrease in total rainfall and increase in dry spell days. Nevertheless the overall Fire Weather Index is expected to have a small increase. However this is not the case for Autumn and spring seasons.

The Canadian Fire Weather Index consists of six components that account for the effects of fuel moisture and wind on fire behavior. These include numeric ratings of the moisture content of litter and other fine fuels, the average moisture content of loosely compacted organic layers of moderate depth, and the average moisture content of deep, compact organic layers. The remaining components are fire behavior indices, which represent the rate of fire spread, the fuel available for combustion, and the frontal fire intensity; their values rise as the fire danger increases.

In addition, as already mentioned above, forest fires are highly sensitive to climate change because fire behavior responds immediately to fuel moisture (Weber and Flannigan 1997; Stocks et al. 2001), which is affected by precipitation, relative humidity, air temperature and wind speed. Thus, the projected increase in temperature will increase fuel dryness and reduce relative humidity and this effect will worsen in those regions where rainfall decreases. Accordingly, increases in climate extreme events are expected to have a great impact on forest fire vulnerability (Beniston 2003; Körner et al. 2005).

In Cyprus FWI has an extremely high value during July and August (about 50: extreme high risk) showing an increase of about 2-3 in all the forestry areas of Cyprus. Due to the future increase in temperature and the decrease in precipitation there is elevated fire risk in late spring and early autumn. The overall findings of the analysis (FWI) suggest that number of days with fire risk (FWI>15) will be increased from 5 to 15 days and number of days with extreme fire risk (FWI>30) will have an increase of 1 to 5day for the future period.

The long, hot and dry summers that last from May until October increase the fire risk since they convert the pine into a dry and highly inflammable fuel mass. During the fire season the temperature fluctuates from 30° to 44°C increasing the risk of ignition to very high levels. The relative humidity, which affects considerably the fire environment, ranges between 30-65%. The temperature increase of 1-2 degrees and the decrease precipitation will deteriorate fuel moisture. Rainfall during the fire season is very low and ranges between 0-50mm.

Wind is also a dominant factor of fire behavior. It is one of the hardest elements to predict due to variability of wind speed and direction and the influences of topography, vegetation, and local conditions. Winds during the fire season are mostly northwesterly or northerly (IFFN, 2005). For the future period (2021-2050) summer mean wind speed is not expected to deteriorate fire behavior since it is anticipated to have a decrease of about 0.018-0.23 m/sec with the lower decrease expected in forested areas.

Considering the above, the sensitivity of Cyprus' forests to fires is characterized as **very high**.

Exposure

Forests in Cyprus, like all Mediterranean forests, are exposed to fires especially during the summer period because of the climatic conditions. Due to the increase in temperature and the decrease in precipitation, that will intensify in the near future, it is predicted from PRECIS an elevated fire risk in all areas of about 2 in summer and 0-2 in late spring and early autumn as well.

According to data obtained from the Department of Forests in Cyprus, during the decade 2001-2010 the number of fire outbreaks within the state forest land was 273 and the burned state forest land was estimated at 1,280 hectares.

Cyprus Fire Weather Index (FWI) values for the period 2008-2010 are among the highest in comparison with the other European countries located in the Mediterranean. The overall findings of the analysis (FWI) suggest that number of days with fire risk (FWI>15) will be increased from 5 to 15 days and number of days with extreme fire fire risk (FWI>30) will have an increase of 1 to 5day for the future period.

Continuing with Fire Weather Index (FWI) the index simulating the fire risk, it is obvious that the FWI shows the highest values during summer and more specifically during months July and August. Regarding PRECIS results, Figure 7-14a depicts that, in fact, FWI reaches extremely high values in forested areas of about 50 (extreme high risk) in the control period, during July. Districts that present these excessive values are Limassol, Nicosia and Larnaca where FWI varies from 40 to 50. In Paphos District, FWI presents lower values of about 10 in Akamas peninsula, where National Park of Akamas is located, and 20-30 in Paphos Forest in the northwestern part of Troodos Mountain. As far as PRECIS near future projections are concerned, Figure 7-14c shows a small increase of FWI all over the Troodos Mountain of about 1-2 in low altitudes and 3-5 in high altitudes.

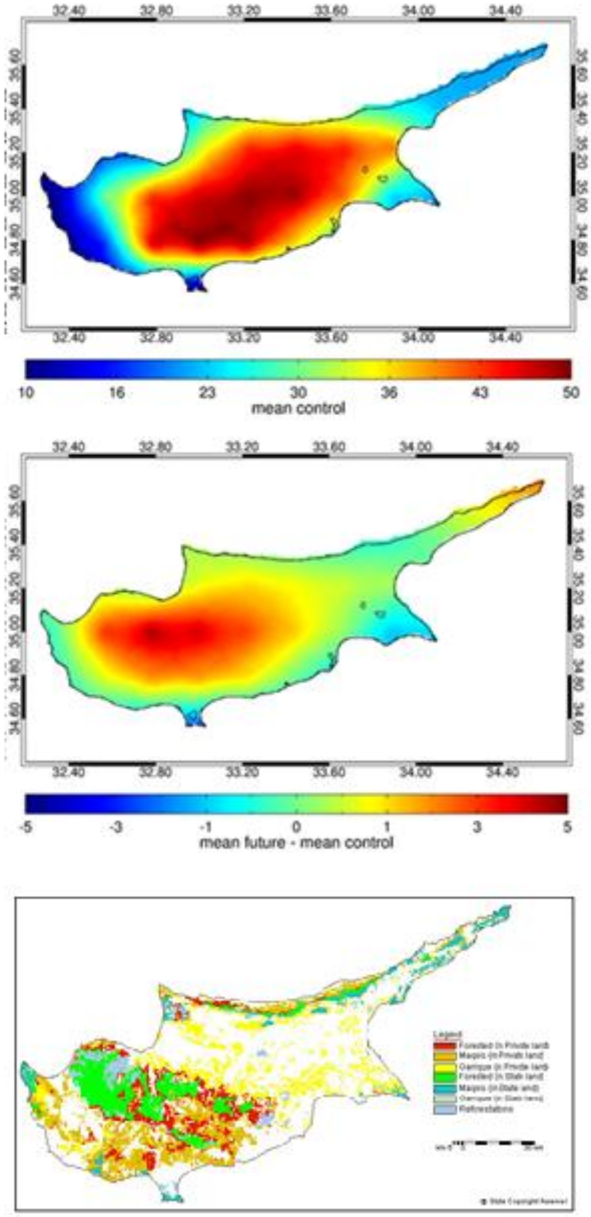


Figure 7-14: July average FWI for control period using PRECIS RCM model (a) Changes in July average FWI in the near future (Future – Control period) using PRECIS RCM model (b) and Natural vegetation of Cyprus (c)

Almost all forested areas of Cyprus will experience FWI>32 in July which is leading to an extreme risk during summer period. As a result forested areas will be in extreme high risk.

August FWI reveals comparable values compared with those in July. Similarly, FWI reaches extremely high values, mainly in the forested areas of Cyprus, of about 50 in Troodos Mountain parts of Limassol and Nicosia Districts (PRECIS plots). Lower values are evident in Larnaca forested areas (Stavrovouni and Rizoelia Forests) of around 40 and even more low values shows Paphos District where FWI varies from 10 in Akamas peninsula to 30 in Paphos

Forest. Regarding future projections, PRECIS shows a small increase in FWI of about 2 in forested areas of Limassol, Nicosia and Larnaca Districts. Also, no increase is projected for Paphos District.

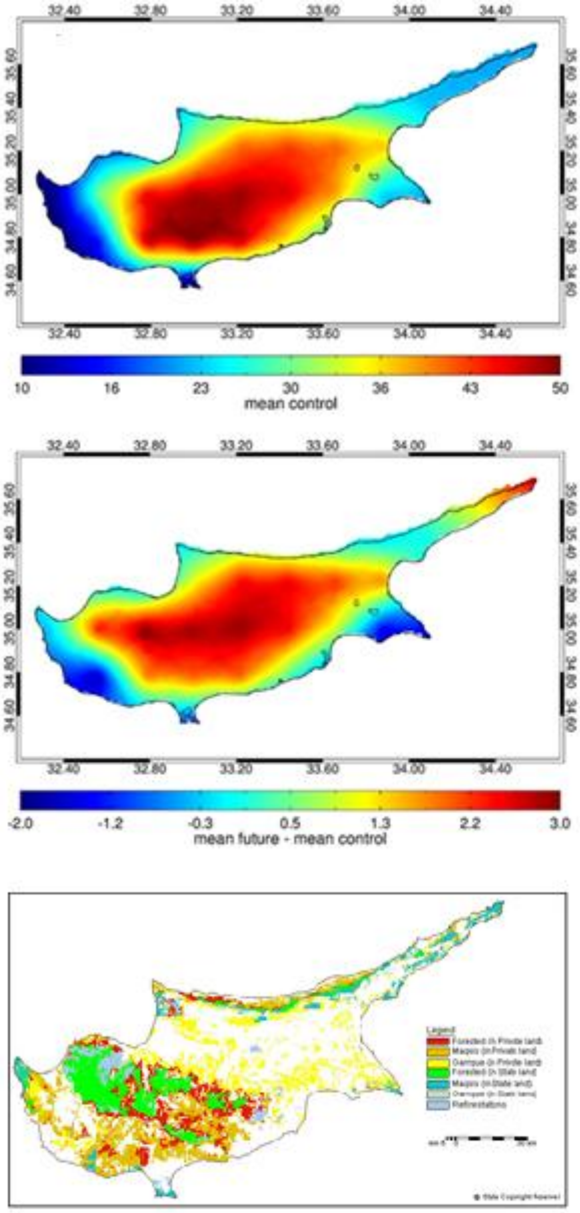


Figure 7-15: August average FWI for control period using PRECIS RCM model (a) Changes in August average FWI in the near future (Future – Control period) using PRECIS RCM model (b) and Natural vegetation of Cyprus (c)

Almost all forested areas of Cyprus will experience FWI>32 in August which is leading to an extreme risk during summer period. As a result forested areas will be in extreme high risk.

However, fire risk is not confined during the summer period. Due to the increase in temperature and the decrease in precipitation, which may intensify in the near future, there is elevated fire risk in late spring and early autumn. To study fire risk before and after summer, April average FWI and October average FWI plots were carried out. PRECIS results depicts that in the present-day climate FWI reaches 20 (high risk) in the forested areas of Larnaca District, 10-15 in Troodos Mountain and 7 in forested areas of Paphos District. As far as future changed are concerned, a small increase of about 2 is projected by PRECIS for Troodos Mountain as well as for forested areas of Larnaca District. Paphos District shows no increase.

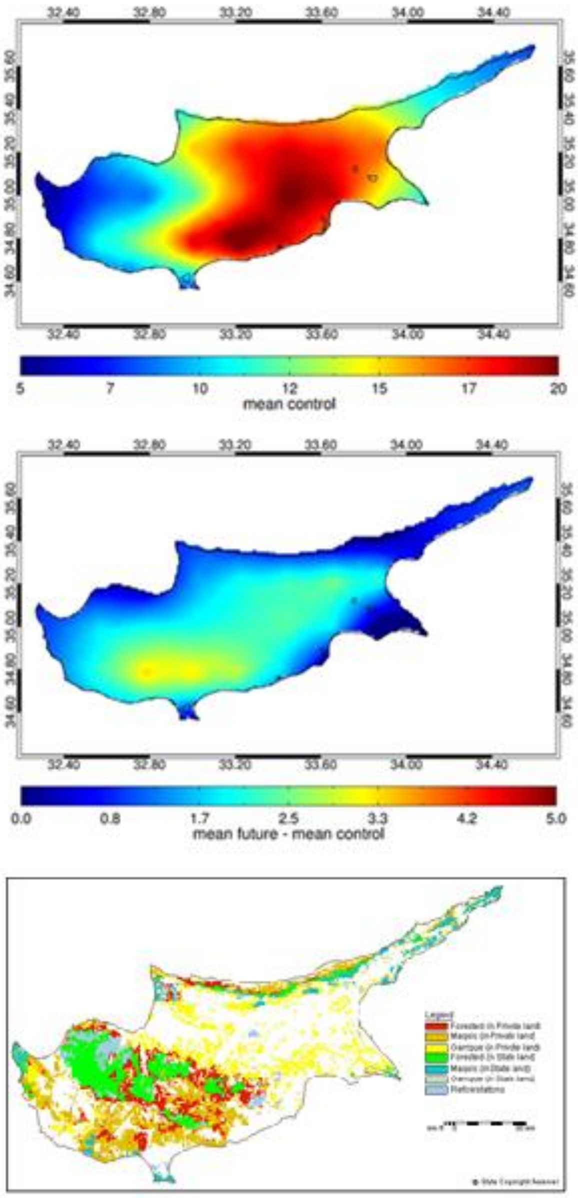


Figure 7-16: April average FWI for control period using PRECIS RCM model (a) Changes in April average FWI in the near future (Future – Control period) using PRECIS RCM model b) and Natural vegetation of Cyprus (c)

As a result future exposure of almost all forested areas in Cyprus to fire risk in spring period is expected to be medium to high.

A relatively similar pattern is evident for the October FWI average. As presented by PRECIS – control period results, Larnaca and Nicosia areas show a high fire risk with FWI varying from 17 to 20. Additionally, the southern parts of Troodos Mountain (Limassol District) as well, present a high fire risk with FWI values varying from 20 to 22. As far as future changes are concerned, PRECIS projections show a small FWI increase of about 1-2 in Troodos Mountain and no increase in Larnaca and Paphos District.

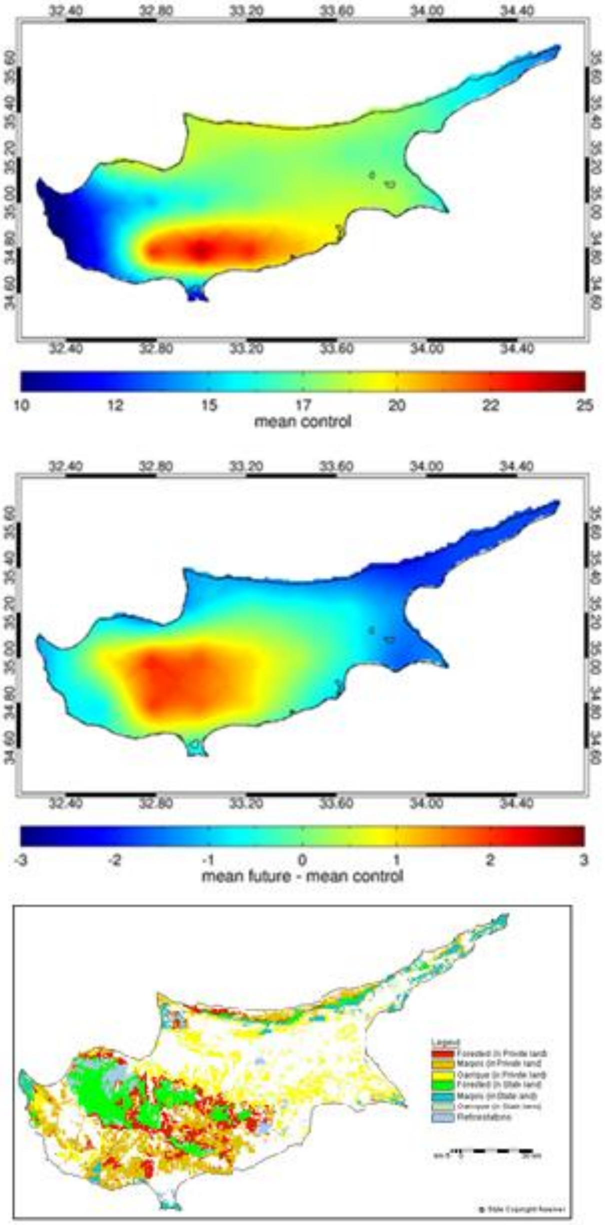


Figure 7-17: October average FWI for control period using PRECIS RCM model (a) Changes in October average FWI in the near future (Future – Control period) using PRECIS RCM model b) and Natural vegetation of Cyprus (c)

As a result future exposure of almost all forested areas in Cyprus to fire risk in autumn period is expected to be high.

In analyzing fire risk it is very important to investigate the number of days during the year, with an increased fire risk, in other words, with an increased FWI. In our study we examined two parameters: the number of days with FWI>15 i.e. days with moderate fire risk and the number of days with FWI>30 i.e. days with extreme fire risk. As evidenced by PRECIS-control period results there are approximately 200 days with FWI>15 in the forested area of Larnaca District and approximately 160 days in Troodos Mountain. The fewest days with FWI>15, approximately 60, are shown in Akamas National Park. As far as future changes are concerned, Troodos shows an important increase of about 15 days while forested areas of Paphos District present an increase of about 5. Also, Larnaca District shows no increase.

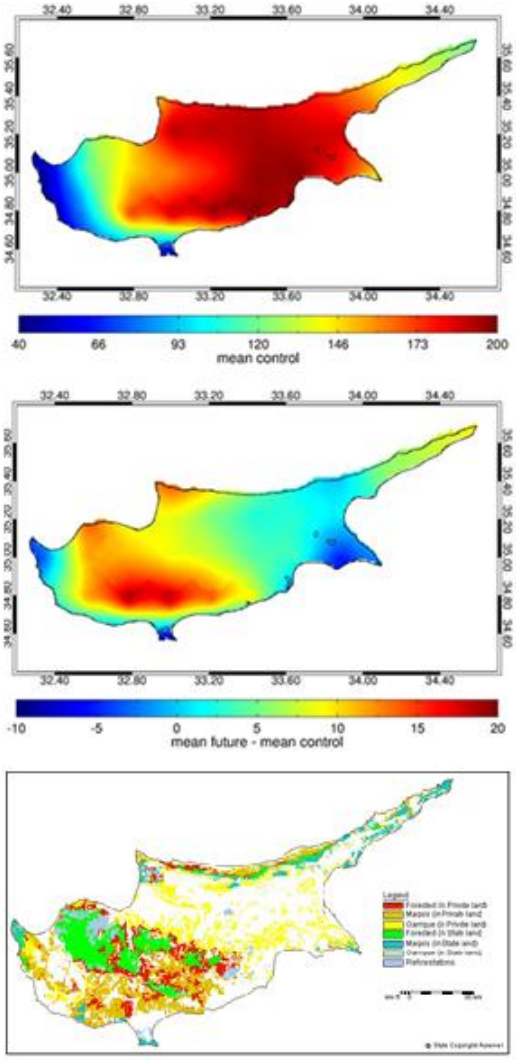


Figure 7-18: Number of days with fire risk (FWI>15) for control period using PRECIS RCM model (a) Changes in the Number of days with fire risk (FWI>15) in the near future (Future – Control period) using PRECIS RCM model b) and Natural vegetation of Cyprus (c)

Forested areas will face extreme high risk and high risk of fires for the more than the half of the year. Number of days with fire risk (FWI>15) is anticipated to be increased more significantly in Troodos mountain (Paphos and Troodos forest) and Agia Fotini Forest. As a result the risk of fires in these areas will be increased. On the contrary all coastal areas and continental lowland areas are not going to present an increase in number of days with fire risk (FWI>15).

Finally, Figure 7-19 shows the number of days with extreme fire risk i.e. FWI >30. Figure 7-19a depicts that the forested areas of Larnaca District as well as Troodos Mountain region of Nicosia and Limassol Districts present 120 days with extreme fire risk, in the present-day climate (PRECIS). Also, the northwestern part of the Troodos Mountain (Paphos District) and Akamas National Park present 55 and 15 days respectively. As far as future changes are concerned, PRECIS projections (Figure 7-19c) testify a small increase of the order of 8-10 days for Troodos Mountain whereas for the remaining forested areas of Cyprus projections show negligible changes (1-2 days) in extreme fire risk occurrence.

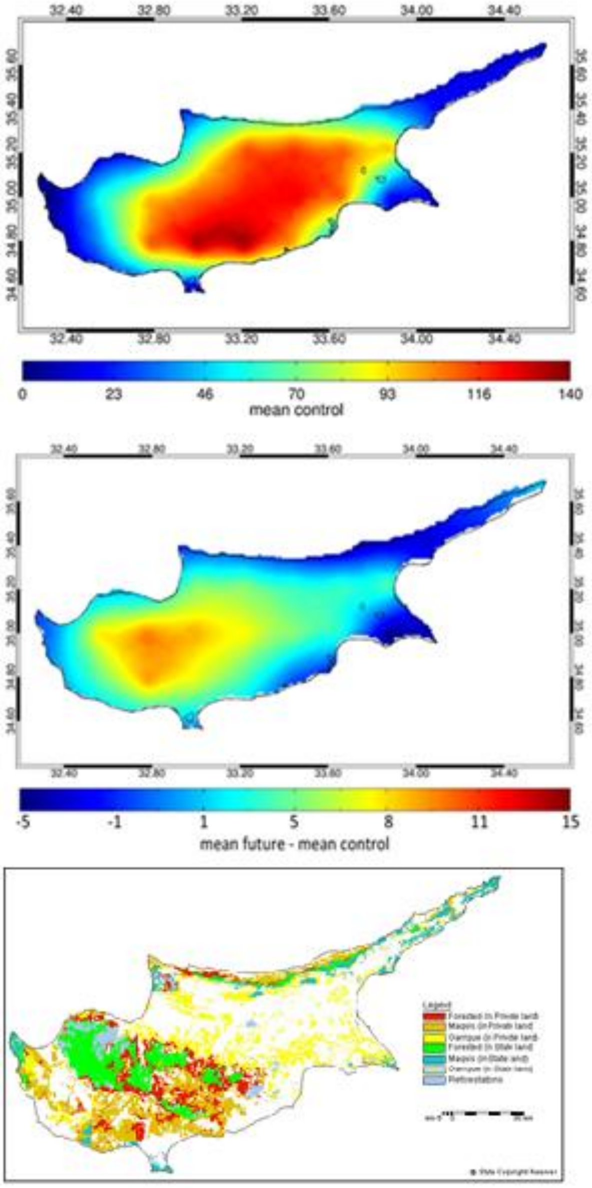


Figure 7-19: Number of days with extreme fire risk (FWI>30) for control period using PRECIS RCM model (a) Changes in the Number of days with extreme fire risk (FWI>30) in the near future (Future – Control period) using PRECIS RCM model b) and Natural vegetation of Cyprus (c)

Forested areas will face extreme high risk of fires for one third of of the year. Number of days with extreme risk (FWI>30) is anticipated to be increased more significantly in Troodos forest while Paphos forest, coastal areas and continental lowland areas will be affected less. As a result the risk of fires Troodos forest will be increased.

Future Weather Index was calculated both for present-day climate and potential near future changes due to climate change. The above findings are presented in the following Table 7-10 and Table 7-11.

Table 7-10: Values of indices with particular relevance to forest fire risk.

	Western Regions	Mountain Regions	Inland Regions	Southern Regions	Southeastern Regions
	PRECIS	PRECIS	PRECIS	PRECIS	PRECIS
July average FWI	10-30	30-50	45	45	45
August average FWI	10-30	25-50	40	45	40
April average FWI	7	10-15	20	17	20
October average FWI	10	15-22	17	21	20
Nb of days with fire risk (FWI>15)	60	160	175	170	200
Nb of days with extreme fire risk (FWI>30)	30	120	120	100	120

Table 7-11: Potential future changes in indices with particular relevance to forest fire risk.

	Western Regions	Mountain Regions	Inland Regions	Southern Regions	Southeastern Regions
	PRECIS	PRECIS	PRECIS	PRECIS	PRECIS
July average FWI	(+) 0-1	(+) 1-5	(+) 2	(+) 1	0
August average FWI	0	(+) 2	(+) 2	(+) 2	(+) 2
April average FWI	0	(+) 2	(+) 2	(+) 2	(+) 2
October average FWI	0	(+) 1-2	(+) 1	(+) 1	0
Nb of days with fire risk (FWI>15)	(+) 5	(+) 15	(+) 10	(+) 15	0
Nb of days with extreme fire risk (FWI>30)	(+) 1	(+) 8-10	(+) 5	(+) 2	1

To sum up, taking into account the current exposure of forests to fires as well as the relative future climate changes the exposure of forests to fires for the future period (2021-2050) can be characterized as **very high.**

7.4.2.2 Assessment of adaptive capacity

Several measures are taken by the Forestry Department of Cyprus aiming to eliminate forest fires. Particularly, the (a) prevention, (b) pre-suppression, (c) detection and suppression measures are presented as follows:

(A) Fire Prevention measures. Fire Prevention measures include all actions and measures aimed at reducing or eliminating the potential for a fire outbreak. The main prevention measures taken are Law enforcement, Information campaigns, establishment of Picnic and camping sites, organization of patrolling and Fire danger mapping (Boustras et al., 2008).

(B) Fire Pre-suppression measures include all actions and measures aimed at reducing the likelihood of spread of a potential fire and at facilitating the efforts of effective fire suppression. The main pre-suppression measures taken are Fire breaks, Forest roads, Forest telecommunications, Forest Stations, Silvicultural treatments, Detection and reporting of forest fires, placement of Fire lookout stations, placement of automatic fire detection system and Reporting of forest fires (Department of Forests, 2012).

(C) Suppression measures: The suppression of forest fires is a complex, difficult and dangerous work that requires specialized knowledge, education and organization. Suppression includes all actions and measures aimed at facilitating rapid intervention and effective suppression of a potential fire. The main suppression measures taken are Forest fire fighting task force, Stand-by of forest officers, establishment of The Cyprus Forestry College, Fire engines, Personnel vehicles, Tractors, Warehouses, Fire protection systems, Water tanks and hydrants, Heliports, Aerial means and Cooperation with other agencies and the public.

Economic incentives

In the framework of the Rural Development Programme 2007-2013 of Cyprus, economic incentives are provided to individuals through the Measure 2.5 "Protection of forests from fires and reforestation areas". The main purpose of the measure is to improve the existing protection system of forests and other forest areas from fire as well as the restoration of burned areas. The measure includes the following two actions: (i) fire prevention, (ii) reforestation of burnt areas.

This measure enhances the protection of private forests which are not covered by the national forest protection programme.

Despite the great efforts and the good results of recent years, the problem of fires still exists and will always constitute a permanent threat for the forests of Cyprus. However further measures can increase the adaptive capacity. Following, additional recommended adaptation measures that are considered to further enhance adaptive capacity towards this impact are presented indicatively. Nevertheless, their assessment and final selection for implementation will be made through the use of the Multicriteria Analysis (MCA) tool which will be developed and implemented in the framework of Actions 4 and 5 of the CYPADAPT project.

- Further increase forest areas through afforestation of bare lands and reforestation of abandoned agricultural lands

- Protection of forests against their enemies, mainly fires, with the investment/availability of vital national resources and the implementation of a national fire protection plan
- Immediate reforestation / restoration of areas destroyed by fire and implementation of appropriate silvicultural measures
- Preparation of management plans for all state forests within 10 years, taking into account national needs, climate changes and the provisions of relevant EU directives
- Meeting the requirements in timber of wood industries and at the same time establishing annual quantity of timber harvested well below the annual increment, in order to improve the quality and land cover of forests
- Creation of a permanent committee with the responsibility of identifying suitable land for the expansion of forests
- Research, data collection and monitoring of biotic and abiotic parameters
- Identification and promotion of micro- climatic benefits and environmental services of trees and forests
- Infrastructure to improve forest resilience to fires
- Classification of forests according to the risk of fire, designation of high-risk areas
- Stricter control on grazing in the Akamas and other forest areas. Grazing in the remaining forest covered areas, outside the State Forests, should be limited to the least possible
- Set up of infrastructure in the private forest areas for protection from fires
- Control of land use change in private forests with relevant incentives and reimbursements
- Purchase by the State private forest areas enclosed or wedging into state forests
- Inclusion of the private forest covered areas in the fire fighting schemes of the Department of Forests
- Planning and development of forest ecosystems that would make the start and speed of expansion of fires more difficult (less flammable plant communities, thinning down and maintenance of suitable structure of forests, cleaning and suitable arrangement or disposal of remains)

Thus, the adaptive capacity of Cyprus forests to fires can be characterized as **moderate.**

7.4.3 Floods, wind throws and storm damages

7.4.3.1 Assessment of sensitivity and exposure

The factors affecting the sensitivity of forests to floods, are the slope of the area, the age of the plant species, their anatomy, the type of soils and others. In Cyprus slopes in excess of 18% and 12% cover 10% and 22% of the island. (Republic of Cyprus, Geological Survey Department; I.A.CO Ltd, 2007). Areas with great inclination do not allow the rain water to accumulate while plain areas are more prone to flooding. Young plant species have not yet established deep rooting, thus are more vulnerable to injuries, inhibition of seed germination, changes in plant anatomy and mortality caused by the impetuous water flow.

Maquis and garique vegetation, which consist 56% of the total forest and OWL area in Cyprus, are more sensitive to floods due to their lower height.

However, as it can be seen from Figure 7-20 and Figure 7-21, forest areas and OWL (including maquis and garique vegetation) are located in areas with inclination, thus they are not considered sensitive to flooding.

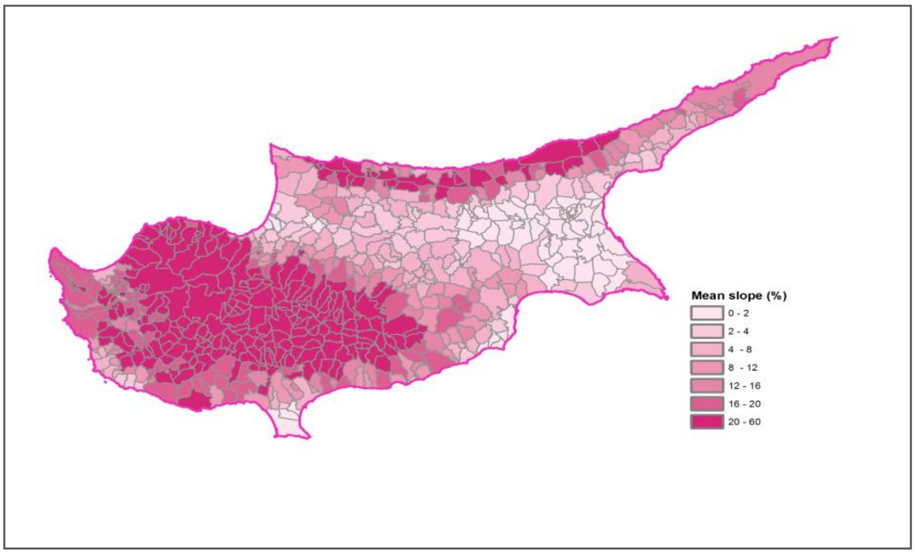


Figure 7-20: Island map depicting slope scores

Source: Deems, 2010

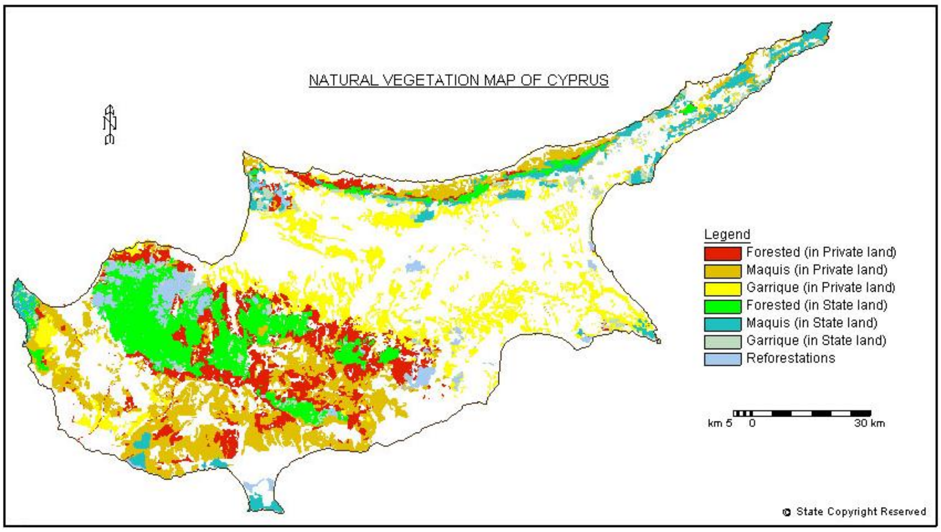


Figure 7-21: Natural vegetation of Cyprus

Source: Department of Forests, 2011a

Consequently, the sensitivity of Cyprus forests to floods is considered to be **limited.**

For the assessment of the sensitivity of Cyprus forests to wind throws and storm damages there were no relative data available.

Exposure

The Water Development Department of MANRE through its report "Preliminary Flood Risk Assessment" identified 19 areas around the island as "Areas with Potential Significant Flood Risk" (Figure 7-22). As it can be seen, the_susceptible areas to floods are mainly the urban centers.

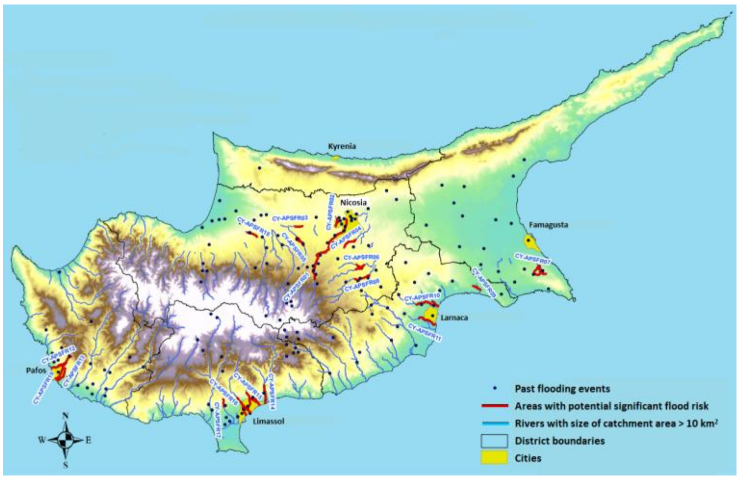


Figure 7-22: Areas with potential significant flood risk in Cyprus

Source: WDD, 2011

Changes in the amount of rainwater that falls in a short period of time within the year for urban areas and the whole domain of study are presented in Figure 7-23. In the future period (2021-2050), annual max total rainfall over 1 day is anticipated to have a slight increase of about 2-4 mm in western, inland and mountain regions. Additionally, southern and southeastern areas present an increase of about 1 mm in annual max total rainfall over 1 day. As it is obvious from the following figure the increase in annual max total rainfall over 1 day will affect most of the Cyprus areas. However due to the fact that the increase is not significant the risk of floods will not be increased significantly.

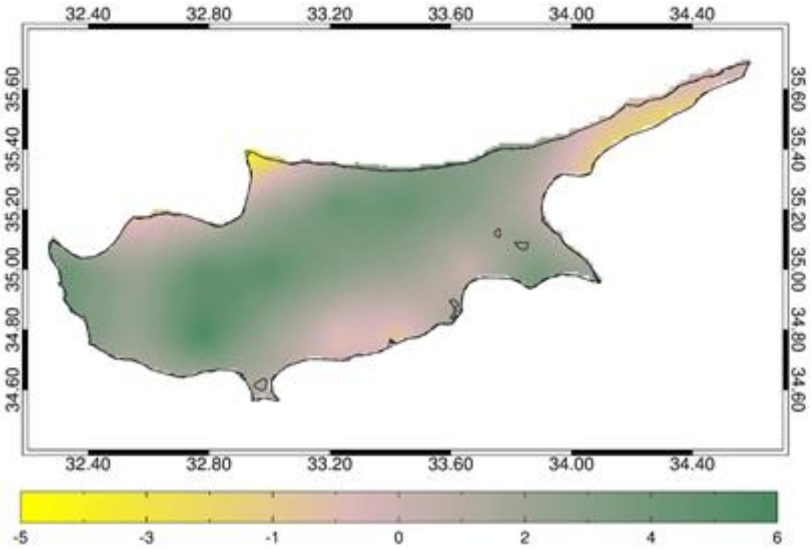


Figure 7-23: Changes in annual maximum total precipitation over 1 day between the future (2021-2050) and the control period (1961-1990).

As a result of the topography of the area with high inclination and the presented dams on the major rivers the risk of flood in forested areas will be insignificant. Taking into account the current exposure to floods as well as the relative future climate changes the exposure of forests to floods for the future period (2021-2050) can be characterized as **limited.**

For the assessment of the exposure of Cyprus forests to wind throws and storm damages there were no relative data available.

7.4.3.2 Assessment of adaptive capacity

The fact that there are limited flooding events in Cyprus forests without any human intervention for their protection, indicates that the forests themselves due to their topography (mountain areas) have the capacity to be self-protected from floods (autonomous adaptive capacity), as water run-off finds its way to the plains. Following, additional recommended adaptation measures that are considered to further enhance adaptive capacity towards this impact are presented indicatively. Nevertheless, their assessment and final selection for implementation will be made through the use of the Multicriteria Analysis (MCA) tool which will be developed and implemented in the framework of Actions 4 and 5 of the CYPADAPT project.

- Further increase forest areas through afforestation of bare lands and reforestation of abandoned agricultural lands
- Use of species with higher carbon sequestration ability (for plantations) and well adapted to hard climatic conditions
- Minimize tillage and associated practices
- Prevent non forest uses to state forest land, with the exception of specific cases and only for the public interest

- Preparation of management plans for all state forests within 10 years, taking into account national needs, climate changes and the provisions of relevant EU directives
- Meeting the requirements in timber of wood industries and at the same time establishing annual quantity of timber harvested well below the annual increment, in order to improve the quality and land cover of forests
- Creation of a permanent committee with the responsibility of identifying suitable land for the expansion of forests
- Research, data collection and monitoring of biotic and abiotic parameters
- Identification and promotion of micro- climatic benefits and environmental services of trees and forests
- Stricter control on grazing in the Akamas and other forest areas. Grazing in the remaining forest covered areas, outside the State Forests, should be limited to the least possible
- Control of land use change in private forests with relevant incentives and reimbursements
- Purchase by the State private forest areas enclosed or wedging into state forests
- Inclusion of the private forest covered areas in the fire fighting schemes of the Department of Forests

Therefore, the adaptive capacity of Cyprus can be characterized as **high.**

7.4.4 Forest growth

7.4.4.1 Assessment of sensitivity and exposure

Sensitivity

Growth of sensitive forest species is affected by increased concentrations of air pollutants and adverse climatic conditions such as increased temperature and decreased precipitation. However due to lack of sufficient information, the sensitivity of forest species in Cyprus was **not assessed**. Further research is required to assess the sensitivity of forest species to increases temperature and decreased precipitation as well as the air pollution.

Exposure

Forest growth and productivity may be affected by projected climate change aspects such as increases in temperature, decrease in precipitation and increases in air pollution. The growing season of forests can be lengthened along with rising temperatures. On the other hand rising temperatures can cause shifting of the geographic ranges of some tree species northward or to higher altitudes or could even cause their extinction if conditions in their current geographic range are no longer suitable. For example, species that currently exist only on mountaintops may die out as the climate warms since they cannot move to a higher altitude (EPA, 2012).

Temperature changes: The anticipated increase in high temperature and in the maximum length of dry spell will have a impact on forest growth in Cyprus forests. Specific information is provided for anticipates winter minimum and summer maximum temperatures in the various forested areas as the most extreme cases. Furthermore with increase in the number of heat wave days, where maximum temperature exceeds 35°C, forests may be unfavorably affected. Thus anticipated changes in the number of heat wave days is presented for the domain of study.

Average winter minimum and summer maximum temperature

In comparison with the natural vegetation map of Cyprus projections of PRECIS regional climate model make evident that all forested areas of Cyprus will experience, in the near future, a warming of about 0.8 – 1.1°C. Consequently, in the near future, winter minimum temperature is anticipated to reach 6°C in Troodos and Paphos Forest and 7-9°C in forested area of Larnaca District in contrast with control period where the respective temperatures is 5°C and 6-8°C respectively. The most significant increases of about 1.1°C are anticipated for Paphos forest and southern non forested region (Maquis in Private and state land) while for the rest of the areas changes are expected to be less significant. Especially in the northern Cyprus changes in winter minimum temperature are anticipated to be minor.

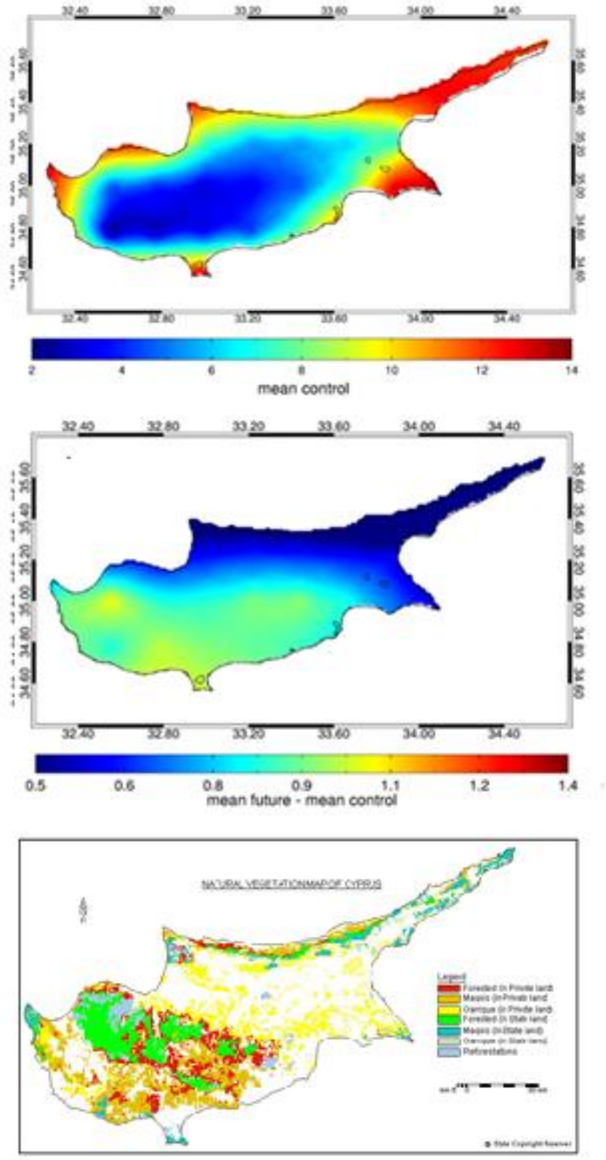


Figure 7-24: Average winter minimum temperature for control period using PRECIS RCM model (a) Changes in average winter minimum temperature in the near future (Future – Control period) using PRECIS RCM model (b) Natural vegetation of Cyprus (c)

Future increase in winter temperature will affect the biggest part of Cyprus and forested areas. However the impact on forest growth cannot be evaluated.

According to PRECIS forested regions of Troodos Mountain (Troodos and Paphos forest) will experience a significant warming of about 2.0 – 2.7°C reaching temperatures of about 32 – 35.7°C in comparison with the current situation (control period). As it presented in the following figure increases in summer maximum temperatures are more significant for forested mountain regions and inland regions in comparison with coastal areas that are either non covered by vegetation or Maquis. In reforestation areas summer maximum temperatures will increase about 1°C, less than all other areas.

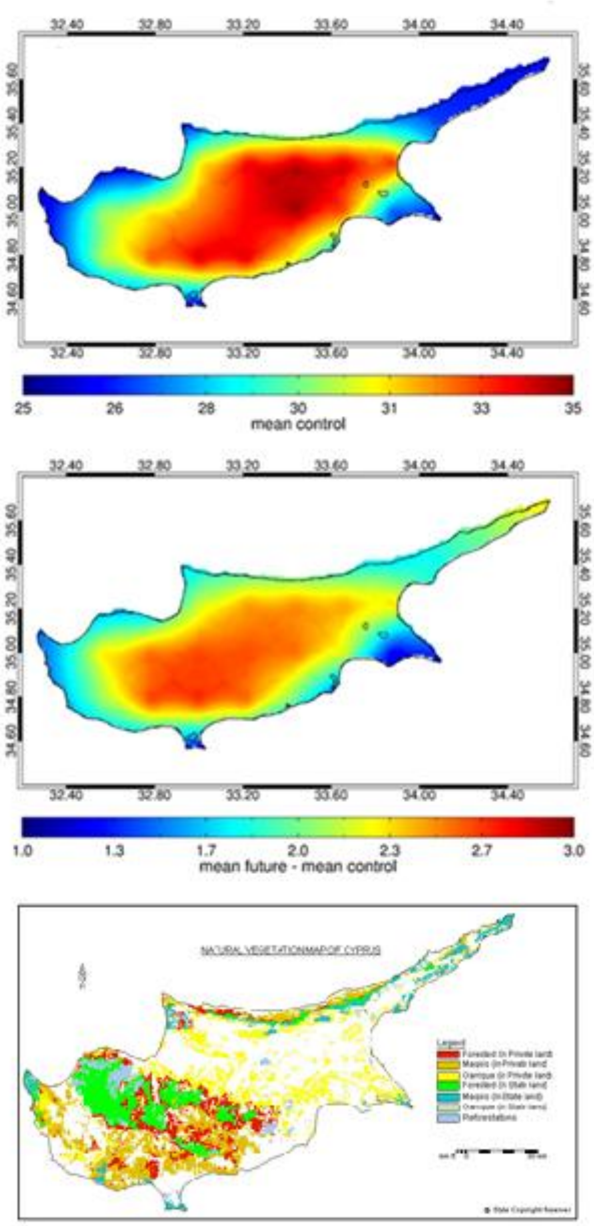


Figure 7-25: Average summer maximum temperatures for control period using PRECIS RCM model (a) Changes in average summer maximum temperature in the near future (Future – Control period) using PRECIS RCM model (b) Natural vegetation of Cyprus (c)

Considering the fact that summer temperatures are already high, a further increase may result in increasing the risk of halting of forest growth in forested areas in the future.

Number of Heatwave days

Number of heatwaves days is a very important factor since in combination with the length of dry period has a negative impact on forest growth. As PRECIS results show, an increase of about 20-30 days is expected for Troodos mountain regions and conversely 10 days for western areas. In specific, number of heatwaves days over 35°C may reach in future 40-60 days in Troodos forest and 20 days in Paphos forest in contrast with current period where heatwaves days are approximately 20-30 and 8-10 respectively. As a result Troodos forest is affected more than Paphos forest while southwestern regions covered mainly by Maquis will be affected even less.

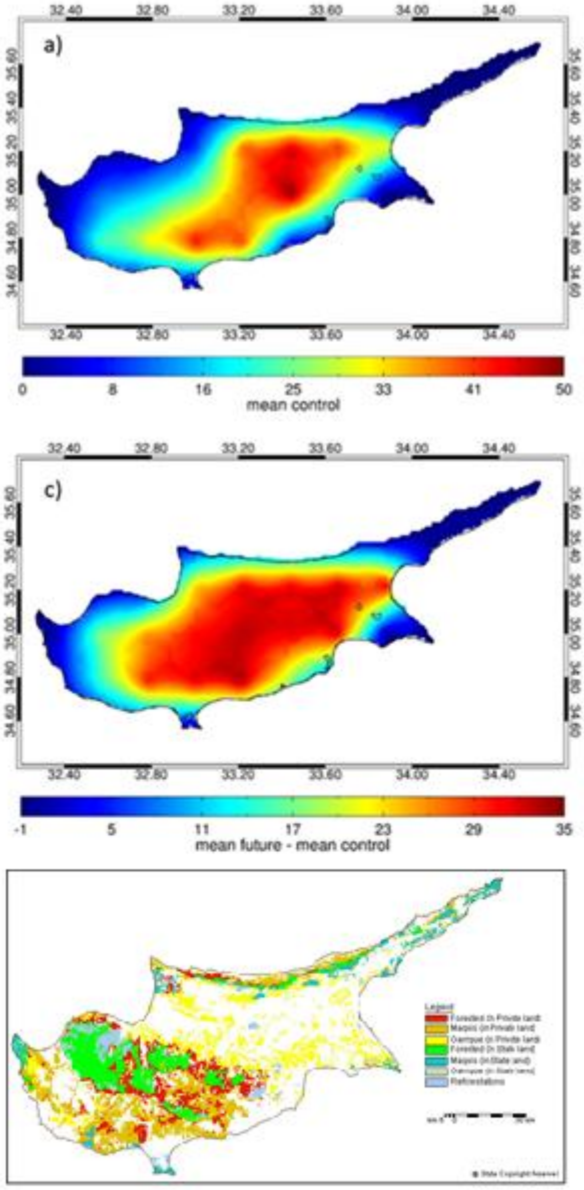


Figure 7-26: Number of heatwaves days for control period using PRECIS RCM model (a) Number of heatwaves days in the near future (Future – Control period) using PRECIS RCM model (b) and Natural vegetation of Cyprus (c)

The most significant increase in number of heat wave days appears in the central part of Cyprus affecting significantly Troodos forest and increasing in this area the risk of forest growth. However is Paphos forest and southeastern forested areas the increase is less

intense but still very significant. The predicted increase of 100% in heat wave days in Paphos may also put at high risk forest growth.

Precipitation changes: Decrease in rainfall except from decreased soil moisture which is known to largely affect forestry species affects negatively forest growth. Decrease in precipitation for the future period are not significant however they are most evident for winter and autumn seasons. More specifically for Troodos Mountain and Paphos District is anticipated a winter total rainfall of about 210 mm while for Larnaca District 70 mm in comparison with present-day climate where precipitation is 230 mm and 90 mm respectively. **A decrease though in precipitation of about 20mm may not have a significant affect in forest growth. However further research is required.**

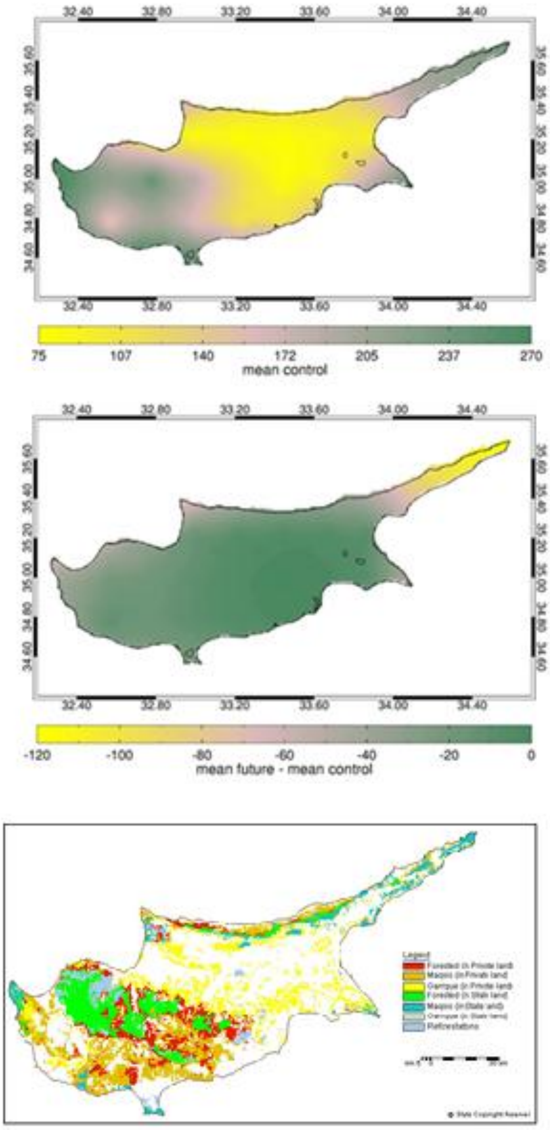


Figure 7-27: Winter total precipitation (mm) for control period using PRECIS RCM model (a) Changes in winter total precipitation in the near future (Future – Control period) using PRECIS RCM model (b) and Natural vegetation of Cyprus (c)

A similar pattern to winter is evident for autumn precipitation regarding PRECIS plots. A decrease in the amount of rainfall of about 15 mm is projected for the near future in forested areas. Future amounts of autumn rainfall will reach 55 mm for Larnaca District, 95 mm for Troodos Mountain and 135 mm for Paphos District compared with current amounts which are 70 mm, 110 mm and 150 mm respectively.

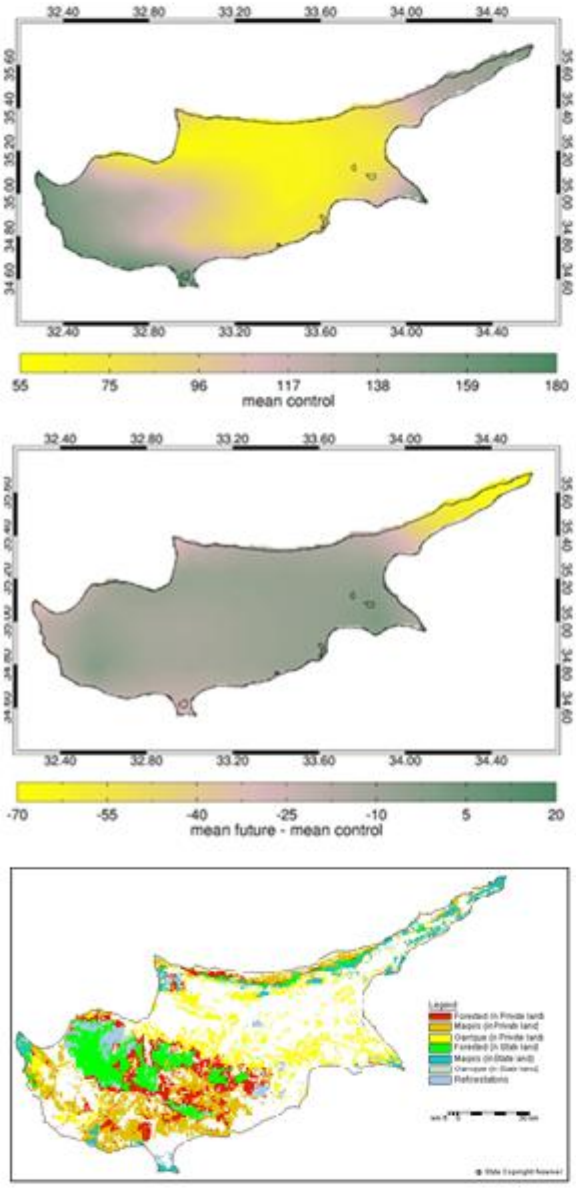


Figure 7-28: Autumn total precipitation (mm) for control period using PRECIS RCM model (a) and Changes in autumn total precipitation in the near future (Future – Control period) using PRECIS RCM model (b) and Natural vegetation of Cyprus (c)

PRECIS results indicate that all forested areas in Cyprus will experience a decrease in rainfall during autumn season. The decrease in autumn rainfall may have an effect on forest growth since it follows a prolonged dry summer period which may put forested

areas under stress.

Maximum length of dry spell

Dry spell has an impact on soil moisture. Increase in length of dry spell can decrease soil moisture. Low level of soil moisture has a negative impact on forest growth. Increases in maximum length of dry spell can affect negatively forest species sensitive to soil moisture content. Following figure depicts that areas of Nicosia and Larnaca and Troodos forest reveal increases of about 10 days. Conversely, western regions that include a major part of Paphos forest show no increases. As a result increases in maximum length of dry spell will affect mostly forested areas situated in the central part of Cyprus and less the western areas.

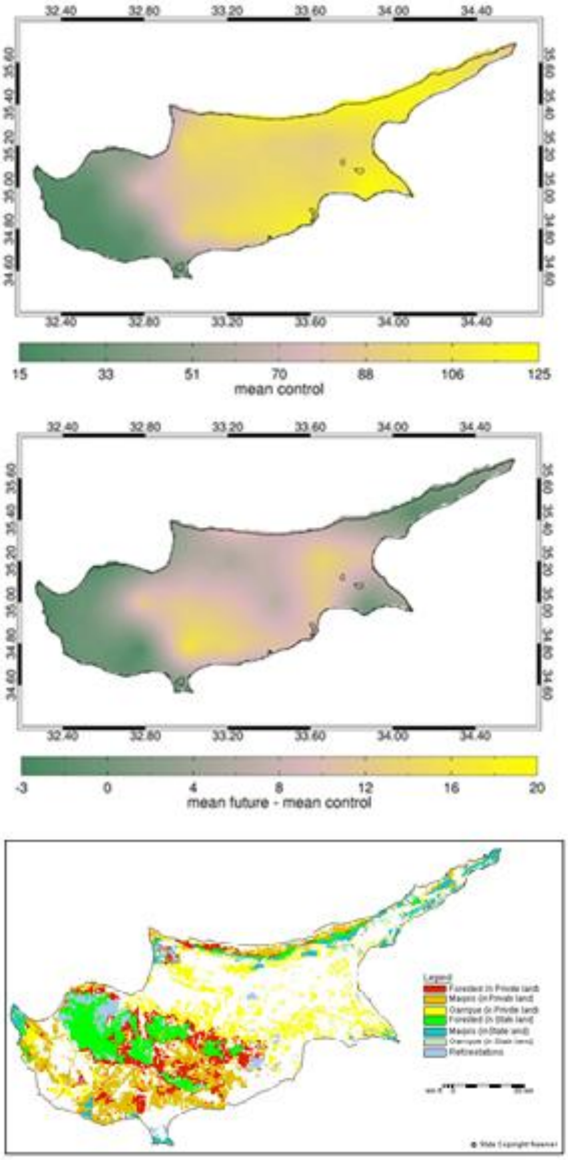


Figure 7-29: Maximum length of dry spell for control period using PRECIS RCM model (a) Changes in maximum length of dry spell in the near future (Future – Control period) using PRECIS RCM model (b) and Natural vegetation of Cyprus (c)

Increase in maximum length of dry spell is affecting the central part of Cyprus and more significantly Troodos forest increasing in this area the risk of halting of forest growth in the future.

Increase in CO2: Expected increase in CO2 and temperature can lead to an extension of the growing season of plants (Chmielewski and Rotzer, 2001), which will positively contribute to the production of forests and meadows. Increased productivity, however, is likely to be mitigated by a decrease in precipitation and the frequency and intensity of extreme weather events such as heat waves, floods, etc. In absence of relative data on CO_2 concentrations, an overall assessment of the exposure did not take place.

The biogeograpfic model **BIOME4 makes an estimation of the** rate of carbon sequestration by forests in the future and has been used in Portugal to predict vegetation distribution, structure and biogeochemistry. However soil property information is essential for the model (Chmielewski, F.-M. and T. Rotzer, 2001).

To sum up, taking into account the current exposure of Cyprus forest to changes in temperature, precipitation and CO2 level for the future period (2021-2050) can be characterized as **very high**. Further research is required

7.4.4.2 Assessment of adaptive capacity

Cyprus has joined the International Co-operative Program on the Assessment and Monitoring of Air Pollution Effects on Forests (ICP-Forests) in 2001 aiming at the better monitoring and understanding of ecosystems in Cyprus. The Cyprus Department of Forests of the Ministry of Agriculture, Natural Resources and Environment, has been nominated as the National Focal Centre of the ICP-Program in Cyprus, being responsible for the collection, validation, evaluation, storage and management of the monitoring data. In the context of this Program, 19 permanent plots have been established in Cyprus State forests aiming at the collection of the necessary data, relevant to the above activities. In monitoring plots, covering an area of 0.1 hectare each, the following ecosystems were monitored: Calabrian pine (Pinus brutia), Black pine (Pinus nigra), and Cyprus cedar (Cedrus brevifolia) ecosystems (Weiskel, 2009).

Monitoring of the effect of air pollution to Cyprus forests is the first step in the adaptation planning process. However, as soon as the effects of air pollution become fully understood the necessary actions will be undertaken in order to reduce to the degree possible adverse effects. From the European experience in the implementation of mitigation measures, it was seen that acidity has successfully abated, while increased concentrations of nutrient nitrogen in soils has not abated and it is expected to continue constitute a problem in the future based on current legislative framework. It must be noted however that, even if no further increase in the pollution levels in soils was succeeded, it would take several decades for the rehabilitation of soils (LRTAP/IWF, 2011).

Following, additional recommended adaptation measures that are considered to further enhance adaptive capacity towards this impact are presented indicatively. Nevertheless, their assessment and final selection for implementation will be made through the use of the Multicriteria Analysis (MCA) tool which will be developed and implemented in the framework of Actions 4 and 5 of the CYPADAPT project.

- Further increase forest areas through afforestation of bare lands and reforestation of abandoned agricultural lands
- Use of species with higher carbon sequestration ability (for plantations) and well adapted to hard climatic conditions
- Minimize tillage and associated practices
- Prevent non forest uses to state forest land, with the exception of specific cases and only for the public interest
- Preparation of management plans for all state forests within 10 years, taking into account national needs, climate changes and the provisions of relevant EU directives
- Meeting the requirements in timber of wood industries and at the same time establishing annual quantity of timber harvested well below the annual increment, in order to improve the quality and land cover of forests
- Creation of a permanent committee with the responsibility of identifying suitable land for the expansion of forests
- Research, data collection and monitoring of biotic and abiotic parameters
- Identification and promotion of micro- climatic benefits and environmental services of trees and forests
- Stricter control on grazing in the Akamas and other forest areas. Grazing in the remaining forest covered areas, outside the State Forests, should be limited to the least possible
- Control of land use change in private forests with relevant incentives and reimbursements
- Purchase by the State private forest areas enclosed or wedging into state forests
- Inclusion of the private forest covered areas in the fire fighting schemes of the Department of Forests

The future adaptive capacity of Cyprus can be characterized as **moderate**.

7.4.5 Assessment of overall vulnerability

The principal aim of this chapter is to identify the key future vulnerabilities of forests to climate changes, as well as to assess the magnitude of these future vulnerabilities. However, it must be noted that, as there were no sufficient data to evaluate all indicators further research is required.

In order to quantify the vulnerability potential of forests against a climatic change impact, the values of sensitivity, exposure, adaptive capacity and vulnerability are quantified as follows:

Table 7-12: Degree of sensitivity, exposure & adaptive capacity

Degree of sensitivity, exposure & adaptive capacity		Degree of vulnerability		Legend
None	0	None	V≤0	
Limited	1	Limited	0<V≤1	🟩
Limited to Moderate	2	Limited to Moderate	1<V≤2	🟨
Moderate	3	Moderate	2<V≤3	🟨
Moderate to High	4	Moderate to High	3<V≤4	🟧
High	5	High	4<V≤5	🟧
High to Very high	6	High to Very high	5<V≤6	🟥
Very high	7	Very high	6<V≤7	🟥
Not evaluated	-	Not evaluated	-	▨

Since vulnerability is defined by the following formula:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity * Exposure$$

“Impacts” and “Adaptive capacity” should be evaluated on the same scale (1-7). For this to be achieved, the square root of “Sensitivity x Exposure” is used. The results of the vulnerability assessment for the forest sector in Cyprus are summarized in Table 7-13.

Table 7-13: Overall vulnerability assessment of forests in Cyprus to climate changes

Impact	Sensitivity	Exposure	Adaptive Capacity	Vulnerability
Dieback of tree species, insect attacks and diseases	Very high (7)	Very high (7)	Moderate (3)	Moderate to high (4)
Fires	Very high (7)	Very high (7)	Moderate (3)	Moderate to high (4)
Floods	Limited (1)	Limited (1)	High (5)	None (-5)
Forest growth	Not evaluated	Very high (7)	Moderate (3)	Not evaluated

As it can be seen from the table above, the first future vulnerability priorities for the forests of Cyprus are the impact of climate changes on the dieback of tree species, insect attacks and diseases as a significant part of Cyprus' forests has already been affected and the effect of increased frequency and intensity of forest fires as the latter cause severe and extended damages on forests. Finally, it is considered that the forests of Cyprus are not vulnerable at all to floods mainly due to the fact that they are located at mountains where the risk for floods is limited, while the vulnerability of forest growth to climate changes was not evaluated due to lack of sufficient data.

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8 FISHERIES & AQUACULTURE

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Abbreviations and Acronyms

CFP	Common Fisheries Policy
DFMR	Department of Fisheries and Marine Research
EAP	Economically Active Population
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FEAP	Fishing Effort Adjustment Plan
FMP	Fisheries Management Plan
IAS	Invasive Alien Species
MCA	Multi-Criteria Analysis
MeMARS	Meneou Marine Aquaculture Research Station
PRECIS	Providing Regional Climates for Impact Studies
RCM	Regional Climate Model
RR	Precipitation
SLR	Sea Level Rise
SST	Sea Surface Temperature
TX	Maximum Temperature

8.1. Climate change and fisheries & aquaculture

Climate changes are affecting fisheries and aquaculture directly by influencing fish stocks and the local supply of fish for consumption, or indirectly by influencing fish prices or the cost of goods and services required by fishers and fish farmers (World Fish Centre, 2007). These changes are related with certain impacts such as sea level rise, alteration of inland and sea water temperature etc.

Many people dependent on fisheries and aquaculture – as producers, consumers or intermediaries in inland or coastal areas – will be particularly vulnerable to the direct and indirect impacts of climatic changes, whether through changes in physical environments, ecosystems and aquatic stocks, or through impacts on infrastructure, fishing and farming operations, or livelihood options (FAO, 2008).

The term ‘fishery sector’ includes sub sectors that are related with the activities of (i) inshore and offshore pelagic fishery, (ii) inland fishery and (iii) marine and freshwater aquaculture.

For the case of Cyprus, inland fishery is limited due to the lack of large water basins (lakes and/or rivers) and it implies only sport fisheries mainly at dams. To this end, the study of climate change impacts and the respective adaptive measures will focus on inshore and offshore fishery and on marine and freshwater aquaculture.

The impact, vulnerability and adaptation assessment for the sector of fisheries and aquaculture regarding the climate changes that have occurred the recent years in Cyprus (Deliverable 1.2), revealed that the main impacts on the sector are the reduction of the quantity and diversity of fishstocks, the deterioration of the fishstock physical environment as well as the increase of cost implications for fishermen due to increased extreme weather events. However, due to limited availability of data on the current situation, no assessment of the vulnerability was made.

In the sections that follow, an attempt is being made to assess the impacts of future climate changes on the fisheries and aquaculture sector of Cyprus based on the climate projections output produced by the PRECIS (Providing Regional Climates for Impact Studies) regional climate model as well as on other socio-economic projections for the period 2021-2050. The reason why PRECIS was selected to be used in the present study is that, unlike in other regional climate models, in PRECIS Cyprus lies at the center of the domain of the study. The future period 2021-2050 has been chosen, instead of the end of the twenty-first century as frequently used in other climate impact studies, in order to assist stakeholders and policy makers to develop near future plans.

8.2. Baseline Situation

The fishery sector comprises of the marine capture fishery (marine subsector) and the marine and freshwater aquaculture. Recreation fishery, processing and marketing are of minor importance. The marine capture fishery consists of the inshore fishery, the trawl fishery and the multipurpose fishery. There is also one purse seiner operating in Cypriot waters. Sport fishery is included in capture fishery, but it is not reflected in the fishery statistics.

The fisheries and aquaculture sector is a very small sector of the Cypriot economy which contributes approximately to 0.5% of the National Gross Domestic Product and 6% of the wider agricultural sector (Figure 8-1). However, its products have high added value due to the fact that the productivity of Eastern Mediterranean is low and because the fishing areas of Cyprus are highly exploited (Lamans, 2006).

It must be noted that, a significant increase has been recorded in the added value of the sector during the last decades which was cut though by a sudden and steep decrease that occurred in 2009 (Figure 8-2).

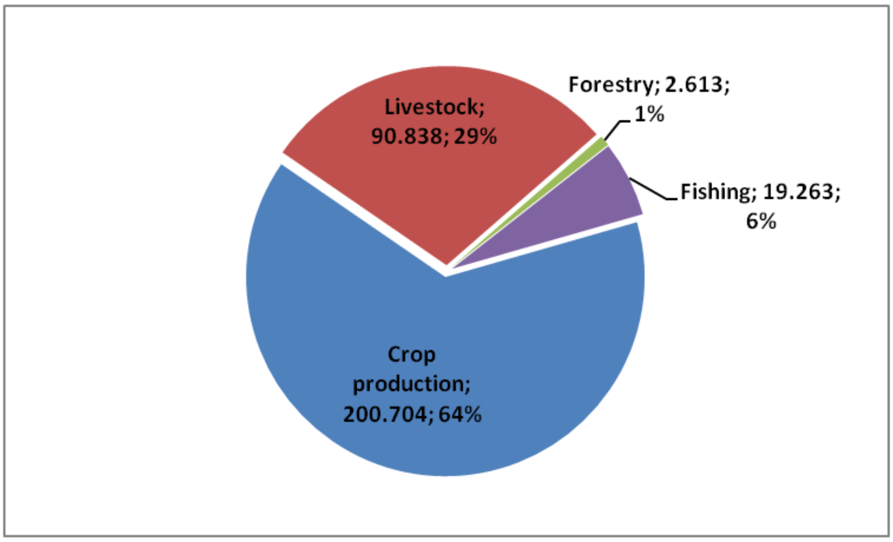

Figure 8-1: Average value added of the agricultural sector by sub-sector (1989-2010)

Source: CYSTAT, 2012

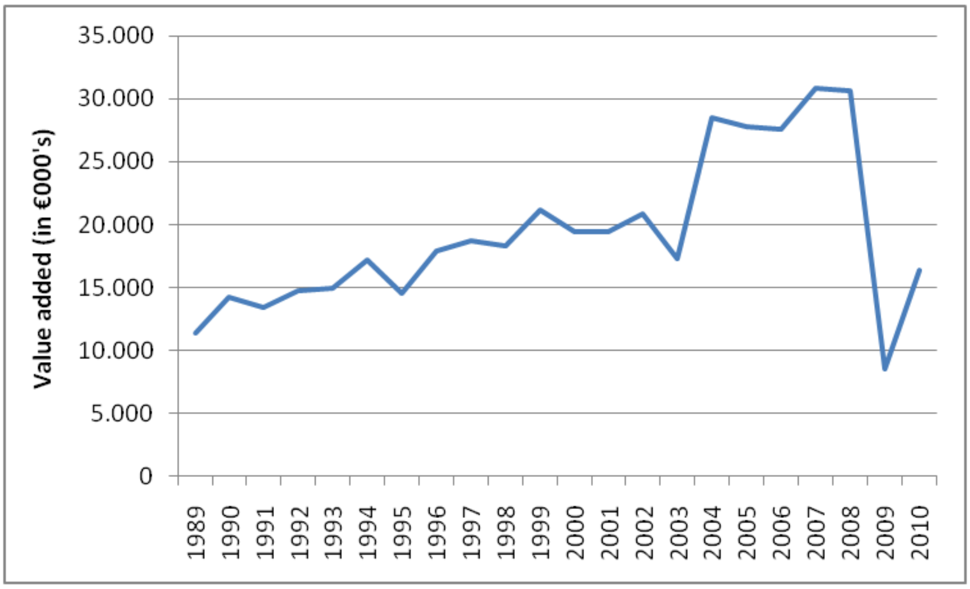

Figure 8-2: Average value added of the fisheries & aquaculture sector (1989-2010)

Source: CYSTAT, 2012; CYSTAT, 2010

In 1988 capture fisheries (inshore and trawl fishery) represented in quantity about 98% of the total domestic fisheries (capture fisheries and aquaculture), while in 1998 its contribution dropped to 67.2%, because of the substantial increase of marine aquaculture production. As regards value of production, capture fisheries in 1998 represented about 64% of the total domestic fisheries. The respective numbers for the period 2004-2010 were 28.9% for capture fisheries and 69.6% for the marine aquaculture on average (Figure 8-3). The important increase in marine aquaculture is attributed to the fact that marine capture fisheries did not satisfy domestic fish demand and as a result a considerable amount of fish was imported. It is worth noting that, the dynamic intrusion of marine aquaculture in the Cypriot fish market, has led to a substantially increase in fish exports, especially for marine aquaculture product exports which exceeded 50% of total marine aquaculture production in 2010 (see Table 8-1).

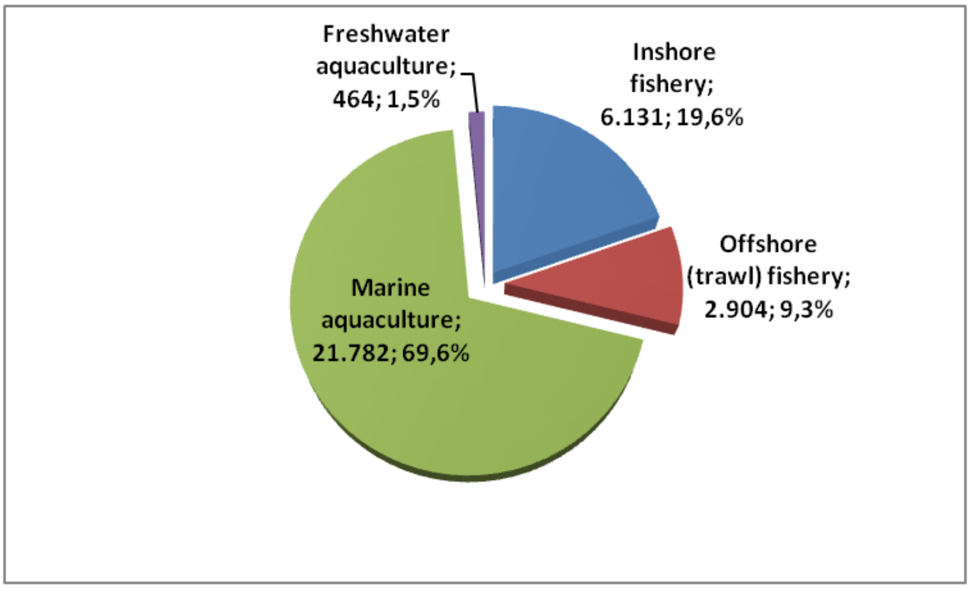

Figure 8-3: Average value added of the fisheries' sub-sestors (2004-2010)

Source: CYSTAT, 2010

The main fish kinds caught during the period 2001-2010 are seabasses and gilt-head seabreams (59.6%), picarels (6.8%), bognes (4,7%), red mullets (2.3%), octopuses (2.2%), swordfishes (1.6%), cuttlefishes and squids (1.5%) and rainbow trouts (1.5%) (CYSTAT, 2012; CYSTAT, 2010). Seabasses and seabreams are found in the marine fish farms of Cyprus, rainbow trouts are the main product of freshwater farms while the rest kinds of fish are found in the open sea.

According to data provided by FAO (Failler et al., 2007), total fish consumption in Cyprus during 2005 reached 19,000 tones while average annual per capita consumption equalled 25 kg [1], that is, 3 kilograms higher than the respective average annual per capita fish consumption of the EU (22kg). Considering the population of Cyprus in 2010 and the total amount of fish caught during that year, it is estimated that domestic fish supply satisfied only about 25% of the total fish consumption, while the rest 75% were satisfied by imports. The study of *Failler et al.* (2007) also estimated future prospects for the per capita fish consumption in Cyprus which showed that it will gradually decrease starting from 2010 by 1 kg up to 2020 and will remain stable up to 2030. Consumption patterns in Cyprus are similar to those in other Mediterranean countries such as Spain and Portugal, also experiencing a decrease in per capita consumption. Per capita consumption in Cyprus will fall to 23 kg/c/yr in 2030, mostly because the net supply will not be able to keep up with rapid population growth. There also appears to be a change in the pattern of consumption, with consumers moving away from fresh fish products and towards prepared/preserved products, which record a dramatic increase.

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[1] According to data provided by the DFMR, the average annual per capita fish consumption in Cyprus is 19 kg

8.2.1. Inshore & offshore pelagic fishery

Fishery of swordfish was, until recently, the only organized pelagic fishery on the island. In 1999 the first commercial purse seining unit for the fishing of small pelagic fish mostly by light fishing (attraction by lights) started to operate on an experimental basis. The economic viability of this pelagic fishery in Cyprus has to be proved, due to the unknown size of the stocks and the low price that most of its catch brings in the local market, with the exception of bogue (Stephanou, 2003).

Some other pelagic fish, like the amberjack, are caught by fishermen and sport fishermen in small quantities by trolling and spear gunning. Trolling off the coast of Cyprus for pelagic fish, mostly albacore has become a popular sport in the last 2-3 years. The catch which originates from sport fishing is not allowed to be sold (Stephanou, 2003).

8.2.2. Inland Fishery

In 2010 the Department of Fisheries and Marine Research issued 2630 individual and 16 group recreational angling permits for recreational fishing in dams and reservoirs. Within the framework of the promotion and development of recreational angling, 30.000 trout and a small number of other fish were released in several dams and reservoirs (DFMR, 2010).

8.2.3. Marine and freshwater aquaculture

Aquaculture in Cyprus contributes significantly to the production of fishery products, reduces fishing deficit and thereby reduces the negative trade balance. Regarding marine aquaculture, nine fattening farms are operating, all using offshore cage farming techniques. The main cultured species are seabream, seabass, meagre, rabbit fish and pandora, with a total annual production of 4.600 tones. Nonetheless, the most important cultured marine fish species are the seabream and seabass with a production of 3.000 tones and 1.500 tones respectively (DFMR, 2011). Along with the fattening units, three private marine fish hatchery stations are operating as well as a shrimp hatchery/breeding unit. The three marine fish hatcheries are operating in an intensive basis, in coastal areas. Their total annual production is approximately 23 million fingerlings. The shrimp farm, had a total annual production of 7.5 tones (DFMR, 2011).

The freshwater aquaculture in Cyprus is characterized by small-scale fish farms, with smaller growth potential compared to marine aquaculture. The major limiting factor for freshwater aquaculture in Cyprus is the freshwater availability. The fish farms, are mainly focused on the fattening of freshwater fish species i.e. rainbow trout and sturgeon. There are eight freshwater aquaculture farms, all located on Troodos mountains. Their facilities are mainly constituted of concrete tanks with their water intake coming from neighboring springs and rivers. Some of these farms operate as fish hatcheries as well, with a total annual production of 385,000 fingerlings. There is also an ornamental fish hatchery operating in Cyprus. The main fish species that are cultivated are goldfish and ornamental carp, which are then driven into the local and international market (DFMR, 2011).

The total licensed production capacity of Cyprus aquaculture for 2010 was 7,120 tons of table size fish, 22,520,000 fingerlings / fry and 1,020,000 fish for the ornamental fish trade. In 2010 the total value of aquaculture products (table size and fry) reached € 22.1 million out of which € 10.9 million were generated from exports. The majority of the production of fry was marketed locally to Cypriot grow – out units except from a small quantity of ornamental fish.

The estimated production and value of Cyprus aquaculture for 2010 is shown in the tables below (DFMR, 2010).

Table 8-1: Estimated production & value of Cyprus aquaculture, grow - out units (table size products) (2010)

Species	Local Market		Exports		Total	
	Quantity (tons)	Value (€)	Quantity (tons)	Value (€)	Quantity (tons)	Value (€)
Seabream	1,068	5,264,000	1,705	8,012,000	2,773	13,277,000
Seabass	650	3,291,000	555	2,824,000	1,205	6,115,000
Japanese Seabream	14	83,000	0	0	22	85,000
Rabbit Fish	5	41,000	0	0	5	41,000
Meagre	2.8	27,000	0	0	2.8	27,000
Rainbow Trout	65	530,000	0	0	65	530,000
Sturgeon	4.5	54,000	0	0	4.5	54,000
Tilapia	0.1	1,500	0	0	0.1	1,500
Total	**1809.4**	**9,291,500**	**2,260**	**10,836,000**	**4,077.4**	**20,130,500**

Table 8-2: Estimated production & value of Cyprus aquaculture, hatcheries (fry – fingerlings) (2010)

Species	Local Market		Exports		Total	
	Quantity (tons)	Value (€)	Quantity (tons)	Value (€)	Quantity (tons)	Value (€)
Seabream	9,101,000	1,483,000	0	0	9,101,000	1,483,000
Seabass	2,695,000	420,000	0	0	2,695,000	420,000
Japanese Seabream	7,500	1,200	0	0	7,500	1,200

Species	Local Market		Exports		Total	
	Quantity (tons)	Value (€)	Quantity (tons)	Value (€)	Quantity (tons)	Value (€)
Trout	370,000	11,000	0	0	370,000	11,000
Ornamental	30,000	32,000	29,000	46,000	59,000	78,000
Total	**12,203,500**	**1,947,200**	**29,000**	**46,000**	**12,232,500**	**1,993,200**

The DFMR is operating two research stations, the Meneou Marine Aquaculture Research Station (MeMARS) and the Fresh Water Aquaculture Research Station at Kalopanayiotis. (DFMR, 2010).

8.2.4. Pressures on the sector

Marine fishing areas in Cyprus are generally confined due to the geomorphology of Cyprus' coasts (small shelf extention). Thus, fishing effort is concentrated in a relatively narrow zone along Cyprus' coasts which results in the overfishing of most fish populations (Lamans, 2006).

In addition, according to the Food and Agriculture Organization (FAO) of the United Nations, bioproductivity in the eastern Mediterranean is poorer reaching 0.3gr/m^2 in comparison to the bioproductivity of the western Mediterranean which amounts to 60gr/m^2 and to the world average of 200gr/m^2. What is more, overfishing results in further reduction of productivity.

One serious problem recently added is the Lagocephalus fish, an invasion species introduced from Suez Canal and expanded over the whole eastern Mediterranean. It is not only poisonous, but it damages catches and fishing gear as well.

8.3. Future impact assessment

In this section, the climate change impacts on the fisheries and aquaculture sector as these have been identified in Deliverable 1.2 “Climate change impact, vulnerability and adaptation assessment for the case of Cyprus” (CYPADAPT, 2012) will be reassessed in light of the climate projections for the future (2021-2050).

Impacts on aquaculture are arising from direct and indirect impacts on the natural resources namely water, land, seed, feed and energy. As fisheries provide significant feed and seed inputs, the impacts of climate change on them will affect the productivity and profitability of aquaculture systems (FAO, 2008).

Climate changes could increase physiological stress on cultured stock. This would not only affect productivity but also increase vulnerability to diseases. Interactions of fisheries and aquaculture subsectors could induce other impacts also. For example, extreme weather events could result in escapes of farmed stock and contribute to reductions in genetic diversity of the wild stock, affecting biodiversity more widely (FAO, 2008).

In fisheries, while climate change has been addressed occasionally in scientific literature, the subject has not yet been formally addressed by most industry or fishery management administrations. However, the fishery sector and fisheries research are fairly advanced in this matter, through their dealing with the El Niño, decadal changes in ocean environments and other longer terms fluctuations in fisheries environments and resources. The observation programs, scientific analyses, computer models, the experience gained and strategies developed by fishers, processors, fishfarmers, and management authorities confronted with the problem of medium-to-long-term natural fluctuations, is extremely useful for dealing with climate change. Many of the principles and strategies developed to deal with ‘unstable’ stocks will be of use when having to deal with climate change (FAO).

Following, the changes in climate and their respective impacts on the fisheries and aquaculture sector for the case of Cyprus are presented in Table 8-3.

Table 8-3: Relationship between climate changes and impacts on the fisheries sector

Potential climate changes	Impacts
Sea water and inland water temperature changes	– Alterations in abundance and species composition of fish stocks – Potential loss of species or shift in composition in capture fisheries – Changes in infrastructure and operating costs from worsened infestations of fouling organisms, pests, nuisance species and/or predators – Potential for increased production and profit or losses – Alterations on seed availability – Possibly enhanced/reduced fish stocks – Potential reduced growth where the food supply does not increase sufficiently in line with temperature – Possible benefits for aquaculture, especially intensive and semi-

Potential climate changes	Impacts
	intensive pond systems – Possibly higher capital costs for aeration equipment or deeper ponds
Sea Level Rise	– Damage or loss of freshwater fisheries – Shifts in species abundance, distribution and composition of fish stocks and aquaculture seed – Reduced freshwater availability for aquaculture and a shift to brackish water species – Reduced recruitment and stocks for capture fisheries and seed for aquaculture – Worsened exposure to waves and storm surges and risk, inundation of inland aquaculture and fisheries
Changes in precipitation and water availability	– Higher costs for maintaining pond water levels – Reduced production capacity – Conflict with other water users – Change of culture species – Altered distribution, composition and abundance of fish stocks – Fishers forced to migrate more and expend more effort
Increase in the frequency and intensity of extreme weather events	– Loss of aquaculture stock and damage to or loss of aquaculture facilities and fishing gear – Impacts on wild fish recruitment and stocks – Higher direct risk to fishers; capital costs needed to design cage moorings, pond walls, jetties, etc. that can withstand storms and insurance costs – Loss of wild and cultured stock. Increased production costs – Loss of opportunity as production is limited – Intensified competition for fishing areas and more migration by fisherfolk

In the following sections of this chapter, the future impacts of climate change on the fisheries and aquaculture sector are further analyzed where relative data and information are available. The impacts are presented according to their initial categorization in the current impact assessment (CYPADAPT, 2012), namely:

- Quantity and diversity of fishstocks
- Fishstock physical environment
- Cost implications for fishermen

8.3.1. Quantity and diversity of fishstocks

(a) Inshore and offshore pelagic fishery

In general, the climate change induced impacts on the quantity and diversity of fishstocks of inshore and pelagic fishery are mainly related with the increase in seawater temperature.

Changing sea temperature and current flows will likely bring shifts in the distribution of marine fish stocks, with some areas benefiting while others lose. An increase is Sea Surface Temperature (SST) may result in an increase in the frequency of occurrence of harmful algal blooms in sea waters, a decrease in dissolved oxygen and changes in plankton composition. As a consequence, it is expected that diseases and parasites in fish stock will increase. Furthermore, the changes in the distribution of the marine fish stocks caused by the increased SST are expected to alter the balance between competitors, predators and invasive species. All the above mentioned changes definitely have an effect on the abundance and species composition of the fish stock (World Fish Centre, 2007).

In addition, changes in timing and success of migrations, spawning and peak abundance, as well as in sex ratios and changes in the location and size of suitable range for particular species caused by changes in temperature may cause species loss and altered species composition (World Fish Centre, 2007).

On the other hand, increased water temperature allows for longer growing seasons, enhances metabolic and growth rates and decreases natural mortality in winter which, all, have as a result an increase in production (World Fish Centre, 2007).

(b) Marine and freshwater aquaculture

The main climate changes that are considered to affect the quantity and diversity of freshwater and marine aquaculture are the changes in SST and the inland water temperature, the changes in precipitation and water availability as well as, the changes in the frequency and intensity of extreme weather events.

Higher inland water temperatures lead to more stable vertical stratification of deep lakes, increased oxygen depletion in lake bottoms and more frequent harmful algal blooms, which may in turn worsen dry season mortality, bring new predators and temperature-dependent diseases and change the abundance of food available to fishery species thus reducing the overall availability of fish stocks (EEA/JRC/ WHO, 2008; World Fish Centre, 2007).

Reduced precipitation and longer periods of droughts will result in deterioration of water quality causing diseases and reduced fish survival during lower summer season flows. On the other hand, higher wet season river flows may induce reduced spawning success of river fishes. Regarding shallow lakes and dams, water level is the most important factor determining stock size and catch rates decline when water levels are low (World Fish Centre, 2007). Reductions in river flow caused by climate change as well as the construction of dams lead to reductions in the availability of floodplain habitats which can in turn lead to rapid decline in fisheries (Dugan et al., 2010).

In addition, extreme weather events such as large waves, storm surges and flooding events may cause the introduction of diseases or predators into aquaculture facilities and lead to losses of aquaculture stock (World Fish Centre, 2007).

Situation in Cyprus

Next, the climate changes (changes in SST, inland water temperature, precipitation and extreme events) in Cyprus that are considered to be associated with the potential impacts on the quantity and diversity of fishstocks are presented in brief.

According to (Skliris et al., 2011) the Sea Surface Temperature (SST) in the Mediterranean has recorded an average warming rate over the period 1985–2008 of about 0.037°C year^{-1} while for the eastern sub-basin where the island of Cyprus is located this warming rate is about 0.042°C year^{-1}. In addition, according to *Samuel-Rhoads et al., 2012*, over the period 1996-2011 a general warming has occurred over the Levantine Basin where Cyprus belongs, at an average rate of approximately 0.065°C per year.

As for the changes in inland water temperature, these are related to the changes in air temperature. The projections for the period 2021-2050 according to the PRECIS model indicate that the change in annual mean temperature will range from 1-2 ^{o}C on average. In general, it is expected that water temperature will rise as air temperature rises, with a slower rate though.

Minor changes or no changes at all are projected according to the PRECIS model in the future annual average precipitation over the period 2021-2050. However, seasonal changes may be discerned, with winter and autumn precipitation presenting a decrease of 10-20mm per year and a minor increase in summer precipitation reaching 5 mm on average. The length of the drought periods, which is closely related to water availability for aquaculture is projected to increase up to 12 days per year on average. In addition, it must be mentioned that due to the limited freshwater availability in Cyprus, a large number of dams have been constructed in order to retain as much water as possible, which has led to drying of downstream freshwater habitats.

There are no projections regarding the frequency and intensity of extreme weather events in Cyprus, as the climate projection models used do not provide estimates for storms, waves and floods. The most relative indicator provided by PRECIS refers to the annual maximum total precipitation over one day (heavy rainfall index) which could be associated with flood risk. However, the PRECIS model showed that there will be no significant changes to this indicator in the future period (2021-2050), with only a minor increase of 2-5 mm per year on average.

In addition, it must be mentioned that temperature rise in Cyprus has been related to the increasing number of invasive species introduced in the coastal and offshore waters from southern latitudes.

However, the data available are not sufficient to correlate a potential alteration in the quantity and diversity of fishstock to the climate changes in Cyprus.

8.3.2. Fishstock physical environment

Alterations on fishstock physical environment regarding marine and freshwater fishery and aquaculture are attributed mainly to extreme events in general and in particular for ecosystems that are located nearby the coastal zone to storm surges and sea level rise. In addition, the fishstock physical environment is affected by increased temperatures, reduced precipitation and increased drought periods.

In general, regarding the climatic change impacts on the fishery sector due to sea level rise and increased intensity and frequency of storm surges, these are referring to alterations on the physical environment of marine and freshwater fishstocks. In particular, sea level rise will likely damage or destroy many coastal ecosystems such as mangroves and salt marshes, which are essential to maintaining wild fish stocks, as well as supplying seed to aquaculture. Mangroves and other coastal vegetation buffer the shore from storm surges that can damage fish ponds and other coastal infrastructure and may become more frequent and intense under climate change. Higher sea levels may lead to salinization of groundwater, which is detrimental to freshwater fisheries and aquaculture (World Fish Centre, 2007; Nicholls et al., 2007).

Reduced precipitation leads to lower water availability for freshwater aquaculture and increased competition with other water users. In addition, reduced precipitation and long drought periods result in lower lake and river levels and in the reduction of the overall extent and movement pattern of surface water. The water quality of freshwater aquaculture and inland fisheries is affected by low water availability and increased temperatures causing the development of diseases (World Fish Centre, 2007). Furthermore, lower water availability may lead a country to the expansion of dams which interrupt the connectivity of river systems, erect barriers to fish migration, and reduce the availability of breeding and feeding habitat. Dams with large reservoirs alter seasonal flood regimes and retain sediments useful as feeding supply to downstream floodplains. Furthermore, river channelization and dredging remove riverine habitats and alter flow and flood patterns, thus reducing the availability of floodplain habitats (Dugan et al., 2010).

There is strong evidence that global sea level gradually rose in the 20th century and is currently rising at an increased rate while it is projected to rise during the 21st century at an even greater rate. Estimates for the 20th century show that global average sea level rose at a rate of about 1.7mm per year. The average rate of sea level rise from 1961 to 2003 was 1.8mm/year and increased to 3.1mm/year from 1993 to 2003. Climate model projections, satellite data and hydrographic observations show that sea level is not rising uniformly around the globe. In some regions, rates are up to several times the global mean rise, while in other regions sea level is falling (Shoukri & Zachariadis, 2012).

For the Mediterranean basin, satellite measurements calculate that sea level has been rising at a rate of 2.4 to 3.8 mm/yr since 1993, more than 50% faster than the rate that tide gauges estimate over the last century. Therefore, sea level appears to be rising about 50% faster than recent models suggest. Although there is no proof for their lack of validity, given the uncertainty of the models, satellite measurements suggest that average sea level rise rate is being underestimated (Ramos-Esplá et al., 2007).

Situation in Cyprus

Sea Level Rise: Based on archaeological data, Cyprus appears to be experiencing long-term uplift of between 0 and 1 mm per year. This uplift will counteract global sea-level rise and given a global rise in sea level of 0.5m by 2100, relative sea-level rise in Cyprus will be in the range 0.4-0.5m (Nicholls and Hoozemans, 1996).

Changes in precipitation: The rate of decrease of the average precipitation in Cyprus during the 20th century and at the beginning of the 21st was one millimeter per year. Regarding future, minor changes or no changes at all are projected according to the PRECIS model annual average precipitation over the period 2021-2050. However, seasonal changes may be discerned, with winter and autumn precipitation presenting a decrease of 10-20mm per year and a minor increase in summer precipitation reaching 5 mm on average. The length of the drought periods, which is closely related to water availability for aquaculture is projected to range from slight decreases to an increase of up to 13 days/year on average.

However, due to limited data availability for the case of Cyprus, the degree of the climate changes impact on the fishstock physical environment cannot be assessed.

8.3.3. Cost implications for fishermen

The main cost implications of climate induced impacts for fishermen are mainly attributed to extreme weather events.

In particular, sea level rise may cause loss of harbours and coastal infrastructure (e.g households). Increased intensity and frequency of storms may lead to decreased frequency of inshore and offshore pelagic fishing due to increased risk to fishers. To deal with it, capital costs will be needed in order to design cage moorings, pond walls, jetties, etc. that can withstand storms. Furthermore, storms may result in loss of aquaculture stock and damage to or loss of aquaculture facilities and fishing gear with the aquaculture installations (coastal ponds, sea cages) being at greater risk of damage. The intrusion of some Invasive Alien Species (IAS) may be detrimental for a country's fishery sector and cause significant damages to the fishing gear and catches. Last but not least, important cost implications are related with the loss of wild and cultured stock, the increased production costs and the loss of opportunity as production is limited (World Fish Centre, 2007).

Situation in Cyprus

Sea Level Rise: Based on archaeological data, Cyprus appears to be experiencing long-term uplift of between 0 and 1 mm per year. This uplift will counteract global sea-level rise and given a global rise in sea level of 0.5m by 2100, relative sea-level rise in Cyprus will be in the range 0.4-0.5m (Nicholls and Hoozemans, 1996).

Extreme weather events: There are no projections regarding the frequency and intensity of extreme weather events in Cyprus, as the climate projection models used do not provide estimates for storms, waves and floods. The most relative indicator provided by PRECIS refers to the annual maximum total precipitation over one day (heavy rainfall index) which could be associated with flood risk. However, the PRECIS model showed that there will be no significant changes to this indicator in the future period (2021-2050), with only a minor increase of 2-5 mm per year on average.

IAS intrusion: The intrusion of the IAS Lagocephalus sceleratus in Cyprus has caused significant damages to the fishing gear and catches.

8.4. Future vulnerability assessment

In this section, the future vulnerability of the fishery sector is assessed in terms of its sensitivity, exposure and adaptive capacity based on the available quantitative and qualitative data for Cyprus and the climate projections for the period 2021-2050. In particular, sensitivity is defined as the degree to which the fishery sector will be affected by climate changes, exposure is the degree to which the fishery sector will be exposed to climate changes and its impacts while the adaptive capacity is defined by the autonomous ability of the fishery sector to adapt to changing environmental conditions as well as by the effectiveness of the relative existing and planned adaptation measures.

For the assessment of future vulnerability, the same indicators used in the current vulnerability assessment (CYPADAPT, 2012) were used, wherever the necessary data were available. These indicators are summarized in Table 8-4.

Table 8-4: Indicators used for the vulnerability assessment of climate change impacts on the fisheries sector of Cyprus

Vulnerability Variable	Selected Indicators
Quantity and Diversity of Fishstocks	
Sensitivity	– Changes of fishstocks in relation to changes in temperature – Changes of fishstocks in relation to changes in precipitation – Rate of Invasive Alien Species intrusion in Cyprus' waters – Overfishing – Bioproductivity – Degree of sensitivity of the different subsectors and share to total production – Share of the sector to national Gross Domestic Product
Exposure	– Changes in the quantity of fish caught – Changes in Sea Surface Temperature – Changes in inland water temperature – Changes in precipitation and in the length of drought periods – Changes in the frequency and intensity of extreme weather events – Proximity to the channel of IAS intrusion
Adaptive capacity	– Sustainable management of fish stocks in order to prevent overfishing – Modernisation of existing aquaculture units – Diversification of aquaculture production – Plan for the control of the population of Lagocephalus sceleratus in the coastal waters of Cyprus – Research programmes
Fishstock Physical Environment	
Sensitivity	– Sensitivity of coastal ecosystems to sea level rise and storm surges – Salinization of groundwater and shallow bodies – Freshwater availability

Vulnerability Variable	Selected Indicators
	– Competition between water users
Exposure	– Increase in storm surges – Decrease in precipitation and increase in the length of drought periods – Sea Level Rise – Number of salinized bodies
Adaptive capacity	– Construction of coastal defense works – Development of fishing shelters – Designation of marine protected areas – Artificial reefs – Measures for the protection of water quality
Cost implications for fishermen	
Sensitivity	– Infrastructure of marine aquaculture – Fishing fleet and gear of pelagic fishery – Contribution of the sensitive sub-sectors to the total value added of the sector – Contribution of the fisheries sector to the national employment (proportion of the Economically Active Population)
Exposure	– Increase in storm surges – Proximity to the channel of IAS intrusion
Adaptive capacity	– Income of the of the affected fishermen and sub-sectors – Promotion of fishing tourism – Compensation against losses due to natural disasters – Plan for the control of the population of Lagocephalus sceleratus in the coastal waters of Cyprus – Construction of coastal defense works – Development of fishing shelters – Artificial reefs

The relationship between sensitivity, exposure and adaptive capacity is based on the following qualitative equation:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity * Exposure$$

Sensitivity, exposure and adaptive capacity are evaluated on a 7-degree qualitative scale ranging from “none” to “very high”.

In the sections that follow, the vulnerability is assessed for each of the impact categories presented in Section 8.3:

1. Quantity and diversity of fishstocks,
2. Fishstock physical environment,
3. Cost implications for fishermen.

It must be noted that, there are no sufficient scientific evidence and data to evaluate or correlate all impacts and indicators to future climate changes. Consequently, further research is required in order to provide concrete information for a more detailed and descriptive assessment of the future vulnerability of the sector. Nevertheless, an attempt was made to provide a preliminary assessment of the future vulnerability. In case additional data are provided by the competent authorities of Cyprus, the future vulnerability of the sector could be re-assessed.

8.4.1. Quantity and diversity of fishstocks

8.4.1.1. Assessment of sensitivity and exposure

Sensitivity

Higher temperature increases metabolic rate which raises oxygen and food requirements while decreases dissolved oxygen in water. In addition, higher temperatures facilitate the survival of parasites and bacteria. However while this combination of challenges may reduce fish survival, growth and reproductive success (Halls, 2009; Welcomme et al., 2010), the precise impacts on individual fisheries are difficult to predict at this time.

In contrast, the potential consequences of hydrological alterations caused by climate change especially in inland fisheries are relatively clear. For example, the Sahelian drought of the 1980s is estimated to have reduced the fish catch in the Inner Niger Delta by 50%, while the Markala and Selingué dams reduced catch by 5,000 tonnes (Laë, 1992). The most striking example of natural change in freshwater ecosystems and their fisheries has been in Lake Chad, where the lake fell from a high water level in 1963 to 10% of that surface area by 2007. Fish catches are very sensitive to declines in river inflows and lake levels since they experience parallel reductions. For example, the sensitivity of fish catches to changes in water flows can be seen in the case of Lake Chilwa in southern Africa which is well known for fluctuating water levels and associated changes in fish populations (Figure 8-4). Should climate change lead to similar changes in water flow, there will be significant changes in inland fisheries, especially in the drier regions (Dugan et al., 2010).

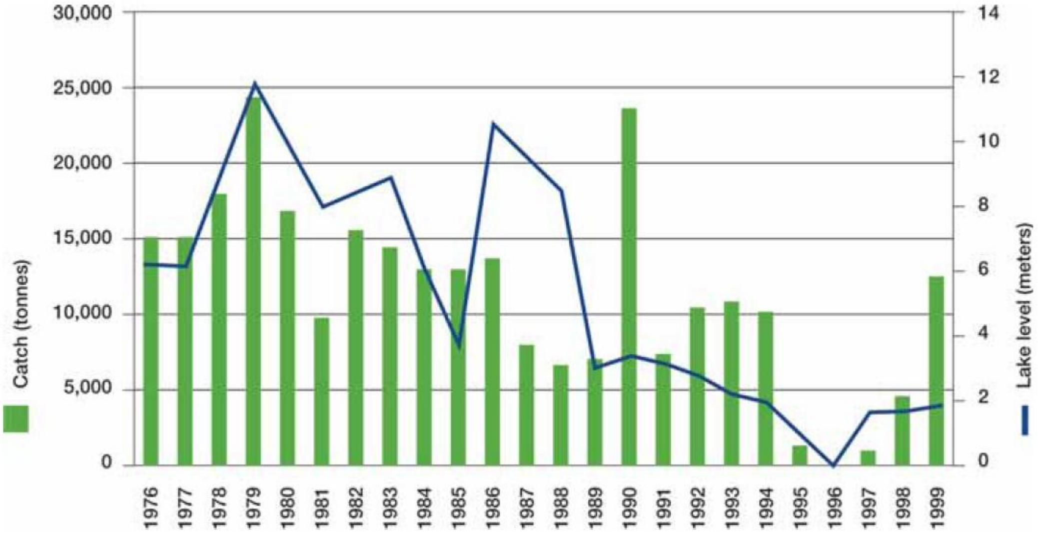


Figure 8-4: Catch fluctuations and water level in Lake Chilwa, Malawi 1976-1999

Source: Njaya, 2002; Allison et al., 2007

For the assessment of the sensitivity of the quantity of fishstocks to climate changes in Cyprus, it is recommended that (i) the changes of fishstocks in relation to changes in Sea Surface Temperature (SST) and (ii) the changes of certain fish species in relation to changes in precipitation should be studied. In order to assess the amount of fish populations, the variations in the change in the annual total capacity of the fishing fleet in the total fishstock quantity should be isolated.

In addition, the quantity and distribution of fishstocks are affected by the southern intrusion of invasive species, the northward movements of Cyprus endemic fish species and the changes in the balances between competitors and predators due to temperature rise. These changes in combination with some physical characteristics, such as the variety of indigenous marine species and the low biomass, make sensitivity to climate change even higher affecting the distribution of fish and the socioeconomic situation for local fishermen.

The number of invasive species introduced in the coastal and offshore waters of Cyprus has grown over the last 50 years, as shown in the following figure.

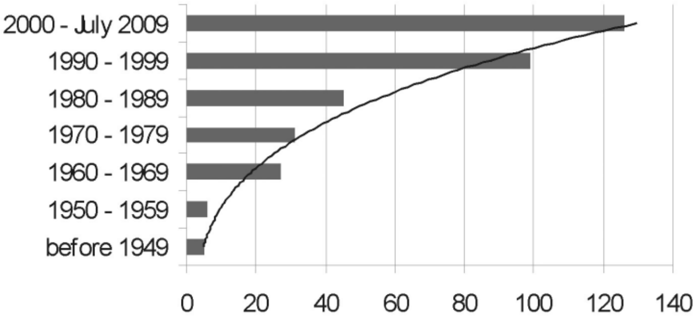


Figure 8-5: Cumulative number of alien marine species in Cyprus per decade

Source: Katsanevakis et al., 2009

However, it has not yet been determined whether the increasing intrusion of exotic fish in the Mediterranean Sea constitutes a serious threat for the extinction of the endemic species (Ben Rais Lasram & Mouillot, 2009).

It must be mentioned that even a small reduction in the amount of fishstocks of Cyprus, will considerably affect the sector and especially marine pelagic fishery since the amount of available fishstock is already limited due to the spatially confined marine fishing areas (small shelf extention) (Lamans, 2006) and to the low bioproductivity potential of the eastern Mediterranean. Thus, it is considered that the sensitivity of the quantity of fishstock is more sensitive to changes in climate.

In general, it can be said that pelagic fishery is more sensitive to changes in climate while aquaculture and especially marine aquaculture is less sensitive, since the confined and controlled environment in which fishstock is reproduced does not allow for the migration of species, the intrusion of IAS, etc with the exception of extreme weather events. As it can be seen by the following figure, fish caught in pelagic fishery in Cyprus during the period 2001-2010 represented 38% of the total fish caught, while marine aquaculture which was substantially increased during that period, represented 61% of the total fish caught. Thus the overall sensitivity of the sector to climate changes is considered to be reduced.

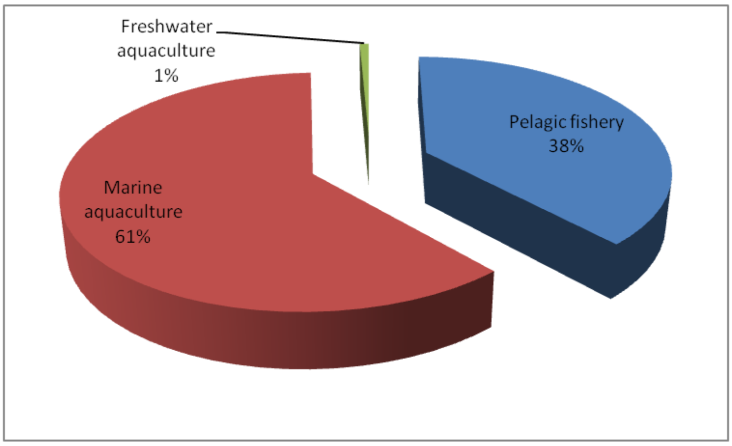


Figure 8-6: Share of fish caught (tons) by sub-sector of the fisheries sector in Cyprus, average 2001-2010

Source: CYSTAT, 2010; CYSTAT, 2012

Finally, it must be noted that the Cypriot economy is not very sensitive to changes in the production of the fisheries sector as the latter constitutes a very small sector of the Cypriot economy which contributes approximately to 0.5% of the National Gross Domestic Product.

Considering the above, it is estimated that the sensitivity of the quantity and diversity of fishstocks to climate changes is **moderate**.

Exposure

To assess the exposure to this impact, first the trend in the quantity of fish caught over the years will be examined. As it can be seen in Figure 8-7, the quantity of total fish caught since 1980 has recorded a general increasing trend with the exception of the years 2002-3 and 2009 where a decrease was noted. However, the increasing trend is mostly attributed to the significant increase of marine aquaculture production (Figure 8-8). Considering the above, no conclusion may be deducted towards this indicator.

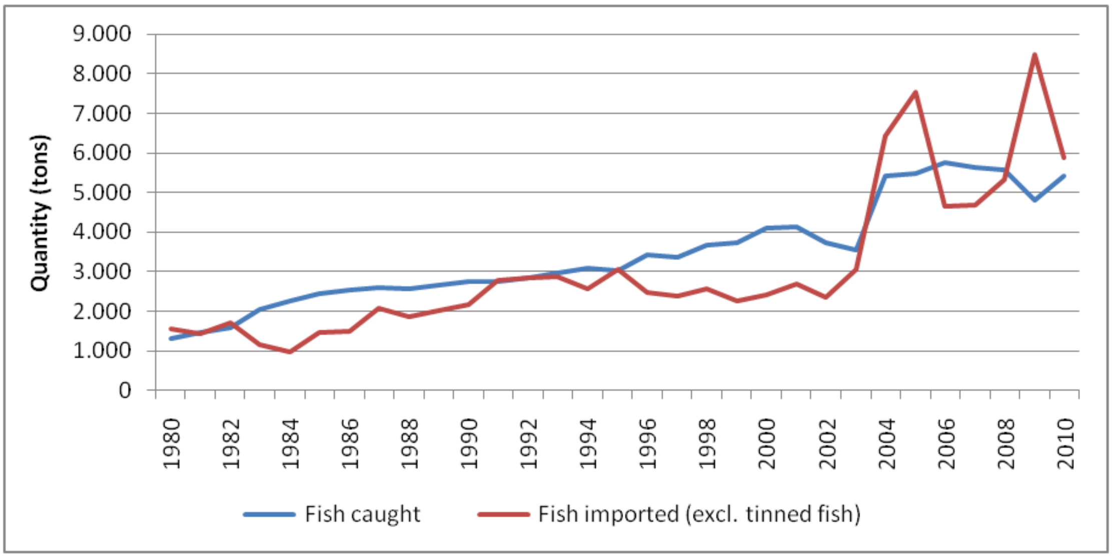


Figure 8-7: Caught and imported fish in Cyprus, 1980-2010

Source: CYSTAT, 2010; CYSTAT, 2012

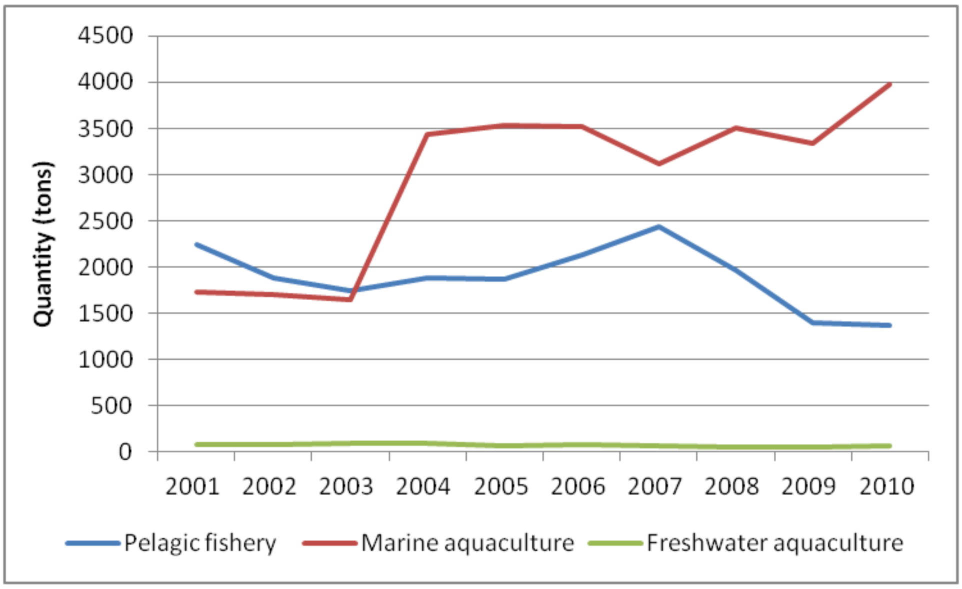


Figure 8-8: Fish caught by subs-ector in Cyprus, 2001-2010

Source: CYSTAT, 2010; CYSTAT, 2012

In order to examine the exposure of the available fishstock in Cyprus to climate changes that could alter its quantity and distribution, first the climate changes of SST and inland water temperature increase, precipitation decrease, increased droughts and increase in extreme weather events will be presented.

Regarding changes in SST, satellite and in situ-derived data indicate a strong eastward increasing sea surface warming trend in the Mediterranean basin from the early 1990s onwards. The satellite-derived mean annual warming rate over the period 1985–2008 is about 0.037°C year$^{–1}$ for the whole basin and about 0.042°C year–1 for the eastern sub-basin where the island of Cyprus is located (Skliris et al., 2011) (Figure 8-9). In addition, analyses of annual mean satellite SST data indicate that over the last 16 years (1996-2011) a general warming has occurred over the Levantine Basin where Cyprus belongs, at an average rate of approximately 0.065°C per year (Samuel-Rhoads et al., 2012) (Figure 8-10). This rate is more than three times higher than the recorded 0.18°C/decade rate of increase of global SSTs (Good et al., 2007).

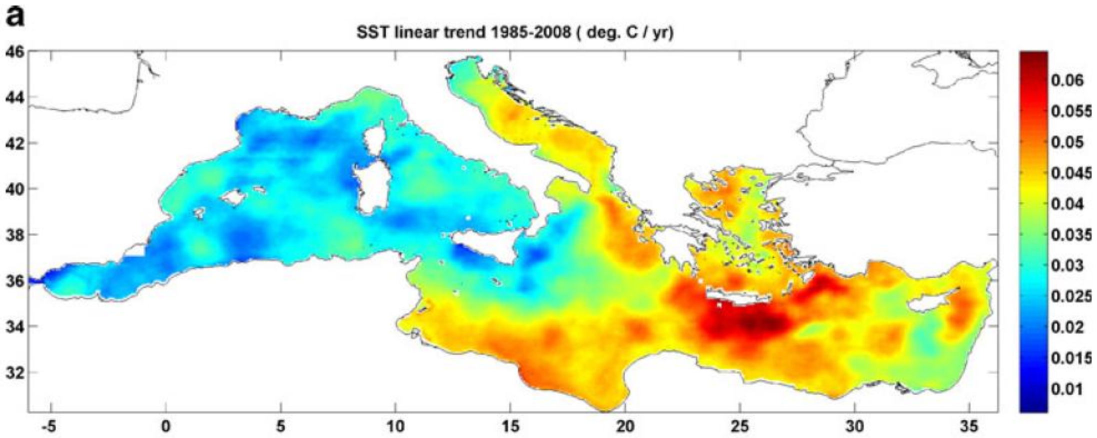
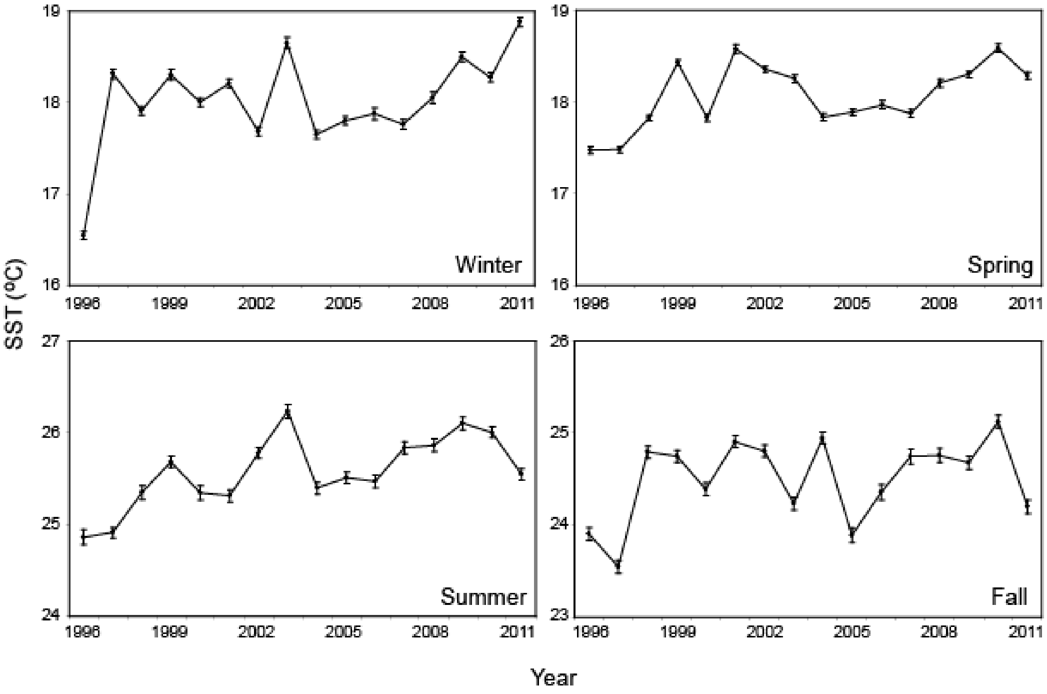


Figure 8-9: Horizontal distribution of satellite-derived SST annual linear trends (°C/year) over 1985–2008



Seasonal mean values are shown in solid line with points. The annual standard error (s.e.m.) is shown in solid vertical bars.

Figure 8-10: Mean satellite remote sensing sea surface temperatures (SSTs) data from 1996 until 2011

Source: Samuel-Rhoads et al., 2012

As for changes in inland water temperature, these are related to the changes in air temperature. Change projections for the period 2021-2050 according to the PRECIS model indicate that the average change in annual maximum temperature (TX) will range from +1.0°C at the eastern and northern coasts to +2.0°C in higher elevation areas and especially at the southwestern side of Troodos. The lowland and continental areas in the central part of the country present also notable changes in the average annual TX (mainly more than +1.5°C), followed by the western and southern coasts with a temperature increase limited to 1.3-1.7°C. It is expected that rivers and storage reservoirs with low flows will be more sensitive to changes in air temperature due to their lower specific heat capacity. In general, it is expected that water temperature will rise as air temperature rises, with a slower rate though.

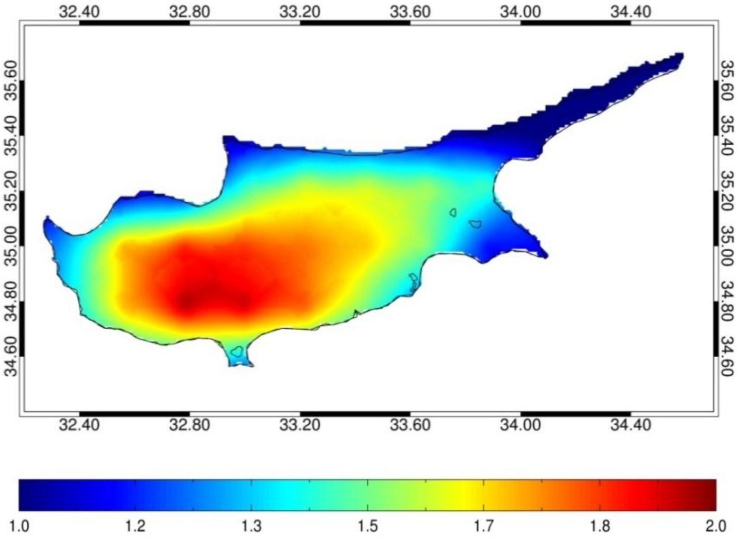


Figure 8-11: Changes in average annual maximum TX between the future (2021-2050) and the control period (1961-1990)

In addition, according to the PRECIS model, all north coasts are expected to receive less annual total precipitation in the future than that estimated for the recent past years 1961-1990. In all other parts of Cyprus, the annual total precipitation appears to have minor decreases or no changes at all with the exception of the area east from Paphos where an increase in total annual precipitation is noticed, minor though (up to 5mm). All freshwater aquaculture farms are located on Troodos mountains where no significant changes in precipitation have been predicted.

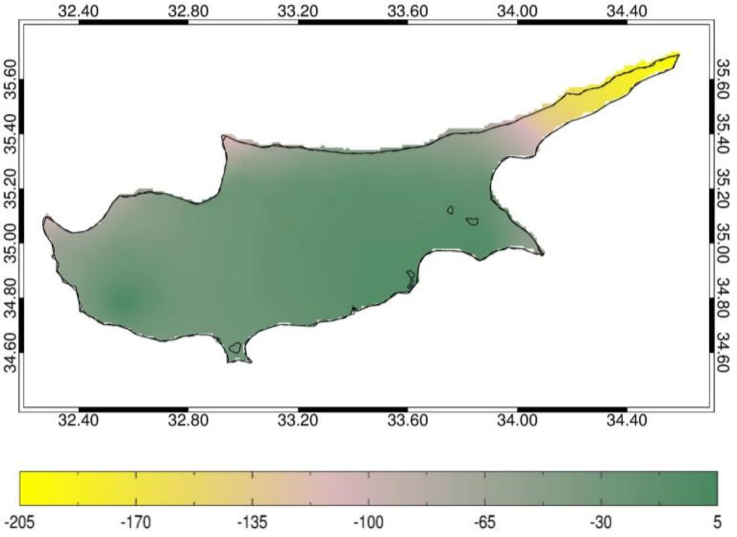


Figure 8-12: Changes in annual total precipitation between the future (2021-2050) and the control period (1961-1990)

As far as the length of drought periods in the future (2021-2050) is concerned, it is expected that the central part of Cyprus will face an increase of the maximum length of dry spell. In particular, the increase of this index will be about 15 days/year in the continental areas near Nicosia and Larnaca and approximately 20 days/year in the eastern part of Troodos (north from Limassol). On the other hand, the western coastal and higher elevation regions of Cyprus, as well as the area of Ayia Napa, is expected to have slight decreases or no changes in the maximum length of dry spell (Figure 8-13). The area of Troodos mountains where the freshwater aquaculture farms are located, is predicted to present increases to the drought period length up to 20 days annually.

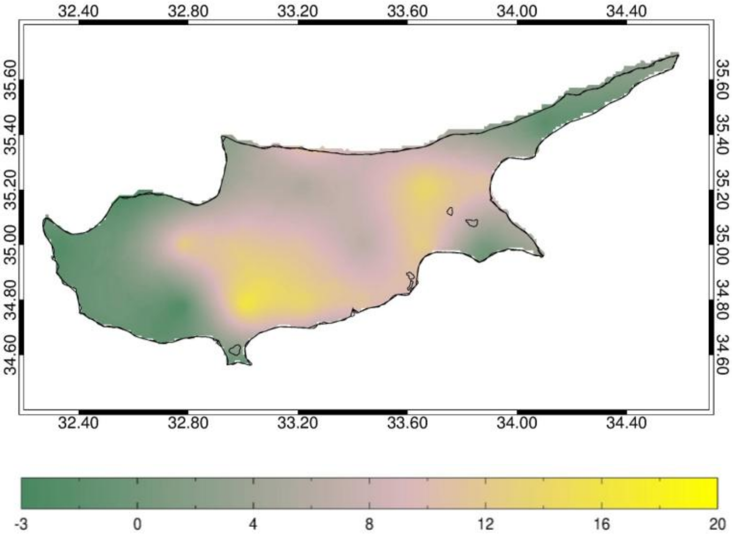


Figure 8-13: Changes in maximum length of dry spell (RR<0.5mm) between the future (2021-2050) and the control period (1961-1990)

The most relative indicator which PRECIS provides regarding extreme weather events, refers to the annual maximum total precipitation over one day. The PRECIS results (Figure 8-14) show that a slight increase of about 2-5 mm is anticipated in western, inland and mountain regions. Additionally, southern and southeastern areas present an increase of about 1 mm in annual max total rainfall over 1 day.

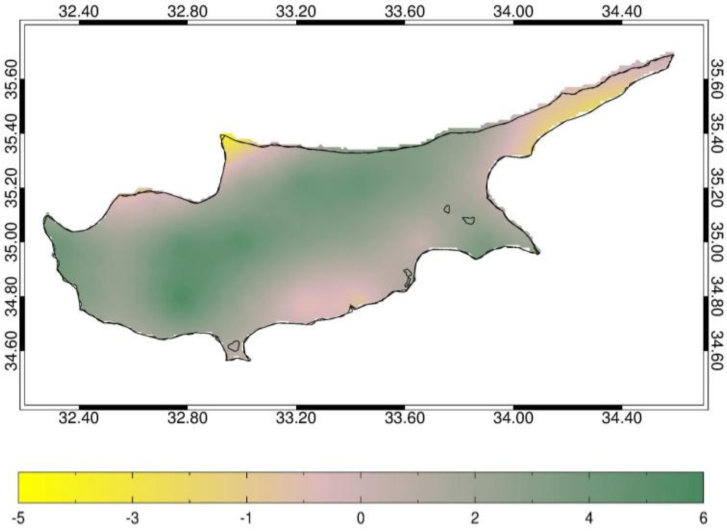
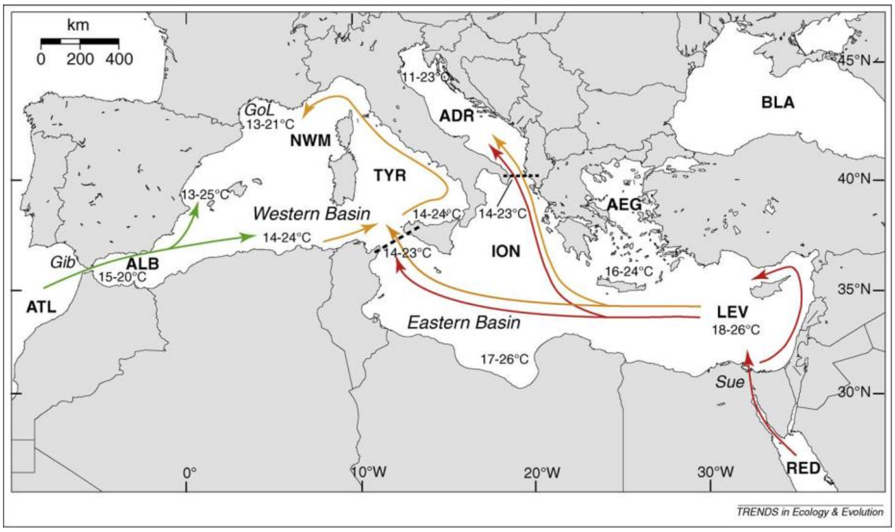


Figure 8-14: Changes in annual maximum total precipitation over 1 day between the future (2021-2050) and the control period (1961-1990)

Regarding the exposure of the fisheries sector to invasive species, it is considered that Cyprus is characterized by high exposure because it is located near the manmade nautical channel of Suez which favours the migration and relocation of the Lessepsian species (Mitov, 2009). However, not all IAS are harmful of the endemic fish populations as many IAS contribute to the enhancement of the fishstock diversity.



Arrows represent main routes of species range expansion according to their origin: Mediterranean natives (orange), Atlantic migrants (green) and Lessepsian migrants (red).

Figure 8-15: Main routes of species range expansion in the Mediterranean Sea

Source: Lejeusne et al., 2010

However, as most of the fishing activity in Cyprus is practiced in the marine environment (pelagic fishery and marine aquaculture), the climate changes considered to mostly affect the fisheries sector in total are the gradual change in SST and the invasion of harmful IAS.

In view of the above, it is considered that the exposure of the fisheries sector in Cyprus to climate changes with adverse impacts on the quantity and diversity of fishstocks is **moderate**.

8.4.1.2. Assessment of adaptive capacity

While the fishery sector cannot do much to impede or seriously affect global climate change, it could contribute to its stabilization or reduction, and to mitigating its effects. Many of the principles and strategies developed to deal with 'unstable' stocks will be of use when having to deal with climate change.

The aims set in the National Fishery Strategy Plan 2007-2013 considered to contribute to climate change adaptation of the fisheries sector in Cyprus are presented below.

Fishery:

- Sustainable management of fish stocks in order to prevent overfishing. Sustainable management such as the use of more selective fishing gear, the reduction of fishing efforts and the establishment of fishing shelters and artificial reefs may contribute to the conservation of fishstock under climate changes.

Aquaculture:

- Modernisation of existing aquaculture units. Modernisation may improve the environmental impact on the marine environment and at the same time increase the productive capacity, thus enhancing adaptive capacity.
- Diversification of production. The diversification of aquaculture production may reduce risk due to reduced productivity of certain less climate resilient fishes by compensating with the increased productivity of some other fishes that may benefit from climate changes.

Furthermore, the Department of Fisheries and Marine Research, taking into account the reports from fishermen regarding the substantial increase and spread of the population of the Invasive Alien Species (IAS) of Lagocephalus and the damage caused to the fishing gear and catches, prepared a study on the species in the coastal waters of Cyprus. After evaluating the results of the study, the DMFR developed a management plan entitled ‘Plan for the control of the population of Lagocephalus sceleratus in the coastal waters of Cyprus’ and in 2012 announced the call for proposals for the implementation of the plan in the framework of the ‘Project Grants for collective actions in the Fisheries Sector’. The purpose of the call is to eliminate the populations of lagocephalus from the coastal commercial fleet of Cyprus, with the exercise of intense fishing pressure on breeding population of the species, just before and during the breeding season, in the main breeding areas of the species.

Regarding the diversification of production, the research programmes that have been undertaken at the Meneou Marine Aquaculture Research Station (MeMARS) focused mainly on new candidate species for fish farming, such as rabbit fish (Siganus rivulatus), common pandora (Pagellus erythrinus), common dentex (Dentex dentex), greater amberjack (Seriola dumerili) and meagre (Argyrosomus regius). The main objective of the research was the diversification of aquaculture production with new species. The main projects during 2010 were:

- Reproduction and larval rearing protocols for the mass production of fry of the rabbitfish (Siganus rivulatus) and fattening in sea cages of market size fish,
- The effect of illumination in the ability of capturing live feed in rabbitfish larvae,
- Study of the effect of temperature and oxygen concentration on the metabolism of rabbitfish,
- Evaluation of vitamin C and astaxanthin supplementation in broodstock diet on reproductive performance and egg and larval quality in common pandora (Pagellus erythrinus),

- Evaluation of different feeds for the fattening of greater amberjack and observation of its feeding behaviour,
- Management of amberjack broodstock, performing a trial on reproduction using LHRHa hormone implants,
- Fattening of meagre in tanks and observation of its feeding behaviour, and
- Evaluation of the culture of rotifers with different feeds and determination of their nutritional value.

Moreover, the MeMARS is participating in a) the European Thematic Educational Network AQUA-TNET, which is funded from the European Commission Socrates Erasmus Programme, b) the European Network Programme COST Action 867 “Welfare of fish in European aquaculture”, c) the European Network Programme COST Action FA0801 “Critical success factors for fish larval production in European Aquaculture: a multidisciplinary network (LARVANET)” and d) the project “The future of research on aquaculture in the Mediterranean region” which was approved under the 7th Framework Programme of the EU. Other activities of MeMARS in 2010 included the support of private fish farms and the information of students of primary and secondary education on aquaculture in Cyprus.

Regardless the fact that a variety of measures have been undertaken, it must be noted that the exploitation of the abovementioned incentives, grants and research outcomes depends on the willingness, awareness and private initiative of fishermen. Thus the adaptive capacity of the fishery sector against these alterations can be considered as **limited to moderate**.

Following, additional recommended adaptation measures (FAO, 2008; DoE, 2010) that are considered to further enhance adaptive capacity towards this impact are presented indicatively. Nevertheless, their assessment and final selection for implementation will be made through the use of the Multicriteria Analysis (MCA) tool which will be developed and implemented in the framework of Actions 4 and 5 of the CYPADAPT project.

- Develop training programs and technical guidance for fishermen
- Implementation of new regulations governing the professional and particularly recreational fishing
- Use better feeds in aquaculture, more care in handling, selective breeding and genetic improvements for higher temperature tolerance (and other related conditions),
- Increasing feeding input in order to adjust harvest and market schedules
- Focus management to reduce stress by setting up biosecurity measures, monitoring to reduce health risks by improving treatments and making genetic improvements for higher resistance
- Using different and faster growing fish species
- Shifting to artificially propagated seed, improving seed quality and production efficiency, closing the life cycle of more farmed species

8.4.2. Fishstock physical environment

8.4.2.1. Assessment of sensitivity and exposure

Sensitivity

Sea level rise will likely damage or destroy many coastal ecosystems such as mangroves and salt marshes are essential to maintaining wild fish stocks, as well as supplying seed to aquaculture. Mangroves and other coastal vegetation buffer the shore from storm surges that can damage fish ponds and other coastal infrastructure. In addition, higher sea levels may lead to salinization of groundwater and swallow waters, which is detrimental to freshwater fisheries and aquaculture. Concequently, it is considered that marine and freshwater aquaculture as well as inland fishery are very sensitive to sea level rise and extreme weather events such as storm surges and flooding. Along with the negative consequences, however, come benefits in the form of increased areas suitable for brackish water culture of such high-value species as shrimp and mud crab (World Fish Centre, 2007).

Furthermore, freshwater aquaculture and inland fisheries are sensitive to reduced precipitation and long drought periods. Reduced precipitation leads to lower water availability for aquaculture and increased competition with other water users. In addition, reduced precipitation and long drought periods result in lower lake and river levels and in the reduction of the overall extent and movement pattern of surface water. The water quality of inland aquaculture and fisheries is affected by low water availability and increased temperatures causing the development of diseases (World Fish Centre, 2007).

The sensitivity of the physical environment of freshwater aquaculture in Cyprus to the abovementioned climate changes is high, since there is already limited freshwater availability and the competition between water users is intense. In dry years, when total water demand exceeds water supply, the most vital needs (i.e. need for drinking water) are satisfied first while the rest of the needs are prioritized according to their importance for the society and the economy. Taking into consideration that the fishery sector and in particular the subsector of freshwater aquaculture constitutes a very small share of the Gross Domestic Product (GDP) and the total employment of the country, it is possible that the satisfaction of the water demand of the fishery sector will not be included among the first priorities in years with limited water availability.

Taking into consideration the above, the fishstock physical environment of freshwater aquaculture and inland fisheries in Cyprus is considered highly sensitive to climate changes while marine fishery and aquaculture are characterized by limited sensitivity. In order to estimate the sensitivity for the fisheries sector in total, the contribution of the fisheries sub-sectors in terms of production (see Figure 8-3) was taken into account, leading to a **limited** sensitivity for the whole sector.

Exposure

For the assessment of the exposure of the fishstock physical environment in Cyprus to climate changes, a number of climatic factors, such as the increase in storm surges and the decrease in precipitation as well as other factors induced by climate change such as sea level rise and groundwater salinization can be used as indicators.

While changes in storminess may contribute to higher coastal water levels, the limited geographical coverage of studies to date and the uncertainties associated with overall storminess changes, do not allow for the assessment of the effects of storminess changes on storm surge at this time (IPCC, 2012).

Results from embedded high-resolution models and global models show a likely increase of peak wind intensities and notably, increased near-storm precipitation in future tropical cyclones. Most recent published modelling studies investigating tropical storm frequency, simulate a decrease in the overall number of storms, though there is less confidence in these projections and in the projected decrease of relatively weak storms in most basins, with an increase in the numbers of the most intense tropical cyclones. Model projections show fewer mid-latitude storms averaged over each hemisphere, associated with the poleward shift of the storm tracks that is particularly notable in the southern hemisphere, with lower central pressures for these poleward-shifted storms. The increased wind speeds result in more extreme wave heights in those regions (Meehl et al., 2007). However, according to the projections of the KNMI climate model, the wind speed in Cyprus during the future period 2021-2050 is not expected to present substantial changes, on the contrary, it presents minor decreases in general.

In addition, according to the PRECIS model, all north coasts are expected to receive less annual total precipitation in the future than that estimated for the recent past years 1961-1990. In all other parts of Cyprus, the annual total precipitation appears to have minor decreases or no changes at all, while there is an area east from Paphos which presents a minor increase in total annual precipitation (up to 5mm). All freshwater aquaculture farms are located on Troodos mountains where no significant changes in precipitation have been predicted.

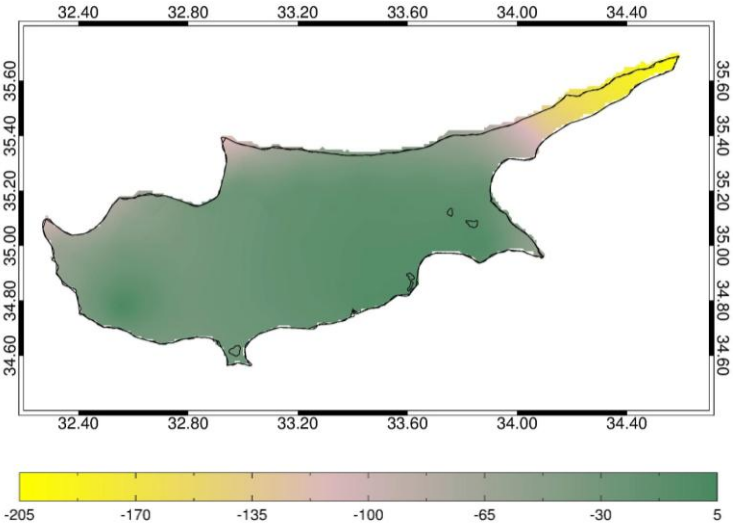


Figure 8-16: Changes in annual total precipitation between the future (2021-2050) and the control period (1961-1990)

As far as the length of drought periods in the future (2021-2050) is concerned, it is expected that the central part of Cyprus will face an increase of the maximum length of dry spell. In particular, the increase of this index will be about 15 days/year in the continental areas near Nicosia and Larnaca and approximately 20 days/year in the eastern part of Troodos (north from Limassol). On the other hand, the western coastal and higher elevation regions of Cyprus, as well as the area of Ayia Napa, is expected to have slight decreases or no changes in the maximum length of dry spell (Figure 8-17). The area of Troodos mountains where the freshwater aquaculture farms are located, is predicted to present increases to the drought period length up to 20 days annually.

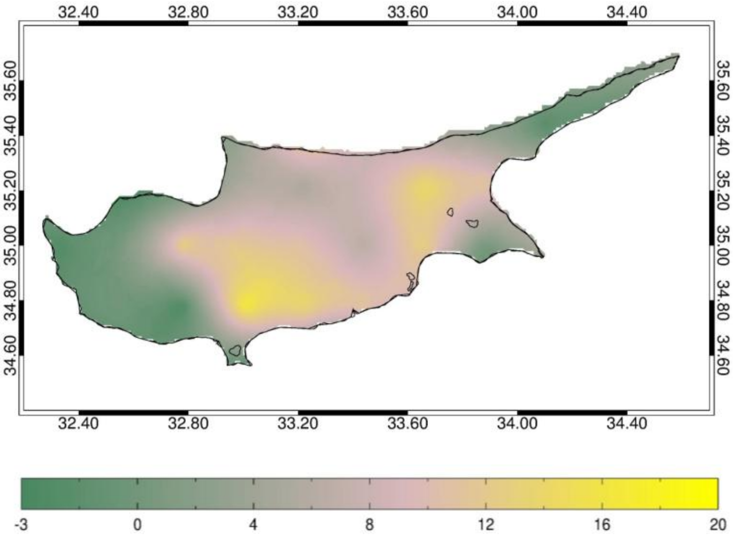


Figure 8-17: Changes in maximum length of dry spell (RR<0.5mm) between the future (2021-2050) and the control period (1961-1990)

Sea level rise in the Mediterranean Sea is not expected to be as high as in the oceans. Especially for the case of Cyprus, the sea level rise is expected to be moderate (EC, 2009). Furthermore it must be added that, based on archaeological data, Cyprus appears to be experiencing long-term uplift of between 0 and 1 mm per year. This uplift is expected to counteract sea-level rise and given a global rise in sea level of 0.5m by 2100, relative sea-level rise in Cyprus will be in the range 0.4-0.5m (Nicholls and Hoozemans, 1996). The sea level changes in Cyprus as observed during the period between 1993 and 2000 show an increase of 5-10 mm/year (Figure 8-18).

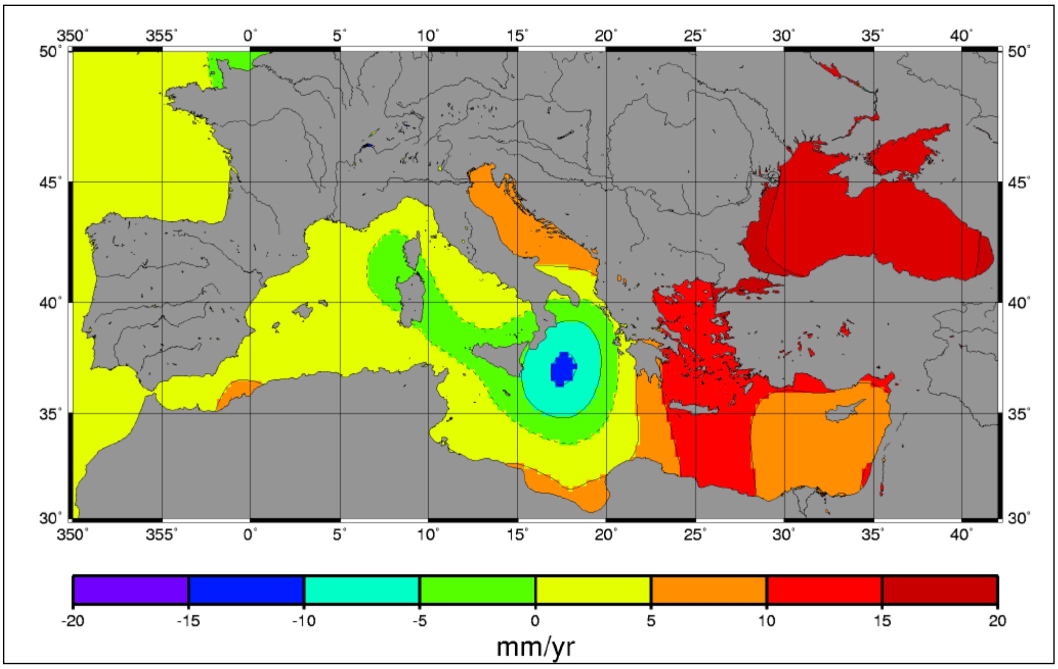


Figure 8-18: Mediterranean basin sea level changes between 1993 and 2000

Source: Ministry of Environment of Lebanon, 2011

As regards to groundwater salinization, 12 out of 19 groundwater bodies in Cyprus have been already exposed to seawater intrusion while the coastal zones of several aquifers in Cyprus have been abandoned due to this phenomenon. However, the areas of Troodos mountains where freshwater aquaculture is practised do not seem to be affected. In Figure 8-19, the aquifers of Cyprus exposed to salinization are presented.

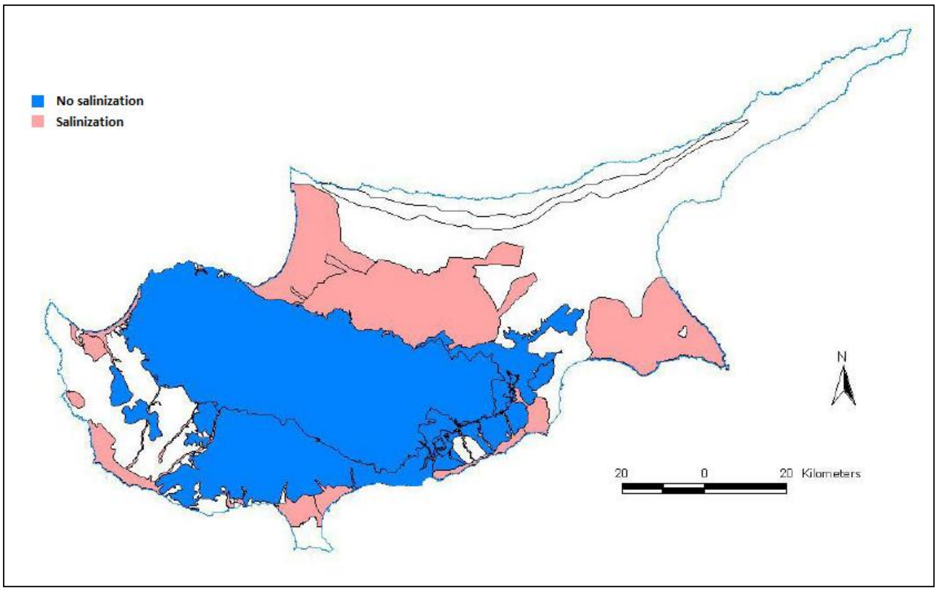


Figure 8-19: Salinization in the groundwater bodies of Cyprus

Source: Water Development Department, 2008

In view of the above, the exposure of the fishstock physical environment in Cyprus to climate changes is considered to be **limited**.

8.4.2.2. Assessment of adaptive capacity

In Cyprus the following measures have been undertaken that can improve the adaptive capacity of fishstock physical environment to sea level rise and storm surges:

- Construction of Coastal Defense Works
- Development of fishing shelters. Fishing shelters are constructed for the protection of fishing boats against extreme events such as storm and large waves. Currently in Cyprus there are 11 fishing shelters in operation. The following economic incentive is provided by the Operational Programme for Fisheries 2007-2013:
  - Measure 3.3: Fishing ports, landing sites and shelters. This measure promotes operations that have to do with safe fishing vessel positioning in ports as well as hygienic and high quality fisheries products.
- Designation of marine protected areas
  Among the most important tools for the conservation of marine biodiversity and the sustainable development of marine resources is the creation of marine protected areas. The marine protected areas have been designated in order to protect fragile ecosystems, endangered species and in general marine biodiversity. In Cyprus there are six marine protected areas.
- Artificial reefs
  Artificial reefs are very important as they provide shelter, food, environment suitable for reproduction, growth and increase in size and number of populations of

living marine organisms and of the fishing productivity. The DMFR will create up to 4 artificial reefs in marine areas of Famagusta, Limassol and Paphos. The following economic incentive is provided by the Operational Programme for Fisheries 2007-2013:

  - Measure 3.2: Protection and development of aquatic fauna and flora. This measure targets the protection and development of the fisheries resources at the coastal fishing areas under particular measures that concern directly the fishing activities. In particular, this measure includes the construction and installation of artificial reefs.

- Measures for the protection of water quality.
  Several measures are foreseen in the water policy of Cyprus in order to attain a good ecological status of all fresh and coastal waters. A monitoring programme for all water bodies has been established in order to access progress of the measures implemented. The policy is compliant with the EU Water Framework Directive as well as with the Directive 91/676/EEC on the protection of waters against point and diffuse pollution caused by nitrates.

With reference to the incentives discussed above, it must be noted that their exploitation depends on the willingness, awareness and private initiative of fishermen. Thus the present adaptive capacity of fishstock physical environment can be considered as **limited to moderate**.

8.4.3. Cost implications for fishermen

8.4.3.1. Assessment of sensitivity and exposure

Sensitivity

The sensitivity in this case was estimated based on the likely impacts on each subsector of the fishery sector in Cyprus in conjunction with the contribution of the subsector to the total value added of the sector. In addition, the contribution of the fisheries sector to the national employment was taken into account. This assumes that a high contribution of valued added to the sector and a high contribution of the sector to national employment are more likely to lead to adverse impacts by warming-related changes.

Extreme events and especially storm surges and tidal waves as well as the invasion of hostile IAS are likely to create cost implications to fishermen. More sensitive to these events are the infrastructure of marine aquaculture as well as the fishing fleet and gear of pelagic fishery. Considering that pelagic fishery contributes approximately 29% to the total valued added of the sector and marine aquaculture 70%, the sensitivity in terms of this indicator is considered high. In particular, marine aquaculture in Cyprus is essential for the fisheries sector as it contributes significantly to the production of fishery products, reduces fishing deficit and thereby reduces the negative trade balance of the sector.

As regards the contribution of the fisheries sector to the national employment, the proportion of the Economically Active Population (EAP) was used as indicator. EAP is the number of employed and unemployed persons (including those persons seeking work for the first time). During the period 2004-2008, the average EAP of the fisheries sector in Cyprus was 0.3% (CYSTAT, 2010), thus indicating a relatively low sensitivity of the sector.

Considering the above, it is estimated that the cost implications for fishermen present **moderate** sensitivity in view of climate changes.

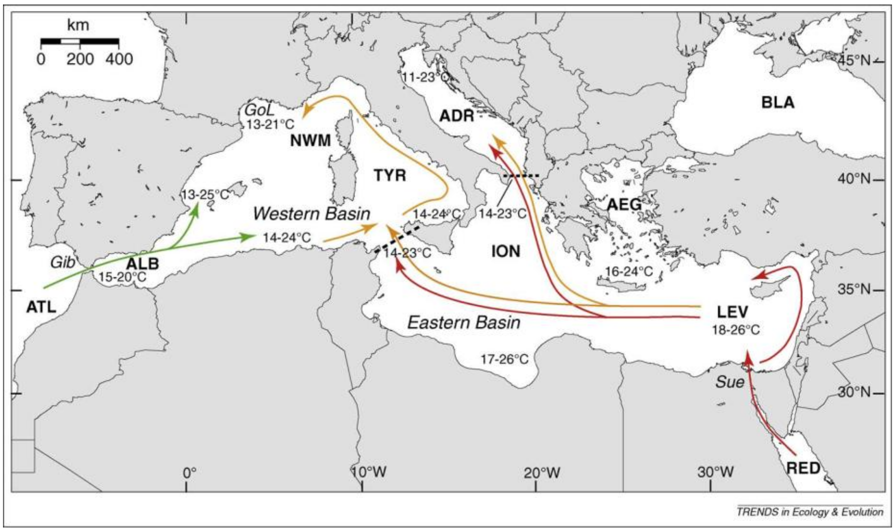
Exposure

For the assessment of the exposure of the sector to climate changes that could incur cost implications for fishermen, the exposure of the fisheries sector in Cyprus to storm surges as well as to the invasion of IAS is presented.

While changes in storminess may contribute to changes in extreme coastal high water levels, the limited geographical coverage of studies to date and the uncertainties associated with overall storminess changes mean that a general assessment of the effects of storminess changes on storm surge is not possible at this time (IPCC, 2012).

Results from embedded high-resolution models and global models show a likely increase of peak wind intensities and notably, increased near-storm precipitation in future tropical cyclones. Most recent published modelling studies investigating tropical storm frequency, simulate a decrease in the overall number of storms, though there is less confidence in these projections and in the projected decrease of relatively weak storms in most basins, with an increase in the numbers of the most intense tropical cyclones. Model projections show fewer mid-latitude storms averaged over each hemisphere, associated with the poleward shift of the storm tracks that is particularly notable in the southern hemisphere, with lower central pressures for these poleward-shifted storms. The increased wind speeds result in more extreme wave heights in those regions (Meehl et al., 2007). However, according to the projections of the KNMI climate model, the wind speed in Cyprus during the future period 2021-2050 is not expected to present substantial changes, on the contrary, it presents minor decreases in general.

Regarding the exposure of the fisheries sector to invasive species, it is considered that Cyprus is characterized by high exposure because it is located near the manmade nautical channel of Suez which favours the migration and relocation of the Lessepsian species (Mitov, 2009). However, the species causing more damages to the fishing fleet and gear of Cyprus is the Lagocephalus sceleratus, while other IAS are not considered harmful at all.



Arrows represent main routes of species range expansion according to their origin: Mediterranean natives (orange), Atlantic migrants (green) and Lessepsian migrants (red).

Figure 8-20: Main routes of species range expansion in the Mediterranean Sea

Source: Lejeusne et al., 2009

In view of the above, it considered that the exposure of fisheries sector in Cyprus to climate changes causing cost implications for fishermen is **moderate**.

8.4.3.2. *Assessment of adaptive capacity*

The adaptive capacity of the sector was primarily estimated based on the income of the affected fishermen. In general, the higher the income the higher the adaptive capacity. Fishermen practicing pelagic fishery are considered are considered to have low adaptive capacity due to the low availability of fishstocks in the sea, the overexploitation of its resources and subsequently the low potential for growth. The income of sea fishermen in Cyprus in general is not sufficient and as a result they are forced to undertake additional jobs or to abandon their profession. On the other hand, the income from marine aquaculture is profitable considering the capacity of production, the potential for growth and the amount of exports succeeded.

One attempt towards supporting sea fishermen in Cyprus was the promotion of fishing tourism. Fishing tourism entails the hosting of people – which do not belong in the boat crew - in professional fishing boats for recreation, demonstration of fishing methods, feeding and generally the provision of tourism services that linked to fishing. This programme is implemented in the framework of the INTERREG program and the European Fishery Fund for the 2007-2013 period that offered the ability for amplifying the professional fishermen to create the necessary infrastructures and to obtain the necessary knowledge. The necessary infrastructures and the necessary boat equipment, as well as the necessary training and tutoring for fishermen receive significant financial support from the Operational Fishery Programme 2007-2013 (DFMR[2]).

Other relative adaptation measures that have been undertaken in Cyprus are presented next:

- Construction of Coastal Defense Works
- Development of fishing shelters. Fishing shelters are constructed for the protection of fishing boats against extreme events such as storm and large waves. Currently in Cyprus there are 11 fishing shelters in operation. The following economic incentive is provided by the Operational Programme for Fisheries 2007-2013:
    - Measure 3.3: Fishing ports, landing sites and shelters. This measure promotes operations that have to do with safe fishing vessel positioning in ports as well as hygienic and high quality fisheries products.
- Artificial reefs
  Artificial reefs are very important as they provide shelter, food, environment suitable for reproduction, growth and increase in size and number of populations of living marine organisms and of the fishing productivity. The DMFR will create up to 4 artificial reefs in marine areas of Famagusta, Limassol and Paphos. The following economic incentive is provided by the Operational Programme for Fisheries 2007-2013:
    - Measure 3.2: Protection and development of aquatic fauna and flora. This measure targets the protection and development of the fisheries resources at the coastal fishing areas under particular measures that concern directly the fishing activities. In particular, this measure includes the construction and installation of artificial reefs.
- Compensation against losses due to natural disasters. The following relative economic aid is provided by the Operational Programme for Fisheries 2007-2013:
    - Measure 1.2: Temporary cessation of fishing activities. Under this measure, the beneficiaries shall get aid in case of natural disasters or other exceptional occurrence which pose a hazard to the public health and cause the suspension of fishing activities for a limited time.

Furthermore, the Department of Fisheries and Marine Research, taking into account the reports from fishermen regarding the substantial increase and spread of the population of the Invasive Alien Species (IAS) of Lagocephalus sceleratus and the damage caused to the fishing gear and catches, prepared a study on the species in the coastal waters of Cyprus. After evaluating the results of the study, the DMFR developed a management plan entitled 'Plan for the control of the population of Lagocephalus sceleratus in the coastal waters of Cyprus' and in 2012 announced the call for proposals for the implementation of the plan in

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[2] Department of Fisheries and Marine Research, 'Fishing tourism Cyprus - Principles & guidelines for the development of Fishing Tourism in Cyprus. INTERREG Greece-Cyprus 2000-2006 – International cooperation for the development of fishing tourism'. http://www.moa.gov.cy/moa/dfmr/dfmr.nsf/All/8053A6523C47E2FA422579EA002CD122/$file/english.pdf?OpenElement

the framework of the 'Project Grants for collective actions in the Fisheries Sector'. The purpose of the call is to eliminate the populations of lagocephalus from the coastal commercial fleet of Cyprus, with the exercise of intense fishing pressure on breeding population of the species, just before and during the breeding season, in the main breeding areas of the species.

To this end, the adaptive capacity is characterized as **moderate**.

8.4.4. Assessment of overall vulnerability

The principal aim of this chapter is to identify the key vulnerabilities of the fisheries sector to future climate changes, as well as to assess the magnitude of these vulnerabilities. However, it must be noted that, as there were no sufficient data to evaluate all indicators further research is required.

In order to quantify the future vulnerability potential of the fisheries sector against a climatic change impact, the values of sensitivity, exposure, adaptive capacity and vulnerability are quantified as follows:

Degree of sensitivity, exposure & adaptive capacity		Degree of vulnerability		Legend
None	0	None	V≤0	
Limited	1	Limited	0<V≤1	🟩
Limited to Moderate	2	Limited to Moderate	1<V≤2	🟨
Moderate	3	Moderate	2<V≤3	🟨
Moderate to High	4	Moderate to High	3<V≤4	🟧
High	5	High	4<V≤5	🟧
High to Very high	6	High to Very high	5<V≤6	🟥
Very high	7	Very high	6<V≤7	🟥
Not evaluated	-	Not evaluated	-	⬜

Since vulnerability is defined by the following formula:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity * Exposure$$

“Impacts” and “Adaptive capacity” should be evaluated on the same scale (1-7). For this to be achieved, the square root of “Sensitivity x Exposure” is used. The results of the future vulnerability assessment for the fishery sector in Cyprus are summarized in Table 8-5.

Table 8-5: Overall vulnerability assessment of the fisheries sector in Cyprus to climate changes

Impact	Sensitivity	Exposure	Adaptive Capacity	Vulnerability
Quantity and diversity of fishstocks	Moderate (3)	Moderate (3)	Limited to Moderate (2)	Limited (1)
Fishstock physical environment	Limited (1)	Limited (1)	Limited to Moderate (2)	None (-1)
Cost implications for fishermen	Moderate (3)	Moderate (3)	Moderate (3)	None (0)

To sum up, the future vulnerability assessment of the fisheries sector in Cyprus indicated only one vulnerability to climate changes which is related to the potential reductions in the quantity and diversity of fishstocks. The vulnerability is rated as of limited importance despite the fact that some fish species as well as the rate of IAS intrusion seem to be sensitive to changes in climate while the fisheries sector is considered to be already exposed to changes in SST and to the intrusion of IAS due to the geographical proximity of Cyprus to the channel of IAS entrance. Although several adaptation measures have been undertaken, the adaptation potential especially for pelagic fishery is limited. Consequently, the vulnerability of this impact is rated as limited.

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9 PUBLIC HEALTH

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Abbreviations and Acronyms

cCASHh project	Climate change and adaptation strategies for human health
CRI	Climate Risk Index
CYSTAT	Statistical Service of Cyprus
DALY	Disability-Adjusted Life Year
ECEH	Regional Office for Europe, European Centre for Environment and Health
EEA	European Environment Agency
EU	European Union
GDP	Gross domestic product
GHG	Greenhouse gases
GWW	Government Water Works
IPCC	Intergovernmental Panel on Climate Change
MANRE	Ministry of Agriculture, Natural Resources and Environment
MCA	Multi-Criteria Analysis
PM	Particulate matter
PRECIS	Providing Regional Climates for Impact Studies
PWC	Pancyprian Welfare Council
RCM	Regional Climate Model
RR	Precipitation
SES	Socio-economic status
SUDS	Sustainable Urban Drainage Systems
TX	Maximum temperature
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
VBD	Vector-borne diseases
VOCs	Volatile organic compounds
WDD	Water Development Department
WEI	Water Exploitation Index
WHO	World Health Organization

9.1. Climate change and public health

Climate change is now widely recognized as the major environmental problem facing the globe as well as the largest threat to human health (Oygar, 2009). According to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), there is a chance of 80% that there will be an increase in mortality and morbidity owing to climate change related extreme weather events. In 2007, the 95% of the 16,000 global fatalities from extreme weather effects can be attributed to climate change (GSK/Accenture/SSEE, 2011).

In case of a continuous increase of current emissions, the next generations will face more diseases, deaths related to heat waves and natural disasters, higher rates of climate-related infections and morbidity /mortality associated with allergic and air pollution diseases (Oygar, 2009). There is high confidence according to the IPCC (80% confidence) that in the future the increase in cardio-respiratory morbidity and mortality will be attributed to ground-level ozone (GSK/Accenture/SSEE, 2011).

To date, there is significant evidence that the Mediterranean Basin is already experiencing some of the impacts of climate change including those on public health. The main climate change related phenomena that have been recorded in Cyprus are temperature increase (especially during the summer months), an enhance in the frequency and intensity of heat waves, a reduction in the total precipitation amounts in parallel with increasing rainfall intensity and enhanced drought.

The history of human adaptation and response to climatic factors can be characterized both by great successes as well as by disastrous failures. Humans have successfully managed to live in almost every climatic zone on earth despite the fact that regional climatic shifts have affected the development of civilizations and specifically the rise or fall of them (WHO, 2005).

Addressing the health impacts of climate change requires integration of public health and climate change knowledge. Health authorities have expressed concern about climate change and its impact on human health since 1998 and particularly at the World Health Assembly by recognizing that climate change could be a potential threat to human health. At the Third Ministerial Conference for Environment and Health, in 1999, ministers of health and environment for the World Health Organization (WHO) European Region had acknowledged that “human-induced changes in the global climate system and in stratospheric ozone pose a range of severe health risks and potentially threaten economic development and social and political stability”. They called for national action by all countries aiming at the immediate reduction and prevention of environmental changes in order to limit the exposure of human populations in Europe to climate change and increased ultraviolet irradiation over the coming decades (WHO, 2005).

In generally terms, climate change can have direct impact to human beings via exposure to hazardous meteorological conditions and indirect impact via vector/rodent/water/or food-borne diseases and allergic disorders (McMichael et al., 2003).

The impact, vulnerability and adaptation assessment for the sector of public health regarding the climate changes that have occurred the recent years in Cyprus (Deliverable 1.2), showed that public health in Cyprus is not considered vulnerable to climate changes mainly due to the fact that it is characterized by a good adaptive capacity. The only vulnerability that was identified through the present study, is related to the deaths and health problems related to the frequent heat waves and high temperatures especially during summer which are also associated with high levels of humidity in Cyprus resulting in human discomfort. A significant percentage of the population in Cyprus is particularly sensitive to heatwaves (elderly people), while the adaptive capacity is not satisfactory enough given that the protection of the population from heat waves is not always possible.

In the sections that follow, an attempt is being made to assess the impacts of future climate changes on public health in Cyprus based on the climate projections output produced by the PRECIS (Providing Regional Climates for Impact Studies) regional climate model as well as on other socio-economic projections for the period 2021-2050. The reason why PRECIS was selected to be used in the present study is that, unlike in other regional climate models, in PRECIS Cyprus lies at the center of the domain of the study. The future period 2021-2050 has been chosen, instead of the end of the twenty-first century as frequently used in other climate impact studies, in order to assist stakeholders and policy makers to develop near future plans.

9.2. Baseline situation

9.2.1. Health status and demographics

Cyprus is the third largest island in the eastern part of the Mediterranean. The population in the government-controlled area of Cyprus was estimated at the end of 2011 at 840,407 from which approximately 79% are Cypriots, while the rest are citizens from other countries (CYSTAT, 2011).

It is estimated that in 2011, 16.1% of the population living in the free part of Cyprus were under 15 years of age and 13.3% over 65 (CYSTAT, 2011). The observed demographic changes of the latest years indicate high aging population. Cyprus experiences the 3rd stage of demographic-epidemiology transitional period featured by degenerative diseases related to the age and the way of living. The average age of Cyprus population has been increased given the fact that during 2000-2005 the fertility rate was 2.3 and in 2008 was reduced to 1.5. Also the percentage of children under the age of 15 years was reduced from 25% (1982) to 16.1 (2011) while the percentage of adults over 65 was increased from 10.8% (1982) to 13.3 (2011) (MANRE, 2010; CYSTAT, 2011).

According to data from the EU Statistics on Income and Living Conditions (Eurostat, 2012) for the period 2005-2011, 15.5% of Cyprus population was at risk of poverty on average, a little lower than the respective percentage in the EU27 (16.5%). However, the average poverty risk for the Cypriot elderly (65 and over) during the same period was substantially higher (46.2%) compared to the average EU citizen in the same demographic group (17.9%) (Table 9-1). In fact, Cyprus had the highest percentage of the 65+ age group in poverty risk during that period among all the assessed countries[1]. According to Andreou and Pashardes (2009) "the very high poverty rate associated with old age in Cyprus is due to the immaturity of the current old age pension system guaranteeing a decent pension to private sector retirees".

Table 9-1: At risk of poverty in Cyprus and EU27 by age group (%), 2005–2011

Age groups	Region	2005	2006	2007	2008	2009	2010	2011	Average 2005-11
Less than 18 years	EU27	19.9	19.8	19.5	20.1	19.8	20.5	20.6	**20.0**
	Cyprus	12.8	11.5	12.4	14.0	12.3	12.3	11.9	**12.5**
From 18 to 64 years	EU27	14.6	14.8	15.1	14.7	14.8	15.2	16.0	**15.0**
	Cyprus	11.1	10.6	10.1	10.8	11.2	11.2	11.0	**10.9**
65 years or over	EU27	18.9	19.0	18.4	19.0	18.0	16.0	15.9	**17.9**
	Cyprus	50.3	51.9	50.6	46.3	46.4	40.5	37.2	**46.2**
Total	EU27	16.4	16.5	16.5	16.4	16.3	16.4	16.9	**16.5**

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[1] The comparison was made between the Eurostat countries that data were available for all the years of the period under examination, i.e. 29 countries in total (full data were not available for Turkey, Romania and Switzerland)

Age groups	Region	2005	2006	2007	2008	2009	2010	2011	Average 2005-11
	Cyprus	16.1	15.6	15.5	15.9	15.8	15.1	14.5	**15.5**

Source: Eurostat, 2012

The standard of health in Cyprus is considered to be very high and compares favourably with that of developed countries, as it is shown by the various health indicators, such as the infant mortality rate which stands at 3.3 per 1.000 live births, the expectation of life at birth with 77.9 years for males and 82.4 for females and the number of persons per doctor at 348, in the year 2009 (CYSTAT, 2012).

Injury, poisoning and certain other consequences of external causes have the highest share, (11.5%) of the total patients discharged from general hospitals, followed by diseases of the circulatory system (9,0%), diseases of the respiratory system (7,9%), diseases of the digestive system (7.6%), neoplasms (6.6%), pregnancy, childbirth and puerperium 6.3% and diseases of the genitourinary system (6.1%). All other disease categories account for the remaining 45.0% (CYSTAT, 2012). Diseases of the respiratory system are reported to be associated with climate changes also, due to increased concentrations of particulate matter (PM) and ozon in the atmosphere.

The five leading causes of death for the period 2004-2009 in Cyprus were diseases of the circulatory system, neoplasms, endocrine, nutritional and metabolic diseases, diseases of the respiratory system and external causes of injury and poisoning (Ministry of Health, 2011). Figure 9-1 illustrates the main causes of death in Cyprus for the period 2004-2009.

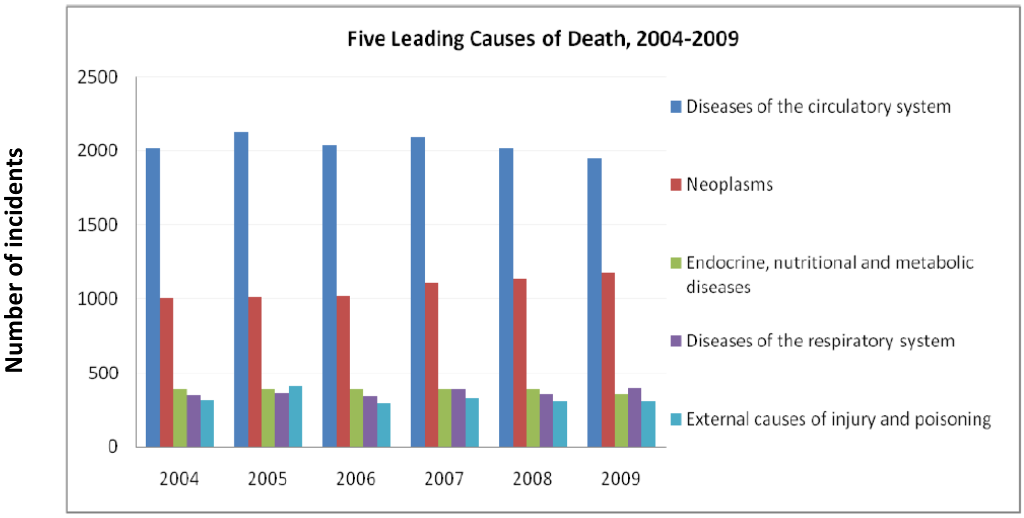

Figure 9-1: Five leading causes of death in Cyprus

Source: Ministry of Health, 2011

The health and demographic indicators of Cyprus are summarized in

Table 9-2.

Table 9-2: Health and demographic indicators of Cyprus

Indicators	Values
Number of persons per 1 doctor (2009) Number of persons per hospital bed (2009)	348 263
% Urbanization (2010) % people living in cities greater than 100,000 inhabitants (2009)	69% of total population 48%
Age structure 0-14 years (2011 census) 15-64 years 65 years and over	16.1% 70.6% 13.3%
Birth rate (2009) Death rate (2009)	12 births / 1,000 population 6.5 deaths/ 1,000 population
Infant mortality rate (2009)	3.3 deaths / 1,000 live births
Total fertility rate (2009)	1.5
Life expectancy at birth (2009)	Male: 77.9 Female: 82.4
Health expenditures (2009)	1,190.6 million € (46% in Public Sector, 54% in Private Sector) 6.2% of GDP

Source: CYSTAT, 2012; CYSTAT, 2011

9.2.2. The health care system in Cyprus

As also recognized by the World Health Organization, Cyprus health system is of high standards providing priority to its health care system and actively promoting the preventive medicine. Government hospitals are located in all the major cities. Smaller government-run hospitals and clinics are present in other areas of the country.

The Ministry of Health, the Ministry of Agriculture, Natural Resources and Environment and the Ministry of Labour and Social Insurance jointly are responsible for environmental health. Their responsibilities include monitoring pollution levels, diagnosing, treating and controlling animal diseases, monitoring the level of environmental pollution, monitoring the microbiological quality of drinking water supplies, and other pollution (pesticides and other micro pollutants), monitoring veterinary drug residues in meat and animal products monitoring radioactivity in drinking water, food etc. Jointly they have taken action to improve the existing legislation relevant to protection of the environment. Furthermore, all households in Cyprus have guaranteed access to safe drinking water and efforts have been made to improve the quality of drinking water in accordance with EU regulations. Finally, almost 100% of the population has adequate sewage-disposal facilities (Golna et al., 2004).

In the period 1990-2005, the expenditures on health in Cyprus as percentage of GDP presented a general increasing trend from 4.5% to 6.3% as shown in Figure 9-2.

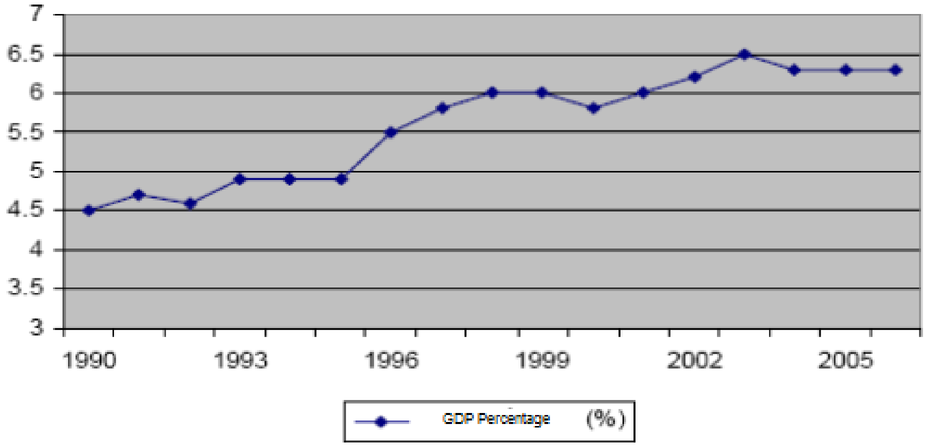

Figure 9-2: Heath expenditures as GDP percentage (1990-2005)

Source: Matsis, 2008

Despite the significant increase in total expenditures on health and the increase in the percentage of GDP being absorbed by the sector, Cyprus compared with other countries spends relatively a small percentage of the GDP for health care. In 2006, Cyprus was ranked 23rd with health expenditure at 6.3% of GDP comparatively to 27 European countries and 53rd universally within 235 countries according to the World Health Statistics 2011 (WHO, 2011)

The rank of Cyprus is mainly attributed to the high age of population in comparison with other European countries. One important feature of the National Health Service of Cyprus is the low percentage of total health expenditure by the public sector (46% of total expenditure in 2009) in comparison with the private sector (54% of total expenditure in 2009), which is a result of the lack of a National Health Scheme. The share of health expenditure in the private sector in the EU-15 countries is around 25% (Golna et. al., 2004; Matsis, 2008).

In addition, in the framework of the research project “Climate change and adaptation strategies for human health in Europe” (cCASHh)[2], a group of experts ranked income, equality, type of health care system, and quick access to information as most important factors enabling effective response to climate change. Countries in the WHO European Region vary tremendously in their response capacities (Alberini et al., 2005). Those with the highest adaptive capacities tend to have high incomes, universal health care coverage and high access to information. The highest the adaptive capacity index, the more the country is considered to be able to adapt in climate change conditions. The adaptive capacity index of Cyprus is 3, while Greece has 4 and Luxembourg has the highest score of 5 (Figure 9-3)(WHO, 2005).

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[2] cCASHh) (May 2001-July 2004) is a research project coordinated by WHO and supported by the Energy, Environment and Sustainable Development Programme in the frame of the Fifth European Union Framework Programme for Research and Development

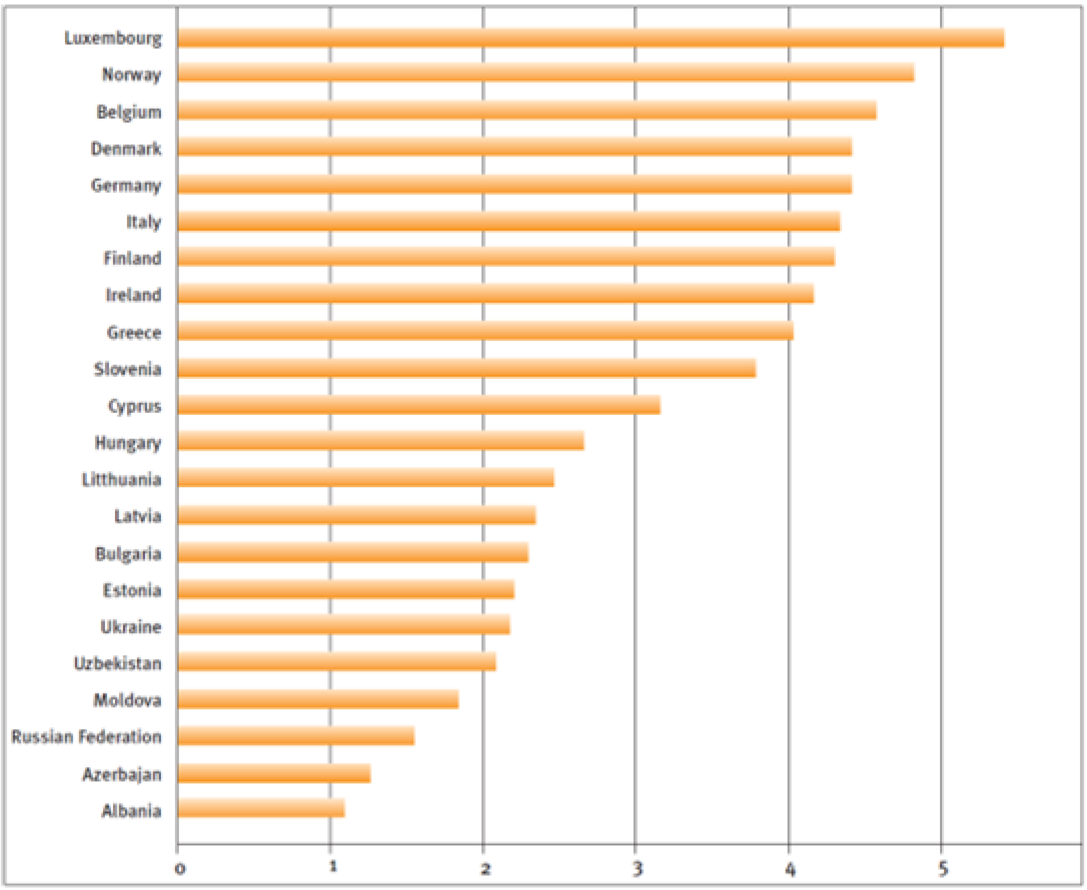

Figure 9-3: Adaptive capacity index for 22 European and Central Asian countries

Source: WHO, 2005

9.2.3. Research on the climate change effects upon public health in Cyprus

Many Institutions and Government Departments in Cyprus are occupied with the collection, analysis and study of climatological data and their possible health effects; the Meteorological Survey Department, the Environment Service, the Ministry of Health and several academic departments (University of Cyprus, Cyprus Institute) (Panayiotou, 2009; CDC, 2009).

MedCLIVAR is an international network where Cyprus also participates aiming to study climate change impacts as well as the challenges that climate change poses to public health and the occurrence of extreme events -closely related to climate variability in the Mediterranean and similar climatic regions around the world. In the context of this join, the workshop “Impacts of Mediterranean Climate Change on Human Health” was implemented in order to reinforce collaborations to better understand the challenges and address potential solutions through research aimed at informing health risk mitigation through regional adaptation policies (Paz et al., 2010).

Furthermore, in 2011 the project "Climate Change and Public Health: Assessment of the Effects of Extreme Weather and Development of Innovative Prevention and Mitigation Strategies" of the Research Promotion Foundation was launched. It is expected that its findings will enhance the adaptive capacity of public health to climate changes and in particular to heat waves.

9.3. Future impact assessment

In this section, the climate change impacts on the public health sector as these have been identified in Deliverable 1.2 “Climate change impact, vulnerability and adaptation assessment for the case of Cyprus” will be reassessed in light of the climate projections for the future (2021-2050).

Human beings are exposed to climate change directly through changing weather patterns, as for example more intense and frequent extreme weather events (heat waves, floods and storms) and indirectly though changes in the ranges of disease vectors, water and air quality and food availability and quality (Confalonieri et al, 2007).

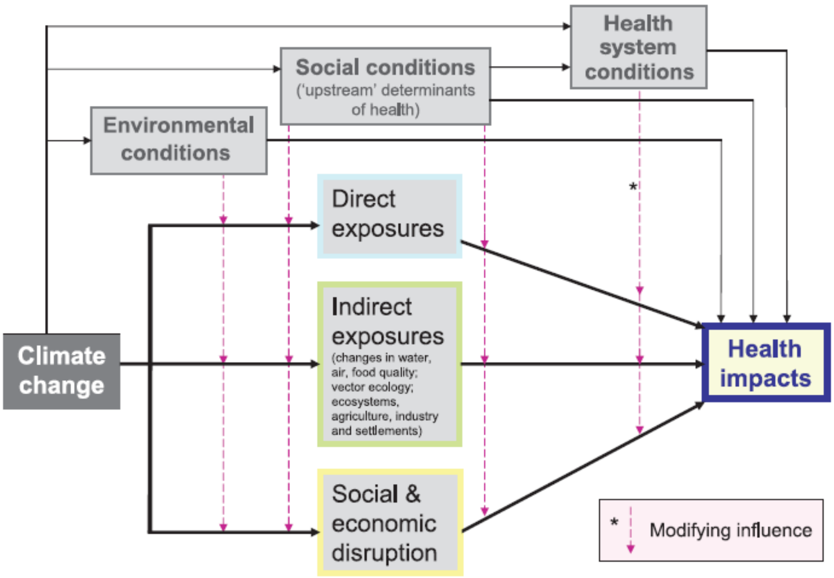

Figure 9-4: Schematic diagram of pathways by which climate change affects health

Source: Confalonieri et al, 2007

In Europe the extreme events are expected to increase in frequency and severity, particularly heatwaves, droughts and intense rainfall events. Changes in the frequencies of extreme heat and cold, floods and droughts as well as and the profile of local air pollution and aeroallergens may affect population health directly. Other indirect health impacts may result from the effects of climate change on ecological and social systems. These impacts include changes in the occurrence of infectious diseases, local food production and under-nutrition, and various health consequences of population displacement and economic disruption (WHO, 2003). However, the effects of climate change on existing environmental and public health problems are difficult to discern. The challenge is to identify their ‘additional’ effect, i.e., the increase in health problems that can be attributed to climate change as an additional risk factor.

The cCASHh project “Climate change and adaptation strategies for human health” which was coordinated by the World Health Organization studied health impacts and policy implications of heat stress related mortality and morbidity, food-borne diseases, waterborne diseases and vector-borne diseases (WHO, 2005). The impacts of climate change and extreme events on human health in Europe as these have been investigated in the framework of the cCASHh project are presented in Figure 9-5.

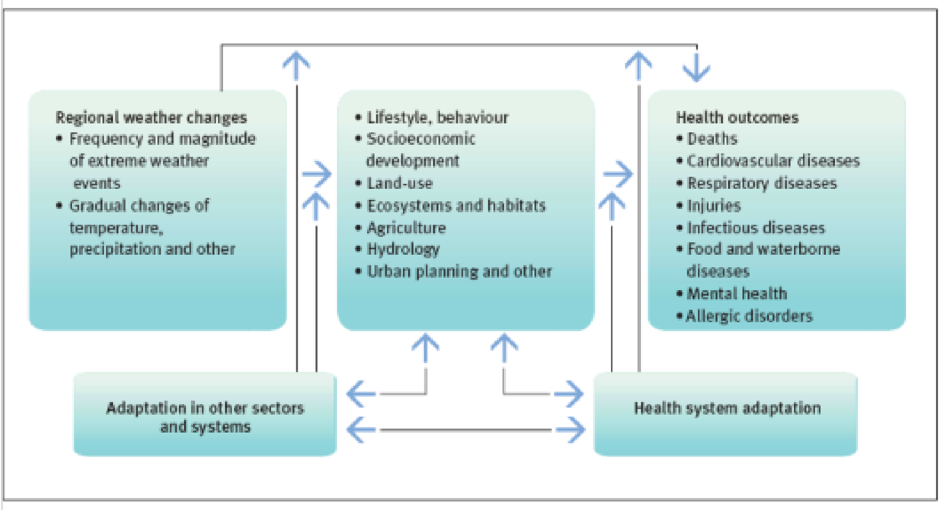

Figure 9-5: The relationship between regional weather changes, exposures and health outcomes

Source: WHO, 2005

A summary of the potential impacts of climate change on human health in Cyprus per climate change factor is presented in Table 9-3.

Table 9-3: Relationship between climate changes and impacts on the public health sector

Potential climate changes	Direct Impacts	Indirect Impacts
High temperatures and heat waves	– Heat related stresses – Deaths due to heat strokes – Cardiovascular diseases – Respiratory and metabolic disorders	– Water-borne diseases due to increased algal blooms – Food-borne diseases due to food contamination – Vector-borne diseases due to the higher risk of transmission and changes in the geographical and seasonal distribution
Increase in the intensity and frequency of extreme events (floods, storms)	– Deaths and injuries from floods, storms, landslides and fires – Psychological morbidity (mental disorders) from floods, storms, landslides and fires	– Water-borne diseases caused by water contamination and water washed diseases caused by poor sanitation conditions – Vector-borne diseases (malaria, Leishmaniasis, Mosquitos) due to stagnant waters – Diarrhoea diseases (including cholera) – Reduced nutritional status

Droughts	– Deaths and injuries from fires caused by high temperatures combined by strong winds and drought	– Vector-borne diseases owing to changes in vector transmission and contamination of small rivers and drainage canals – Water-borne diseases – Respiratory diseases due to increased air-borne particulate matter – Child malnutrition and under-nutrition, due to loss of agricultural production
Air pollution		– Eye irritation – Respiratory tract irritation – Exacerbation of respiratory diseases – Exacerbation of asthma and irritation of bronchi – Exacerbation of allergic rhinitis, asthma and other atopic diseases

The climate change impacts on public health which are analyzed in this chapter were categorized as follows:

Direct impacts: 1. Deaths and health problems related to heat waves and high temperatures, 2. Deaths and injuries from floods, 3. Deaths and injuries from landslides and 4. Deaths and injuries from fires.

Indirect impacts: 1. Vector-borne and rodent-borne diseases, 2. Water- borne and food-borne diseases, 3. Climate-related effects upon nutrition, 4. Air pollution related diseases.

9.3.1. Deaths and health problems related to heat waves and high temperatures

According to the IPCC (2007), hot days, hot nights and heatwaves have become more frequent. Additionally, IPCC ascribes by 50 per cent the increase of heat wave related deaths to climate change, and expresses an 80 per cent level of certainty that increasing temperatures will have a negative impact on health. For each 1°C rise in temperature above a specified ceiling (which varies by region) death rates are predicted to rise by between 1% and 4%. This prediction is in accordance with observations in cities of Mediterranean Basin which have shown that heat waves can have very strong effects on mortality, reporting an increase of 1-4% for each degree of temperature raise (GSK/Accenture/SSEE, 2011).

On the contrary, there is another opinion that the mortality impact of a heat wave is uncertain in terms of the amount of life lost; a proportion of deaths occur in susceptible people who were likely to have died in the near future. Nevertheless, the certainty that the increase in the frequency and intensity of heat waves can increase the numbers of additional deaths from hot weather remains high. Exposure to extreme and prolonged heat is associated with heat cramps, heat syncope, heat exhaustion and heat stroke (Faunt et al., 1995; Semenza et al., 1999). Deaths from heat stroke may be underreported because heat stroke is similar to other more familiar causes of death, especially coronary or cerebral thrombosis, once the body is no longer hot itself or in a hot environment (Keatinge et al., 1986; Mirchandani et al., 1996).

The primary concern in Europe as well as in Cyprus is linked to heat-related mortality and morbidity, due to increases in maximum temperature and more frequent heat waves, although these issues are also influenced by socio-economic changes due to population growth, the increased average age distribution in Cyprus and migration. In addition, mortality is associated to the timing of heat waves as heat-waves early in the summer are associated with higher mortality than late season heat-waves (WHO, 2005).

Changes in climate have implications for occupational health and safety. Heat stress due to high temperature and humidity is an occupational hazard that can lead to death or chronic ill health from the after-effects of heatstroke.

During the 2003 European heat wave, the highest temperature was recorded in Cyprus. In the capital, Nicosia, temperatures unofficially exceeded 57 °C while temperatures usually reach 45°C during the summer period. Many people reported such temperatures on their thermometers in their houses. The official record was 52.1 °C in urban Nicosia. As a result of deaths and high temperatures, the government had to recommend a 3 day curfew between 11am and 5pm (Absolute Astronomy, 2003).

In addition, humidity during summer in the coastal cities of Cyprus reaches high levels which in conjunction with high temperatures, cause great discomfort to people.

Next, the future changes in high temperature in Cyprus that are considered to be associated with the impact of deaths and health problems related to heat waves and high temperatures, as these were projected by PRECIS for the period 2021-2050, are presented in brief.

According to PRECIS, the number of hot days per year when maximum temperature exceeds 30^{o}C is expected to increase all over Cyprus in the future, with the range of changes being between +17 and +24 days per year while the number of heat wave days per year, that is the days with maximum temperature over 35^{o}C, is expected to present a wider range of changes from +2 to +34 days per year. The number of tropical nights, i.e. the nights when temperature exceeds 20^{o}C , is projected to increase by +20 to +45 days per year in Cyprus.

However, there are no sufficient data for estimating whether there is an increasing trend on the incidents of heat related deaths and health problems which could be associated with climate changes in Cyprus.

9.3.2. Flood-related deaths and injuries

The frequency and intensity of extreme weather events such as heavy rainfall, storms and floods are anticipated to increase, having immediate effects such as deaths and injuries caused by drowning and being swept against hard objects.

Generally, the exposure to high-frequency flooding events can result in long-term problems such as increased rates of anxiety and depression stemming from the experience itself, troubles brought about by geographic displacement, damage to the home or loss of family possessions. Moreover, the persistence of flood-related health effects is directly related to flood intensity (WHO, 2005).

There is increasing evidence of the importance of mental disorders as an impact of disasters (Mollica et al., 2004; Ahern et al., 2005). A systematic review of post-traumatic stress disorder in high income countries found a small but significant effect following disasters (Galea et al., 2005). There is also evidence of medium to long-term impacts on behavioural disorders in young children (Durkin et al., 1993; Becht et al., 1998; Bokszczanin, 2000).

Pluviometrical data from the meteorological station in Nicosia (1930-2007) show an increase in the intensity and quantity of precipitation of 37-49% for the period 1970-2007 in comparison with the period 1930-1970 for a duration of precipitation between 5 minutes and 6 hours (Pashiardis, 2009).

Although there is a record of historical floods in Cyprus dating back to 1859 up to 2011, the data were not considered sufficient to make an assessment for an increasing trend in deaths and injuries from floods as it is during the last years that the recording is carried out more systematically. Indicatively, the recorded flooding events in Cyprus where people were injured or killed during the period 1970-2011 are presented in Figure 9-6.

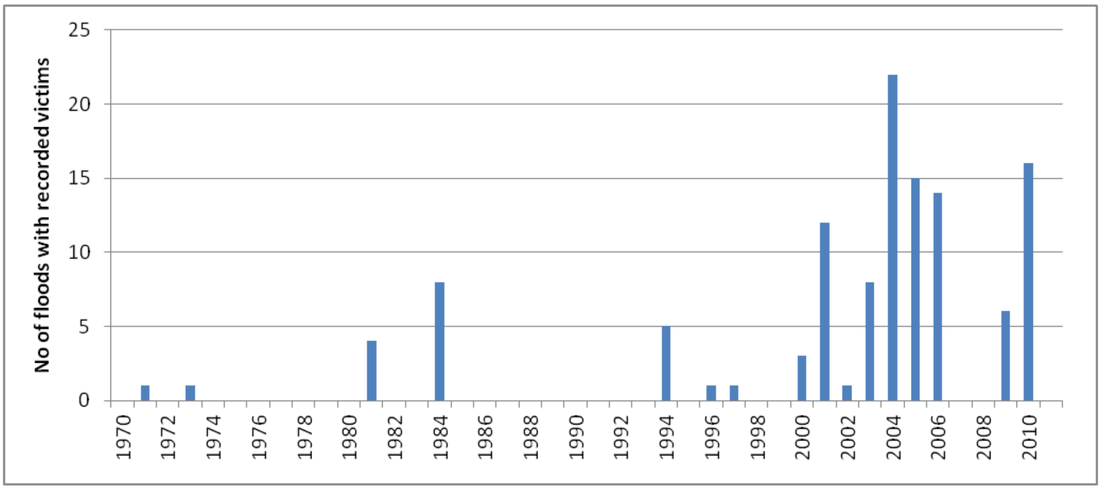

Figure 9-6: Number of flooding events with recorded victims in Cyprus (1970-2011)

Source: WDD, 2011

Next, the future climate changes in Cyprus that are considered to be associated with the impact of flood-related deaths and injuries, as these were projected by PRECIS for the period 2021-2050, are presented in brief.

The only indicator provided by PRECIS which was related to floods refers to the annual maximum total precipitation over one day. This indicator shows minor changes in the future period (2021-2050) ranging from 2 to 5 mm. However, this indicator alone is not sufficient for estimating the impacts of future changes in the frequency and intensity of flooding events.

9.3.3. Landslide-related deaths and injuries

An increase in extreme rainfall events is expected to increase landslide risk (Confaloniery et al., 2007). Landslides may directly affect people by causing deaths and injuries but also may have after affects such as mental disorders caused by the experienced shock, the grief felt by the loss of relatives and friends, the damage to the home or loss of family possessions. In addition, landslides may result in the displacement of communities and migration. However, there is no official record in Cyprus of victims affected.

Next, the future climate changes in Cyprus that are considered to be associated with the impact of landslide-related deaths and injuries, as these were projected by PRECIS for the period 2021-2050, are presented in brief.

The only indicator provided by PRECIS which may be related to the occurrence of landslides refers to the annual maximum total precipitation over one day. This indicator shows minor changes in the future period (2021-2050) ranging from 2 to 5 mm. However, this indicator alone is not sufficient for estimating the impact of future changes in the occurrence of landslides.

9.3.4. Fire- related deaths and injuries

Climate change is expected to increase the risk of forest and rural fires. In particular, forest fires in Cyprus are considered a major and permanent threat causing enormous damage to forest ecosystems and in some cases threaten residential regions (Alker, 2009). Forest and bush fires may cause deaths of people trapped in them, burns and other injuries. Large fires are also accompanied by an increased number of patients seeking emergency services (Hoyt and Gerhart, 2004).

Taking into account certain features characterizing Cyprus such as high temperatures, prolonged and severe drought periods, strong winds and the configuration of the ground and extremely flammable vegetation, the fire risk is high. Other parameters which contribute to an increased fire risk are the accumulation of biomass due to the abandonment of rural areas and the increasing tourism and exodus of city residents to forested areas. However, according to the Cyprus Department of Forests (2012), the highest percentage of fires in Cyprus occurs due to human negligence and not natural causes. Figure 9-7 testifies the increasing trend of fires for the period 2001 - 2010.

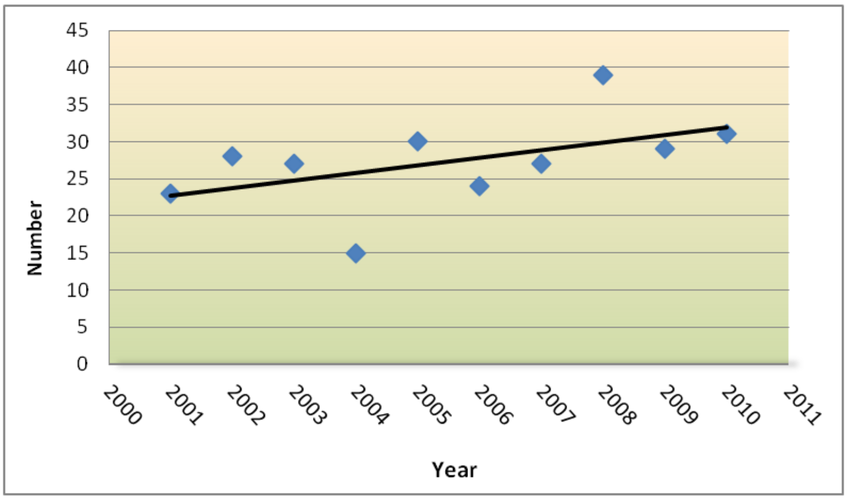

Figure 9-7: Trend of fires in Cyprus for the period 2001 – 2010

Source: Department of Forests, 2011a

In order to assess the future trends of fires in Cyprus, the Canadian Fire Weather Index (FWI) was calculated (van Wagner, 1987) with the use of the PRECIS climate model. The FWI consists of six components that account for the effects of fuel moisture and wind on fire behavior. PRECIS results on FWI show that there will be an increase in the number of days with high fire risk of 5-15 days/year as well as an increase in the number of days with extreme fire risk of 1-10 days/year in the future period (2021-2050) compared to control period (1960-1990).

However, there are no sufficient data for estimating whether there is an increasing trend on the incidents of fire-related deaths and injuries which could be associated with the trend in fires in Cyprus.

9.3.5. Vector-borne and rodent-borne diseases

Vector-borne diseases (VBD) are infections transmitted by the bite of infected arthropod species, such as mosquitoes, ticks, triatomine bugs, sandflies and blackflies. VBDs are among the most well-studied diseases associated with climate change, due to their widespread occurrence and sensitivity to climatic factors.

The transmission of some mosquito-borne diseases is affected by drought events. During droughts, mosquito activity is reduced and, as a consequence, the population of non immune persons increases. When the drought breaks, there is a much larger proportion of susceptible hosts to become infected, thus potentially increasing transmission (Bouma and Dye, 1997; Woodruff et al., 2002). In other areas, droughts may favour increases in mosquito populations due to reductions in mosquito predators (Chase and Knight, 2003). Other drought related factors that may result in a short-term increase in the risk for infectious disease outbreaks include stagnation and contamination of drainage canals and small rivers. In the long term, the incidence of mosquito-borne diseases such as malaria decreases because the mosquito vector lacks the necessary humidity and water for breeding.

Although several models predicted a potential increase of malaria in Europe, there is agreement that the risk is very low under current socioeconomic conditions (WHO, 2005). A number of recent modeling efforts has shown that changes in temperature and precipitation could alter the geographic distribution and intensity of malaria transmission (Parry et al., 2001; Martens and Hall, 2000). Projected changes include an expansion in latitude and altitude, and, in some regions, a longer season during which malaria may be present. Such changes could dramatically increase the number of people at risk. In the early part of the twentieth century, malaria was endemic in many parts of southern Europe, but its prevalence was reduced primarily via improved land drainage, better quality of housing construction and higher levels of socioeconomic development, including better education and nutrition. Any role that climate played in malaria reduction would have been small (WHO, 2005).

According to United Nations Environment Programme data (UNEP), there have been no recent deaths in Cyprus due to malaria. However, Cyprus' geographical location makes it more vulnerable for another epidemic. It is documented by WHO that in the future, malaria could move to the Northern part of Cyprus from Turkey, considering the fact that after the Gulf war malaria was spreaded over the boarders into Turkey and the Eastern Mediterranean (Cosmatos, 2009). Important vector populations in Cyprus include malaria-bearing mosquitoes and potentially Schistosome-spreading snails that can be attributed to the mass immigration of refugees from endemic regions (Alker, 2009).

Leishmaniasis is a sandfly-borne disease endemic to Cyprus, with a high prevalence of human visceral Leishmaniasis. As climate changes, new species, such as L. tropica may colonize Cyprus, as well as the drug-resistant L. Infantum (Alker, 2009; Dujardin et al., 2009).

In addition, West Nile Virus (WNV) which is a Flavivirus transmitted through bird-feeding mosquitoes, has had reported cases in Cyprus. The epidemic potential of this virus begins from 20^{o}C while it reaches its peak at 40^{o}C (Alker, 2009).

Rodent-borne diseases are zoonoses that are transmitted directly to humans by contact with rodent urine, feces, or other body fluids. Rodents are principle hosts for arthropod vectors such as fleas and ticks. Environmental factors that affect rodent population dynamics include unusually high rainfall, drought and introduction of exotic plant species. Rodent-borne pathogens are affected indirectly by ecological determinants of food sources that affect rodent population size (Confalonieri et al., 2007). The rodent-borne diseases that are associated with flooding include leptospirosis, tularaemia and viral hemorrhagic diseases. Other diseases associated with rodents and ticks include plague, Lyme disease, tick borne encephalitis (TBE) and Hantavirus pulmonary syndrome (HPS) (McMichael et al., 2003).

Next, the future climate changes in Cyprus that are considered to be associated with the impact of vector-borne and rodent-borne diseases in public health are presented in brief.

According to PRECIS climate projections in Cyprus for the period 2021-2050, the length of drought periods which is associated with the occurrence of both vector- and rodent- borne diseases is projected to increase up to 13 days/year on average.

The number of days with maximum temperature over 35^{o}C which is related with high epidemic potential of Leishmaniasis, is expected to present a wide range of changes from +2 to +34 days per year.

As for the heavy rainfall events which are associated with flooding events and the increase in leptospirosis, tularaemia and viral hemorrhagic diseases, the most relative indicator provided by PRECIS refers to the annual maximum total precipitation over one day. This indicator shows minor increase in the future period (2021-2050) ranging from 2 to 5 mm on average. However, this indicator alone is not sufficient for estimating future changes in the frequency and intensity of flooding events.

9.3.6. Water-borne and food-borne diseases

Water-borne diseases are likely to increase with climate changes in Cyprus such as decreased rainfall, increased temperature, increase in the frequency of extreme weather events (droughts, heavy rainfall, floods) since drinking water maybe put at risk of contamination.

In general, water-related diseases can be classified into those caused by ingestion of contaminated water and those caused by lack of hygiene. During drought and flooding conditions water can be contaminated with pathogens while water scarcity creates opportunities for transmission of theses pathogens, due to inadequate hand-washing and personal hygiene. Increased faecal bacteria contamination is also likely to affect drinking water intakes (Symeou, 2009). Higher water temperatures may result in increased occurrence of harmful algal blooms, thus deteriorating the quality of water. Organisms directly transmitted via contaminated water include Escherichia coli, Cholera, Salmonella, hepatitis A and E, poliomyelitis, Giardia lamblia and Entamoeba histolytica. Flooding may also lead to contamination of waters with dangerous chemicals, heavy metals or other hazardous substances, from storage or from chemicals already in the environment (e.g., pesticides). However, as in high income countries there is a number of measures in place such as sanitation and drainage systems, they are less vulnerable to the transmission of water-borne diseases.

Contamination of food may be induced by higher temperatures (surface and ocean) which enhance the survival and proliferation of viruses, bacteria and pathogens in foodstuffs (McMichael et al., 1996).

In Cyprus, water supplied from government water works (GWW) has been previously treated and disinfected. In addition, the areas that are not supplied by GWW, use groundwater which is considered of good quality as it comes from deep boreholes. From data available during the period 2005-2007, it is estimated that drinking water supply was provided by 86% from GWW and the remaining 14% by non GWW (WDD, 2009). However, it is expected that the increased contribution of desalinated water in drinking water supply will further increase the share of water distributed by GWW.

The estimated number of “healthy” life years lost (DALYs) related to the burden of diarrhoeal disease attributable to water, sanitation and hygiene for 16 Member States of the EU27, shows that Cyprus is in the first place (reference year 2002)(Figure 9-8).

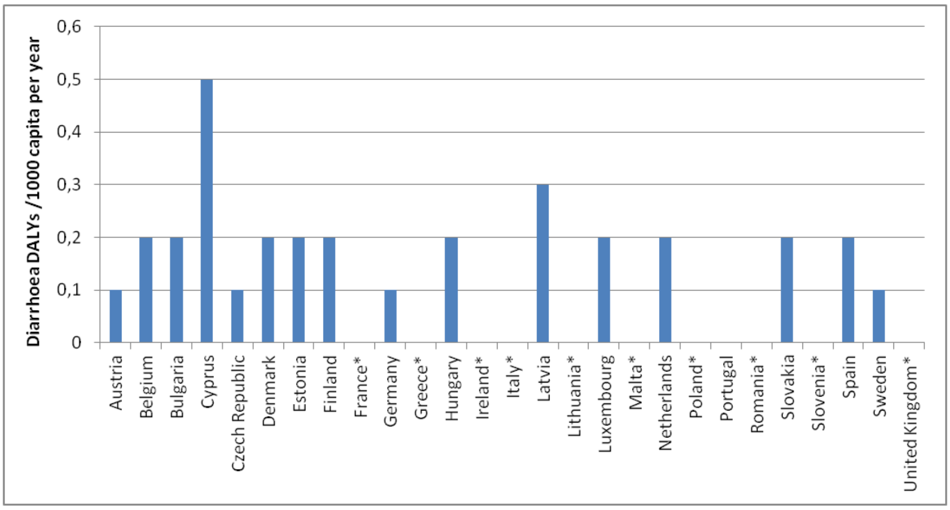

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Figure 9-8: Estimated DALYs/1000 capita attributable to water, sanitation & hygiene in the EU27 (2002)

Source: WHO, 2007

The recorded incidents of salmonellosis in Cyprus for the period 1984-2007 present a general increasing trend, although they remain quite below the average respective values in the EU (Figure 9-9).

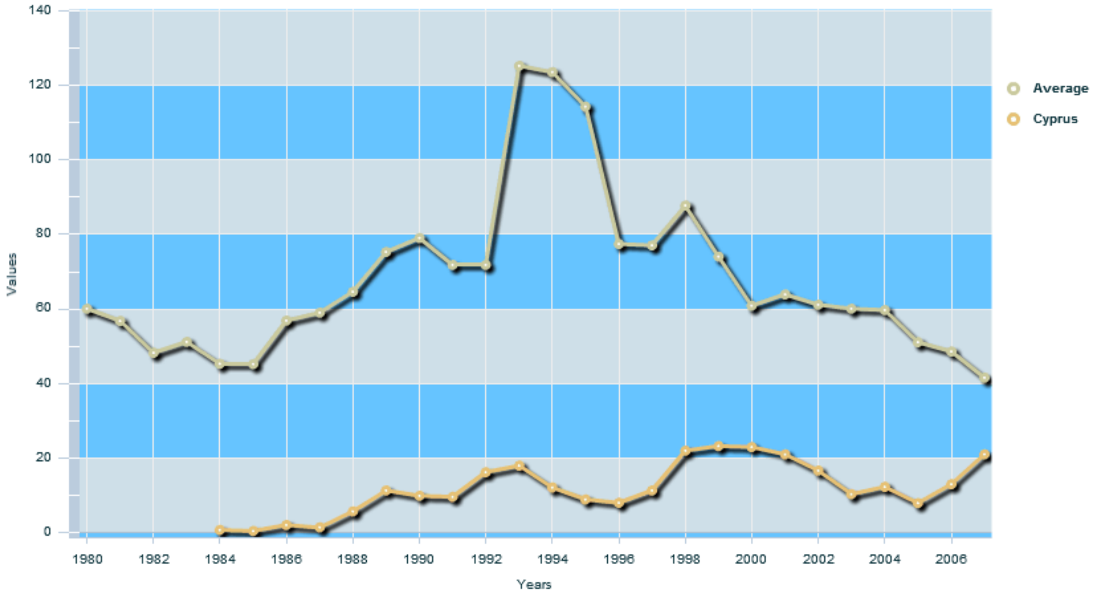


Figure 9-9: Incidence of salmonellosis per 100,000 of population in Europe and in Cyprus (1980-2007)

Source: Heidi tool (EC)

Incidents of Hepatitis A in Cyprus are quite low (less than 1 incident/100,000 capita per year) for the period 1980-2007 while the respective value for the EU was significantly higher until recently when it declined (Figure 9-10).

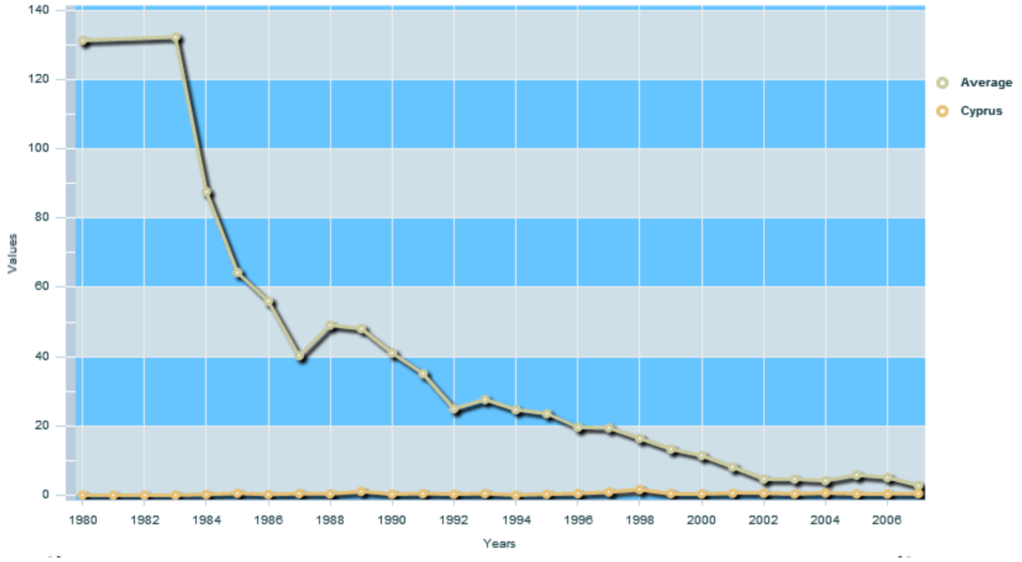


Figure 9-10: Incidence of Hepatitis A per 100,000 of population in Europe and in Cyprus (1980-2007)

Source: Heidi tool (EC)

Next, the future climate changes in Cyprus that are considered to be associated with the impact of water-borne and food-borne diseases in public health are presented in brief.

High air temperatures enhance the survival and proliferation of viruses, bacteria and pathogens in foodstuffs while high water temperatures are reported to deteriorate water quality and enhance the transmission of viruses. According to PRECIS projections for the future period 2021-2050, the number of hot days per year when maximum temperature exceeds 30°C is expected to increase with the range of changes being between +17 and +24 days per year while the number of heat wave days per year, that is the days with maximum temperature over 35°C, is expected to present a wider range of changes from +2 to +34 days per year. High air temperatures in general are expected to increase water temperature too.

Water scarcity creates opportunities for the transmission of pathogens, due to inadequate hand-washing and personal hygiene. However, for the case of Cyprus minor changes or no changes at all are projected in the future annual average precipitation while the length of drought periods is projected to present an increase up to 13 days/year on average. It must be noted that although Cyprus is considered a dry region with limited freshwater availability especially during drought periods, the substantial contribution of desalinated water to drinking water supply has alleviated the problem in a great extent.

As for the heavy rainfall events associated with flooding events which are also related with the contamination of water, the most relative indicator provided by PRECIS refers to the annual maximum total precipitation over one day. This indicator shows minor increases in the future period (2021-2050) ranging from 2 to 5 mm on average. However, this indicator alone is not sufficient for estimating future changes in the frequency and intensity of flooding events.

9.3.7. Climate-related effects upon nutrition

The causal chains through which climate variability and extreme weather influence human nutrition are complex and involve different pathways such as water scarcity, salinisation of agricultural lands, destruction of crops through flood events, wind storms, frosts and hail, disruption of food logistics through disasters, and increased burden of plant infectious diseases or pests (Confalonieri et al., 2007).

Reduced food production may lead in diminished dietary diversity, reduction in overall food consumption and in malnutrition, especially in low-income countries. Both acute and chronic nutritional problems are associated with climate variability and change. Malnutrition increases the risk both of acquiring and of dying from an infectious disease. Drought and the consequent loss of livelihoods is also a major trigger for population movements, particularly rural to urban migration.

During drought years in Cyprus, the agricultural sector is the first to receive water cuts as it consumes approximately 60% of total water demand. Irrigation water is rationed with priority to permanent crops then to green houses while seasonal crops are allocated with a very small amount of water. As a consequence, significant reductions in farmers' yields are recorded and especially in seasonal crops such as vegetables and potatoes.

In absence of data related to the quantities of damaged crops in Cyprus due to extreme climatic phenomena and their impact upon nutrition, the amounts of compensation paid to the farmers may be used to access indirectly the damages to crop yields. The compensations provided to farmers for damages to crops related to extreme weather events such as frosts, droughts, heat waves, wind storms, hail and floods are presented indicatively in Figure 9-11 and Figure 9-12. Assuming that the amount of compensation provided is directly related to the crop areas damaged, the greatest climatic threats for the agricultural production and subsequently for food availability, are frosts and droughts.

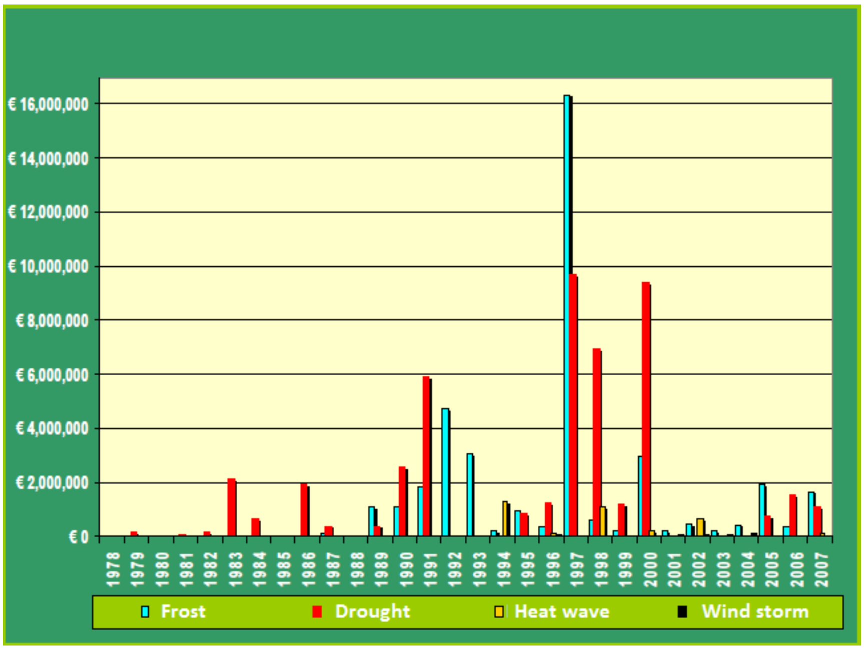


Figure 9-11: Compensation provided for damages to crops caused by frost, drought, heat wave and wind storm in Cyprus (1978-2007)

Source: Pashiardis, 2011

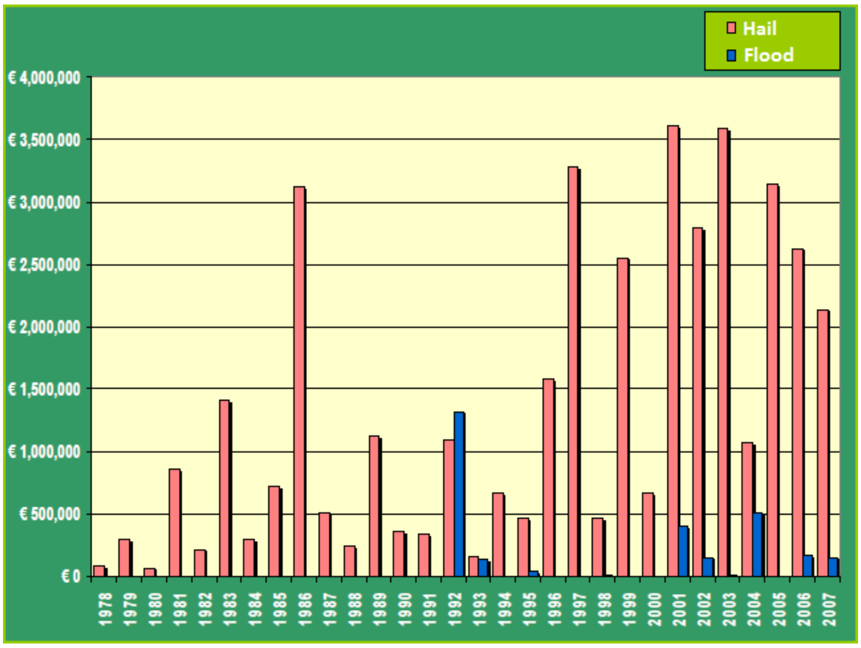


Figure 9-12: Compensation provided for damages to crops caused by hail and flood in Cyprus (1978-2007)

Source: Pashiardis, 2011

The severity of the impact is however associated with the degree of dependence of the population on its agricultural production for satisfying its nutritional requirements.

Next, the future changes in the extreme weather events that are considered to cause serious damages to crops in Cyprus are presented in brief.

According to PRECIS climate projections in Cyprus for the period 2021-2050, the length of drought periods (precipitation<0,5mm) is projected to increase up to 13 days per year on average. However, as drinking water supply will be satisfied by desalinated water in a great extent (except for the areas not connected to government water works), the irrigation water availability will increase compared to the control period.

The mean number of heat wave days per year (temperature>35^{o}C) is expected to increase from +2 to +34 days per year. On the other hand, the mean number of frost nights per year (temperature<0^{o}C) is expected to decrease up to 8 days on average.

As for the heavy rainfall events which are associated with flooding events, the most relative indicator provided by PRECIS refers to the annual maximum total precipitation over one day. This indicator shows minor changes in the future period (2021-2050) ranging from 2 to 5 mm on average. However, this indicator alone is not sufficient for estimating future changes in the frequency and intensity of flooding events.

In addition, the number of days with mean wind speed >5m/s in Cyprus during the future period 2021-2050 is expected to decrease from -5 to -14 days per year.

Based on the PRECIS results, it is expected that the frequency of damages to crops due to frosts and wind storms will decrease while as regards the damages due to heat waves it is expected that they will increase. Concerning the frequency of damages by droughts and floods, it is not clear whether the effect will be negative, positive or none.

9.3.8. Air pollution-related diseases

The diseases related to air pollution include exacerbation of respiratory diseases, tract irritation, exacerbation of asthma, irritation of bronchi, atopic diseases, exacerbation of allergic rhinitis, eye irritation. The air pollution health risks related to climate change are caused primarily from the increased concentrations in the atmosphere of particulate matter and ozone. Tropospheric ozone O_3 is the major pollutant being related to climate change while ground-level ozone (smog), though less concentrated than ozone aloft, is more of a problem because of its health effects. During **heat-waves**, the atmospheric conditions contribute to increases of tropospheric ozone and particulates leading to mortality incidents.

Increases in temperature are likely to extend the duration of flowering and pollen seasons for some grasses and weeds. However, the relationships among changing climate, allergens and allergic disorders need to be further clarified (Huynen et al., 2003).

Ambient air pollutants such as nitrogen dioxide (NO_2), ozone, particulate matter (PM), and components of PM including organic carbon and volatile organic compounds (VOCs) have been linked with increased allergic disease and asthma. Ground-level ozone exposure also exacerbates asthma, can damage lung tissue, as shown in increased emergency department visits and hospitalizations. Ozone exposure may also cause new-onset asthma (Oygar, 2009).

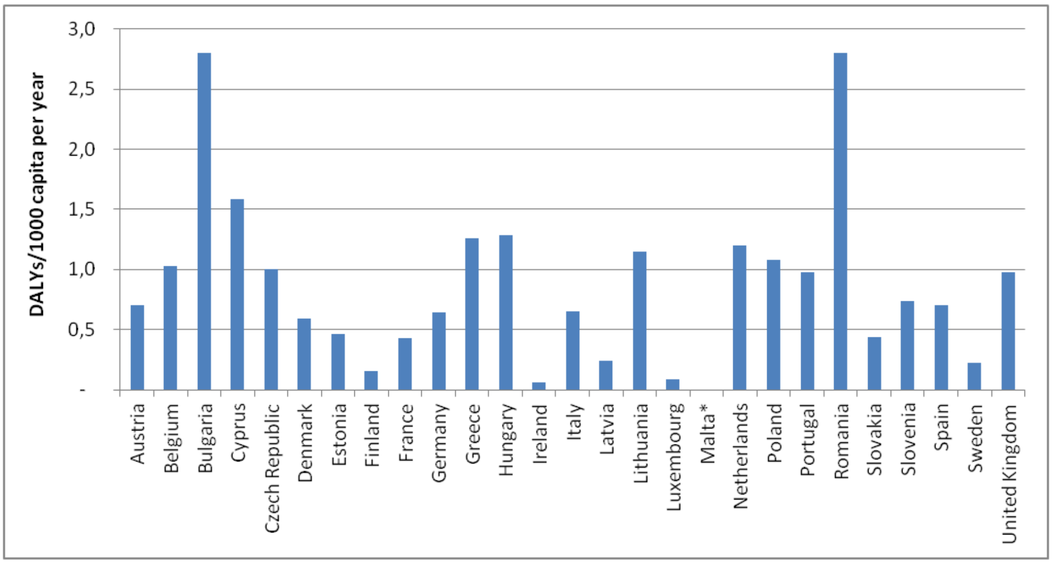
Toxic gaseous and particulate air pollutants released from forest fires into the atmosphere, can significantly contribute to acute and chronic illnesses of the respiratory system, particularly in children, including pneumonia, upper respiratory diseases, asthma and chronic obstructive pulmonary diseases (WHO, 2002; Bowman and Johnston, 2005; Moore et al., 2006).

According to the Preliminary Assessment of Ambient Air Quality in Cyprus (2007) the ozone level shows high values in high elevated background areas like in Troodos mountains while in the cities its concentrations are lower than in the background. The particulate matter PM10 originate from Sahara dust events as well as from anthropogenic activities (mainly traffic) (Department of Labour, 2007).

Due to the dry climate in Cyprus, Particulate Matter PM10 is re-suspended from soils and other surfaces. The wash out of particles from the air occurs only in winter and spring time when it is raining in Cyprus.

Increased temperature rates and humidity in Cyprus may increase pathogen prevalence in air. According to the Meteorological Service of Cyprus relative humidity of the air is on average between 40% and 60% in summer (Meteorological Service of Cyprus). An increase in summer humidity would drastically increase the biological disease potential in the air. Additionally, pollutants from forest fires in Cyprus can effect air quality for thousands kilometers (Sapkota et al., 2005).

As it can be seen from Figure 9-13, in 2002 Cyprus had the 3rd highest value of DALYs attributed to outdoor air pollution among the EU27 Member States (excluding Malta), while only Bulgraria and Romania presented higher DALYs.



** No data available*

Figure 9-13: Estimated DALYs attributable to outdoor air pollution in the EU27

Source: WHO, 2007

The future climate changes in Cyprus that are considered to be associated with the impact of air pollution-related diseases are presented in brief.

According to PRECIS climate projections in Cyprus for the period 2021-2050, the mean number of heat wave days per year (temperature>35°C) which is associated with increases of tropospheric ozone and particulates, is expected to increase from +2 to +34 days per year.

In addition, it is expected that the already dry climate in Cyprus which contributes to the suspension of PM_{10} will be further intensified with the prolongation of drought periods (precipitation<0,5mm) up to 13 days/year on average. However, wind speed which also associated with this effect is expected to decrease.

As for the changes in the mean annual maximum temperature in Cyprus which is related to increased pathogen prevalence in air, this is expected to increase by 1 - 2°C with respect to the control period 1960-1990.

In general, from the PRECIS results it can be said that climate changes will have a negative impact on the air pollution related diseases in Cyprus.

9.4. Future vulnerability assessment

In this section, the future vulnerability of public health to climate change impacts is assessed in terms of its sensitivity, exposure and adaptive capacity, based on selected indicators and on the available quantitative and qualitative data for Cyprus as well as on the climate projections for the period 2021-2050. In particular, sensitivity is defined as the degree to which public health will be affected by climate changes, exposure is the degree to which public health will be exposed to climate changes and their impacts while the adaptive capacity is defined by the autonomous ability of the population to adapt to changing environmental conditions as well as by the effectiveness of the relative existing and planned adaptation measures.

For the assessment of future vulnerability, the same indicators used in the current vulnerability assessment (CYPADAPT, 2012) were used, wherever the necessary data were available. These indicators are summarized in Table 9-4.

Table 9-4: Indicators used for the vulnerability assessment of climate change impacts on Cyprus' public health sector

Vulnerability Assessment	Selected Indicators
Heat waves and heat related impacts on human health	
Sensitivity	- Proportion of vulnerable population groups - Percentage of population living in urban areas - Percentage of population living in areas with high humidity - Relationship between high temperatures and heat related deaths
Exposure	- Risk period for heat waves (number of months) - Heat related mortality and morbidity - Number of days with maximum temperature over 40^{o}c for the period 1961-2000s - Percentage of population exposed to heat waves and magnitude of heat wave - Geographic distribution of heat wave hazard and population density - Number of heat wave days - Humidex
Adaptive capacity	- Warning systems providing forecasts of high temperatures (heat stress conditions) through mass media (television, radio and public web sites) - Curfew, prohibition of outdoor work during the high risk hours/days - Houses, indoor public areas and communal centers fully air-conditioned
Floods/storms related deaths and injuries	
Sensitivity	- Proportion of vulnerable population groups - Impact of flooding events on public health

Vulnerability Assessment	Selected Indicators
Exposure	- Geographic distribution of flood hazard and population density - Percentage of population exposed to floods and magnitude of floods - Heavy rainfall index
Adaptive capacity	- Civil preparedness and defense force - Health care system - Drainage system for stormwater - Identified of high flood risk areas
Landslide- related deaths and injuries	
Sensitivity	- Proportion of vulnerable population groups
Exposure	- Geographic distribution of landslide hazard and population density - Total number and percentage of the population exposed to landslides by level of intensity - Heavy rainfall index
Adaptive capacity	- Civil preparedness and defense force - Health care system - Relocation of landslide prone communities - Landslide protection works - Study of landslides in areas of Paphos District’
Fire-related deaths and injuries	
Sensitivity	- Proportion of vulnerable population groups
Exposure	- Number of people killed or injured during fire events * - Geographic distribution of fire risk areas and population density - Fire risk (Fire Weather Index)
Adaptive capacity	- Civil preparedness and defense force - Health care system - Fire brigade - Fire prevention, pre-suppression, detection and suppression measures
Vector-borne and Rodent diseases	
Sensitivity	- Proportion of vulnerable population groups - Percentage of the population with access to sanitation

Vulnerability Assessment	Selected Indicators
Exposure	- Periods of increased temperatures and prolonged droughts - Number of recorded mosquito species - Rate of vector-borne diseases - Length of drought periods - Number of days with high temperature - Heavy rainfall index
Adaptive capacity	- Mosquito surveillance program - Diagnosis and treatment, vaccination, vector control, reservoir host control, information and health education as well as disease surveillance and monitoring
Water-borne and food-borne diseases	
Sensitivity	- Proportion of vulnerable population groups - Percentage of the population with access to sanitation - Percentage of the population with access to safe water
Exposure	- Quarantine Law on the notification of communicable diseases - Number of cases of infectious diseases notified - DALYs attributable to water, sanitation and hygiene - Recorded incidents of salmonellosis in Cyprus - Recorded incidents of Hepatitis A - Length of drought periods - Number of days with high temperature - Heavy rainfall index
Adaptive capacity	- Food-borne Disease Surveillance System - Monitoring of pollution levels - Monitoring of the environmental pollution level of drinking water supplies - Controls on food and water samples for ensuring quality and safety - Monitoring compliance with state legislation on food safety and quality
Climate-related effects upon nutrition	
Sensitivity	- Proportion of vulnerable population groups
Exposure	- Losses in agricultural production due to extreme events - Dependence of the population on its agricultural production for satisfying its nutritional requirements - Length of drought periods - Number of heat wave days - Heavy rainfall index - Number of days with mean wind speed>5m/s

Vulnerability Assessment	Selected Indicators
Adaptive capacity	- Measures to secure water availability for irrigation in periods of droughts - Measures for the protection of crops from extreme climatic events - Ability for food imports - Safeguarding the production and distribution of food products
Air pollution related diseases	
Sensitivity	- Proportion of vulnerable population groups
Exposure	- Geographic distribution of ozone concentration and population density - Geographic distribution of PM10 and population density - Geographic distribution of nitrogen dioxide and population density - Humidity - Rate of environmental burden of disease by category of air-related diseases - Changes in temperature - Length of drought periods - Wind speed - Number of heat wave days
Adaptive capacity	- Measures for air pollution mitigation

*There were no data regarding this indicator

The relationship between sensitivity, exposure and adaptive capacity is based on the following qualitative equation:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity * Exposure$$

Sensitivity, exposure and adaptive capacity are evaluated on a 7-degree qualitative scale ranging from “none” to “very high”.

In the sections that follow, the vulnerability is assessed for each of the impact categories presented in Section 9.3:

- Deaths and health problems related to heat waves and high temperatures
- Deaths and injuries from floods/storms
- Landslide-related deaths and injuries
- Fire- related deaths and injuries
- Vector-borne and Rodent-borne diseases

- Water-borne and food-borne diseases
- Climate-related effects upon nutrition
- Air pollution-related diseases

It must be noted that, there are no sufficient scientific evidence and data to evaluate or correlate all impacts and indicators to future climate changes. Consequently, further research is required in order to provide concrete information for a more detailed and descriptive assessment of the future vulnerability of the sector. Nevertheless, an attempt was made to provide a preliminary assessment of future vulnerability. In case additional data are provided by the competent authorities of Cyprus, the vulnerability of the sector could be re-assessed.

9.4.1. Deaths and health problems related to heat waves and high temperatures

9.4.1.1. Assessment of sensitivity and exposure

Sensitivity

Excessive heat is a well-known cause of heat stress, exacerbated illness and mortality. Heat waves have readily discernible health outcomes because they result in a large number of deaths and affect relatively large, heterogeneous areas simultaneously. However, not all heat waves have a similar impact on mortality. In addition to the intensity of a heat wave, the duration and the timing of the event are particularly important. Illnesses recognisable as the direct results of exposure to prolonged periods of high environmental temperature are heatstroke, heat exhaustion, and heat cramps.

Empirical-statistical models for heat stress are constructed for the island of Cyprus during summer (June-August). All-cause daily mortality data for the island of Cyprus, for the period 2004-2011, were acquired from the Cyprus Statistical Service (Department of health statistics), whereas daily maximum temperature data for Nicosia were provided by the Cyprus Meteorological Service for the same time period. We considered Nicosia to be representative of hot weather conditions prevailing in the island during summer. The aim of this study is to examine the relationship between hot weather conditions and mortality for Cyprus since excessive heat is a well-known cause of heat stress, exacerbated illness and mortality.

A time series plot of the all-cause daily mortality for the island Cyprus, covering the period from 2004 to 2011, together with the 30-days running mean (light blue line), and the daily maximum air temperature for Nicosia, are given in Figure 9-14. Figure 9-14 shows a clear seasonal variation of mortality: higher in winter and in summer, lower during transient seasons. This is most noticeable in the smoothed 30-days running mean line. It is also apparent that there have been considerable heat or cold related deaths in Cyprus.

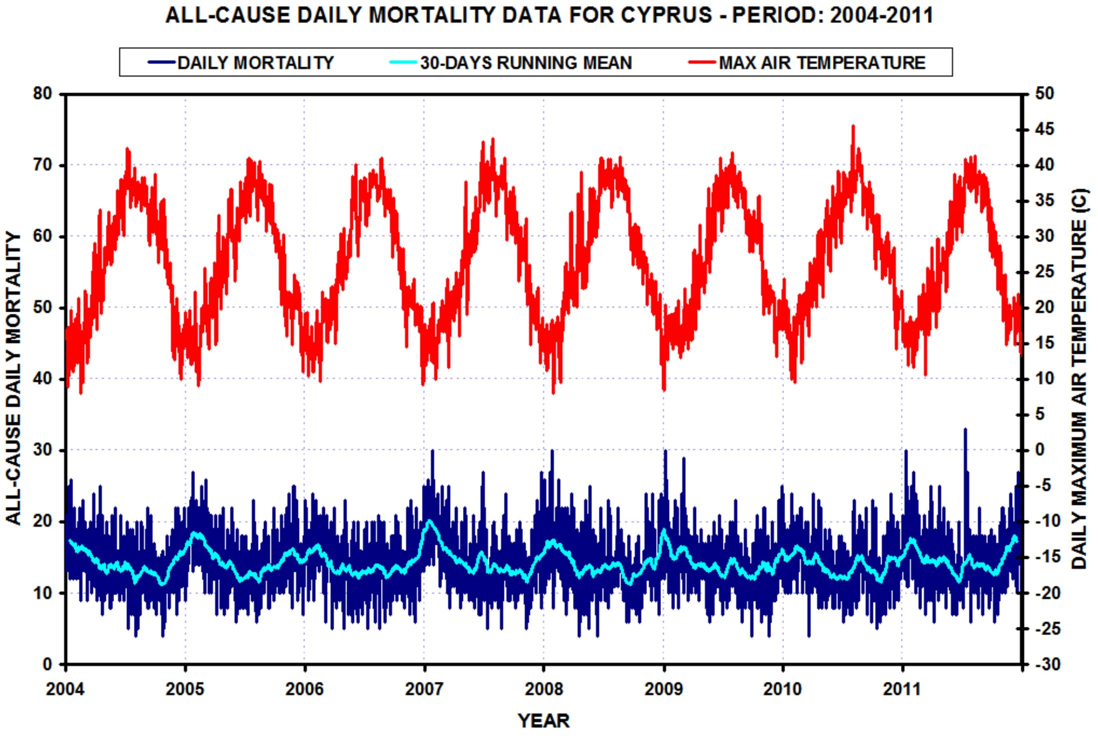


Figure 9-14: All-cause daily mortality data for Cyprus (blue line, left-hand axis) and daily maximum air temperature (red line, right-hand axis) for the period 2004-2011. The light blue line represents the smoothed 30-day running mean.

An empirical-statistical model for heat stress is then constructed for Cyprus, for the summer months (June-August) of the common data period 2004-2011. Heat-related deaths are defined as the number of deaths occurring in excess of the number that would have been expected for that population in the absence of stressful weather.

For the calculation of excess deaths, i.e. deaths beyond those expected for a specific period in a specific population, we have used the fixed mean of daily mortality for each summer month, for the period 2004-2011 (12.9 deaths in June, 13.4 in July and 13.6 in August). Daily excess deaths were then calculated by subtracting the expected (fixed mean) from the observed daily death values (Dessai, 2002a). For example, that meant subtracting 12.9 from every observed daily death for June, 13.4 from every observed daily death of July, and 13.6 from every observed daily death of August. Each number of excess deaths was then grouped into the corresponding 1°C interval of maximum air temperature. For example, if on a particular day, the maximum temperature was 39.3°C and there were 10 excess deaths, 10 would be put in the 39-39.9°C interval. All excess deaths in each 1°C interval for the entire period were added in order to find out where heat-related deaths were no longer detectable. In this way only temperatures over a certain threshold were regressed. This level of aggregation was necessary because no statistically significant relationship could be established when each excess death was plotted against its corresponding maximum air temperature. For example, if the maximum temperature on the interval 39-39.9°C was observed 5 times, and the calculated excess deaths were: +20, -15, +12, -7 and +10, then the SUM = (+20) + (-15) + (+12) + (-7) + (+10) = 20. Finally, the sum of the excess deaths in each interval was divided by the frequency of occurrence of that temperature interval in the 2004-2011 period, to give the number of deaths per day for a particular temperature interval. For example, if there were 681 deaths (the sum of all excess deaths) in the 39°C interval (i.e. 39-39.9°C), and the number of times this temperature interval was observed in the period 2004-2011 was 27, then the number of excess deaths per day would be equal to 681/27=25.2.

Following the methodology given above, the calculated summer excess deaths (or the heat-related mortality) per day for each maximum air temperature interval, for Cyprus during the period 2004-2011, are presented in Figure 9-15. The frequency of occurrence of the temperature intervals during this period examined is also included, indicating the percentage of days in a year that this temperature interval occurs. For example a 0.15 frequency of temperature interval of 38°C means that 15% of the days in the examined period (about 101 days out of a total 684 days) will experience temperatures between 38°C and 38.9°C.

A fairly linear increase of mortality with increasing temperature and thus high sensitivity is observed - with hotter days associated with greater morality risk. Heat-related deaths start to be discernible when the maximum temperature is 38°C or above.

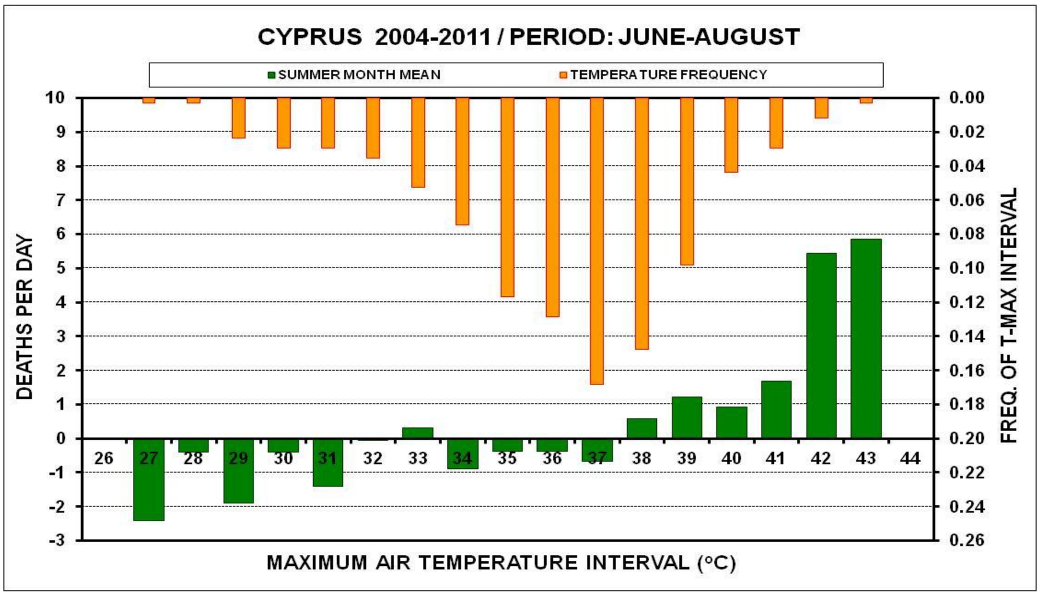


Figure 9-15: Daily excess summer deaths (green bars, left-hand axis) in Cyprus by maximum air temperature interval for the years 2004-2011. The frequency of occurrence of each temperature interval (right-hand axis) is shown using orange bars

In addition, local factors, apart from climate, such as topography, heat-island magnitude, income, and the proportion of elderly people, are also important in determining the underlying temperature–mortality relationship in a population (Curriero et al., 2002; Hajat, 2006).

The population groups that are most vulnerable to heat waves are the elderly, persons with pre-existing chronic diseases, people confined to bed, children, population groups with low socio-economic status, workers in outdoor environments. The occupations most at risk of heatstroke, include construction and agriculture/forestry/fishing work. Considering the fact that a high percentage of immigrants laborers, work in outdoor environments, the risk for the particular vulnerable group is high.

In Cyprus, senior citizens (>65 years) represent 13.3% of the total population (CYSTAT, 2011). They are mostly sensitive to direct climate change effects such as thermal stress during heat waves and health stress during other extreme weather events. The elderly population can face unequal access to healthcare, as they are often unable to travel long distances to the nearest health facility. Children (<14 years), which represent 16.1% of Cypriot population (CYSTAT, 2011), is another high-risk group to heat waves because they do not have fully developed temperature regulation mechanisms and are unable to change their environments without help from adults. The very young are at higher risk of death while older children have more heat stress due to time spent in exercise – playing outdoors. Therefore, about 30% of Cyprus population can be characterized as sensitive to heat waves, without taking into consideration parameters such as socio-economic status, health status and standards of living.

Moreover, heat waves have a much bigger health impact in cities than in surrounding suburban and rural areas (Kilbourne, 1997; Rooney et al., 1998). People living in the urban areas are more sensitive to an extreme rise in the temperature than those in the rural areas. This is due to the ‘heat islands’ that develop owing to the presence of concrete constructions, paved and tarred roads. This prediction is in accordance with observations in cities of Mediterranean Basin which have shown that heat waves can have very strong effects on mortality, reporting an increase of 1-4% for each degree of temperature raise (GSK/Accenture/SSEE, 2011). In the urban areas where the air pollution levels are elevated, heat waves are more frequent. Furthermore, the increases in temperatures would be higher in the interior than on the coast of Cyprus which leads to higher adverse health implications on the population living inland. The majority of population in Cyprus (70%) is living in the urban areas and thus a great percent of the population is considered more sensitive to heat waves. In addition, a large percentage of the urban population is located in the coastal cities, where the high humidity level combined with heat waves increases the vulnerability of population and the risk of mortality and morbidity.

Taking into consideration the aforementioned indicators, the sensitivity of public health in Cyprus to heat waves is considered **high**.

Exposure

Generally, the risk period for heat waves in Cyprus is identified during the whole summer, that is, from June to August (three months). According to the international disaster database of the Centre for Research on the Epidemiology of Disasters (CRED, 2011), during three heat wave events that were recorded in Cyprus, a total of 61 people were killed while another 500 people were affected.

As it can be seen from Figure 9-16, the number of days with maximum temperature over 40^{o}C for the period 1961-2000 is presenting a general increasing trend in Nicosia, meaning that people are increasingly exposed to heat waves during the last decades.

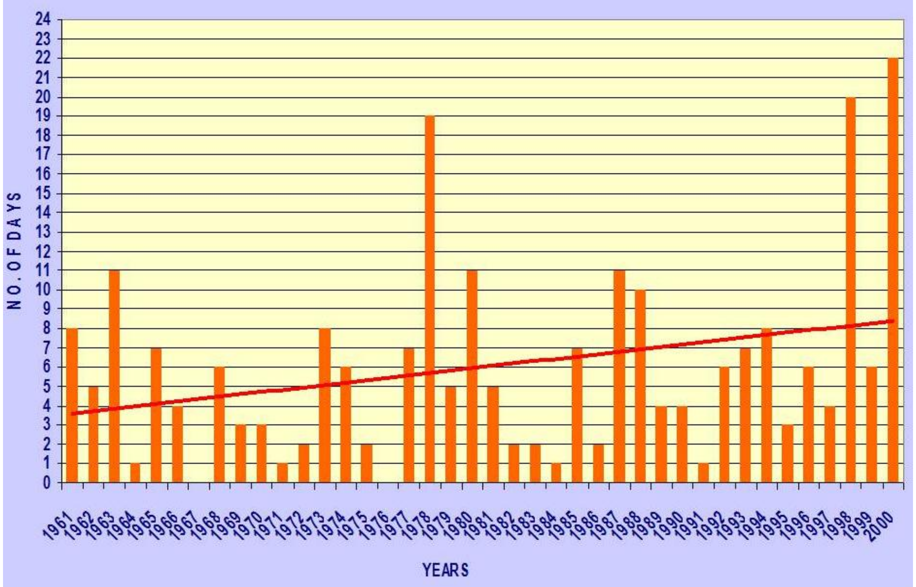


Figure 9-16: Number of days with maximum temperature ≥ 40 ^{o}C, Nicosia (1961-2000)

Source: Cyprus Meteorological Service

It should also be noted that the temperature of 38^{o}C when the heat-related deaths start to be discernible, has the second highest frequency of occurrence in Nicosia (the most common is 37^{o}C) (see Figure 9-15).

According to WHO (2010), almost 100% of the population in Cyprus is exposed to moderate heat wave hazard (Table 9-5).

Table 9-5: Total number and percentage of the population exposed to heat waves by level of intensity for Cyprus

Return period	Very high No. exposed (%)	High No. exposed (%)	Medium No. exposed (%)	Low No. exposed (%)	Very low No. exposed (%)	No data No. exposed (%)
Heat wave (2 Years)	0 (0.00%)	0 (0.00%)	869519 (98.84 %)	10192 (1.16%)	12 (0.00%)	0 (0.00%)
Heat wave (5 Years)	0 (0.00%)	0 (0.00%)	876547 (99.64 %)	3176 (0.36%)	0 (0.00%)	0 (0.00%)

Return period	Very high No. exposed (%)	High No. exposed (%)	Medium No. exposed (%)	Low No. exposed (%)	Very low No. exposed (%)	No data No. exposed (%)
Heat wave (10 Years)	0 (0.00%)	0 (0.00%)	877279 (99.72 %)	2444 (0.28%)	0 (0.00%)	0 (0.00%)

Source: World Health Organization 2010

In Figure 9-17, the area of Cyprus which is exposed to heat waves as well as the heat wave hazard (temperature) is presented. According to Figure 9-17, the biggest part of the population in the island of Cyprus (98.8%) is exposed to medium heat wave hazard (32-41^{o}C), while the population in mountain areas are exposed to low heat wave hazard (27-32^{o}C) for a 2-year return period. As the return period increases, the mountain population that is exposed to low heat wave hazard decreases.

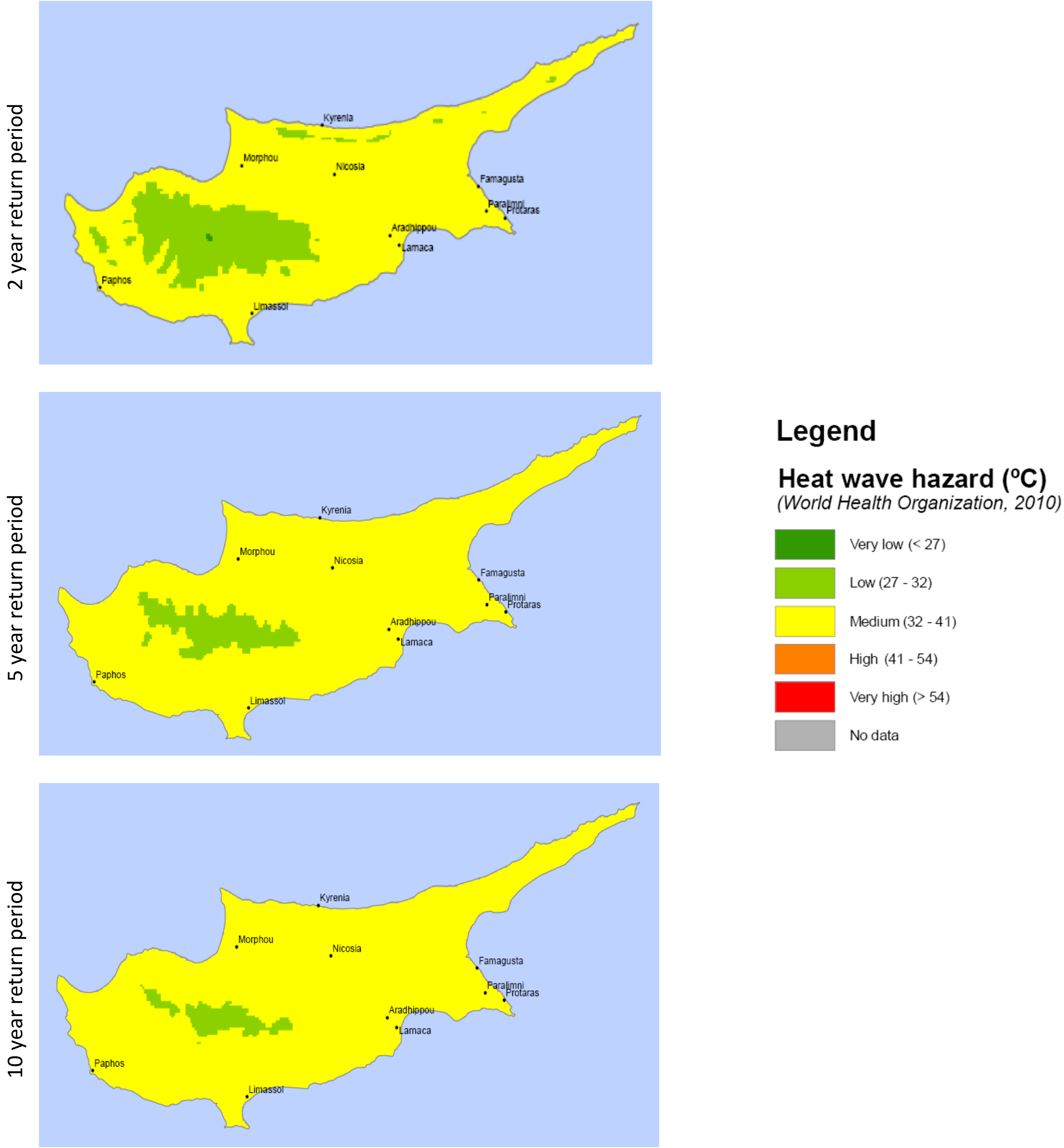


Figure 9-17: Heat Wave Hazard Distribution Map (2, 5 and 10 year return period)

Source: WHO (http://www.who-eatlas.org/europe/countries/cyprus/cyprus-hazard.html)

With regard to the future projections on heat waves, as these were calculated by the PRECIS model, it is expected that the increase of days per year with daily maximum temperature higher than 35°C will not exceed 20 days in coastal areas (40 days in total) , with the exception of Larnaca and the coastal area between Larnaca and Limassol, where the increase in heat wave days will reach 30 days (50-60 in total). It is also noted that the heat wave index increase, ranges from 30 to 35 days in the southeastern part of Troodos and in continental lowlands (80-85 days in total), especially near Nicosia. In conclusion, PRECIS shows the spatial temperature difference between coastal and continental regions (Figure 9-18).

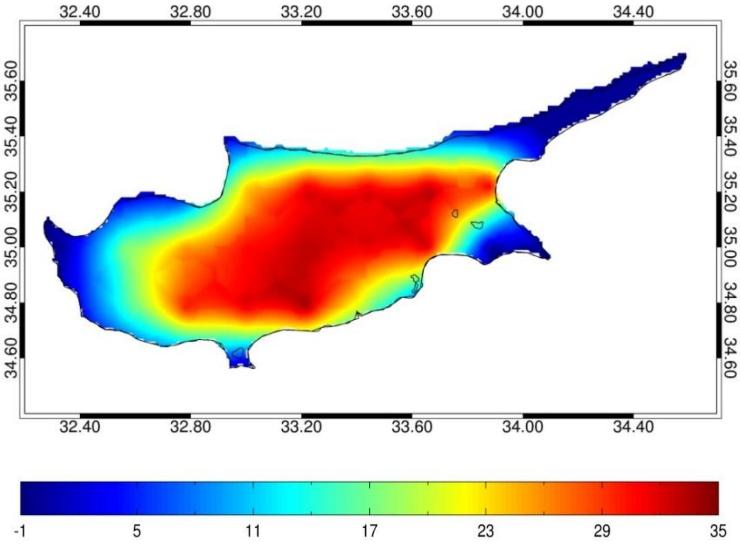


Figure 9-18: Changes in the number of heat wave days (T>35oC) between the future (2021-2050) and the control period (1961-1990)

A linear model was used to project heat-related mortality to the future climate of 2021-2050 using temperature output from the PRECIS climate model simulation under the A1B emissions scenario. An 'adaptation' or acclimatisation factor of 1°C per 30 years (Dessai, 2002b) was included to allow for physiological and behavioural adjustment to higher temperatures. The same model was also applied for the 6 ENSEMBLES RCMs for the 2021-2050 period.

Figure 9-19 shows that there will be an increase of heat related mortality with up to 10 excess deaths per day under very hot weather conditions. This increase is shown by the shift to the right and the longer tails of the simulated bars compared to the red observed bars. There are some differences in projected mortality between the examined models. The METNO model, especially fails to capture the high summer temperatures recorded in Nicosia, and thus shows much less excess mortality in the future. The other models, including PRECIS, have a much better fit to observations. Therefore, even after adjustment for adaptation, there are significant increases in excess heat-related mortality for the period 2021-2050 and this should be seriously be taken into account by government health services in their planning.

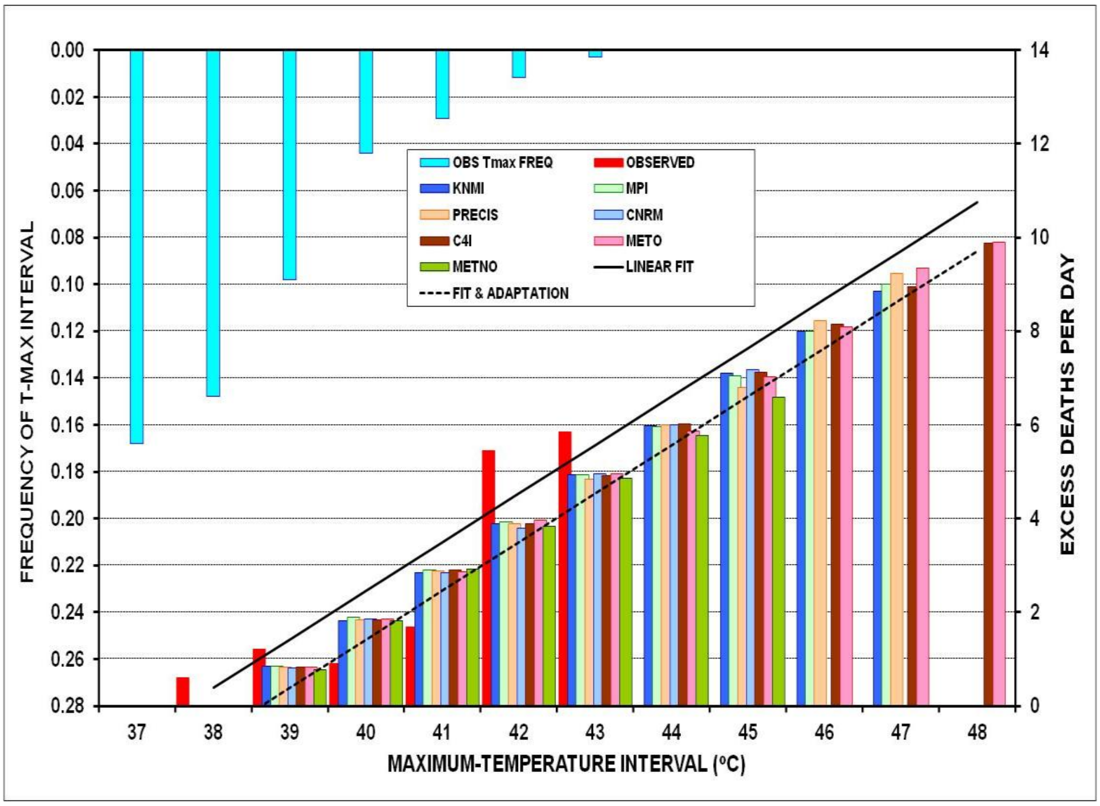


Figure 9-19: Excess deaths (right axis; model and observation bars for present and future climate with adaptation) and daily temperature frequencies (left axis; light blue bars) in Cyprus for the future period 2021-2050

To investigate the potential negative impacts of climate warming on human life, the humidity index or “Humidex” (Masterton and Richardson, 1979) - a parameter employed to express the temperature perceived by people - has also been examined. Humidex is applied in summer and generally warm periods and describes the temperature felt by an individual exposed to heat and humidity. More specifically, the humidex parameter (in °C) is calculated by the following equation:

$$T\ (h) = Tmax\ +\ {}^{5}/_{9}\ \times (e - 10)\ ,$$

Where *e* is the vapour pressure:

$$e = 6.112\ \times 10^{\left(7.5 \times {}^{Tmax}/_{(237.7\ + Tmax)}\right)} \times\ {}^{h}/_{100}$$

Tmax is the maximum 2 m air temperature (°C) and *h* is the humidity (%).

Furthermore, six classes of humidex ranges are established to inform the general public for discomfort conditions (http://www.eurometeo.com/english/read/doc_heat):

- <29°C comfortable
- 30–34°C some discomfort
- 35–39°C discomfort; avoid intense exertion

- 40–45°C great discomfort; avoid exertion
- 46–53°C significant danger; avoid any activity
- >54°C imminent danger; heart stroke.

All calculations were performed using PRECIS Regional Climate Model (RCM). In addition, six RCMs of the ENSEMBLES project have also been used namely KNMI, METNO, CNRM, METO, C4I and MPI. The results of models were used as an ensemble mean for testing and comparing the respective results of PRECIS.

To begin with, Figure 9-20 illustrates the average summer humidex for the control period as calculated by PRECIS. In inland (Nicosia) and southeastern (Larnaca) regions, humidex varies from 40 to 42°C revealing "great discomfort" conditions for people. Less discomfort is presented in the mountain regions of Troodos as well as in southern and western parts of Cyprus where humidex reaches approximately 36 - 37°C. As far as future changes are concerned, a significant increase in humidex of about 3.5 – 4°C is projected (Figure 9-21) for all the domain of study. This means that "significant danger" conditions are anticipated mainly for inland regions where humidex is projected to reach approximately 47°C.

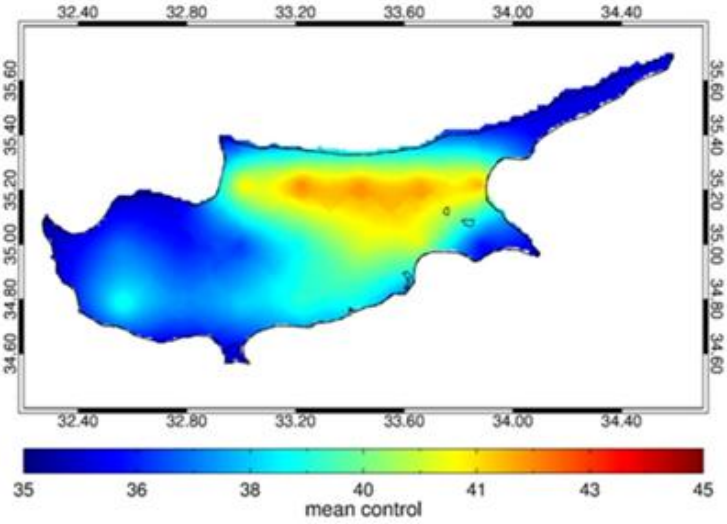


Figure 9-20: Average summer Humidex for control period (1960-1990), PRECIS RCM model

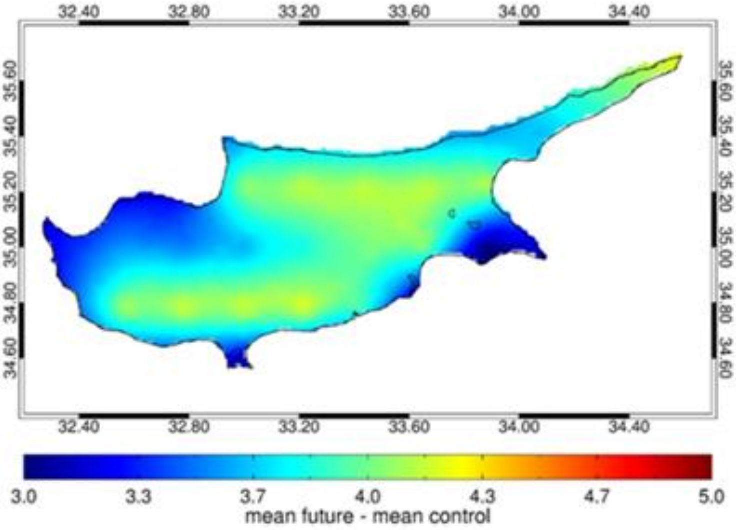


Figure 9-21: Change in average summer Humidex in the near future 2021-2050 (Future – Control period), PRECIS RCM model

To examine the potential influence of the anticipating warming of late spring and early autumn periods on the human comfort or discomfort, the average spring humidex and the average fall humidex have also been studied. Regarding spring, Figure 9-22 illustrates that in the present-day climate, humidex varies below 29°C (20 – 25°C) revealing “comfortable” conditions for residents. As regards near future changes, a slight increase in humidex of about 2 – 2.5°C is projected by PRECIS (Figure 9-23) for the domain of study. This increase is not expected to influence “comfortable” conditions according to the classification.

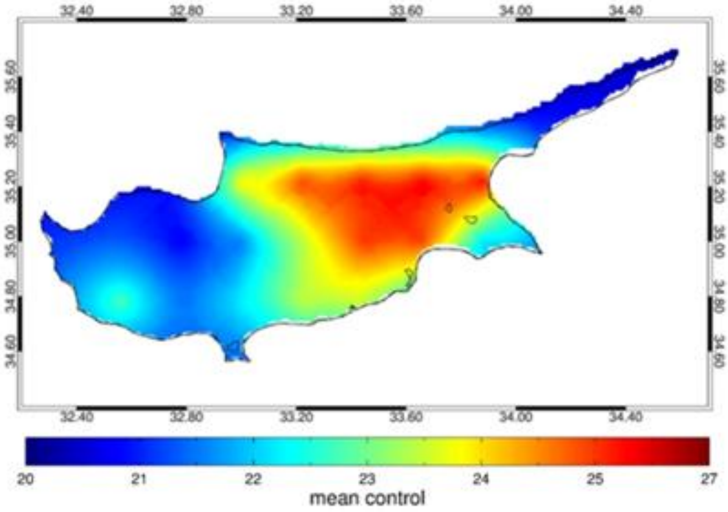


Figure 9-22: Average spring Humidex for the control period (1960-1990), PRECIS RCM model

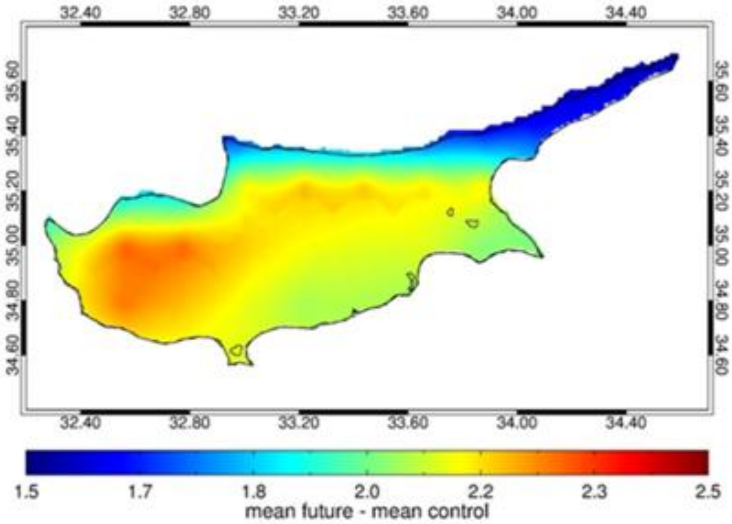


Figure 9-23: Change in average spring Humidex in the near future (Future – Control period), PRECIS RCM model

Autumn, in contrast with spring, presents higher humidex as Figure 9-24 shows. In particular, inland and southeastern regions show the higher humidex of about 31°C testifying "some discomfort" for people. Mountain, southern and western regions present the lower humidex varying from 27 – 28°C. Regarding future changes, PRECIS projects a slight increase in humidex of around 2.5°C in all the domain of study (Figure 9-25). Future projections show that the foreseeing atmosphere warming during autumn will create "some discomfort" to residents mainly in inland and southeastern regions.

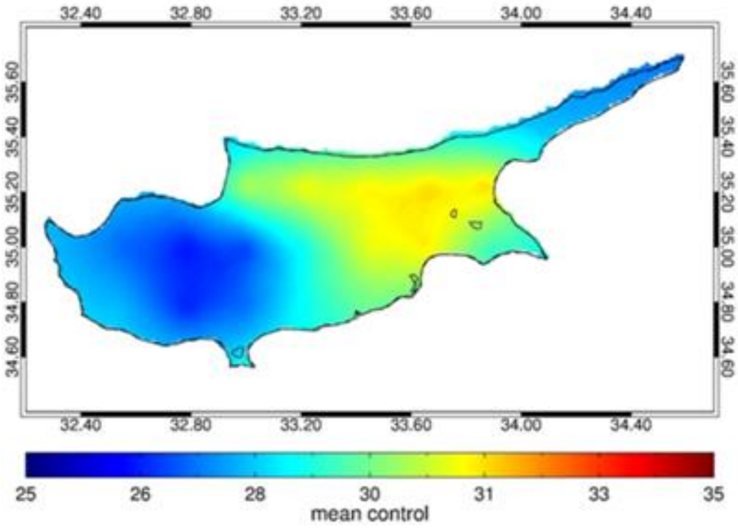


Figure 9-24: Average autumn Humidex for the control period (1960-1990), PRECIS RCM model

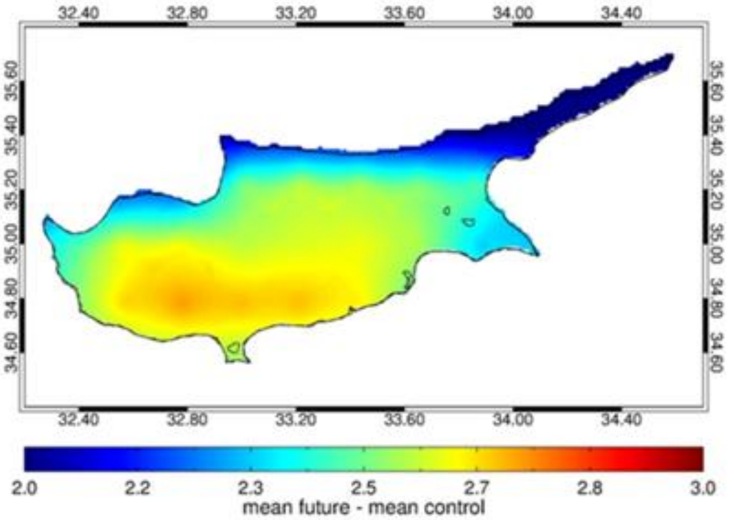


Figure 9-25: Change in average autumn Humidex in the near future (Future – Control period), PRECIS RCM model

As for the annual pattern of humidex, a similar distribution to seasonal, namely higher humidex in inland and southeastern regions and lesser in southern, western and mountain regions is observed. More specifically, in inland and southeastern regions annual humidex varies around 26-28°C while in southern, western and mountain regions humidex varies around 24-26°C (Figure 9-26). In both cases, humidex is classified as "comfortable" for the residents. As regards future changes, a slight increase in humidex varying between 2-2.5°C for the domain of study is projected (Figure 9-27). Similarly with the respective results of present-day climate, near future annual humidex is classified as "comfortable".

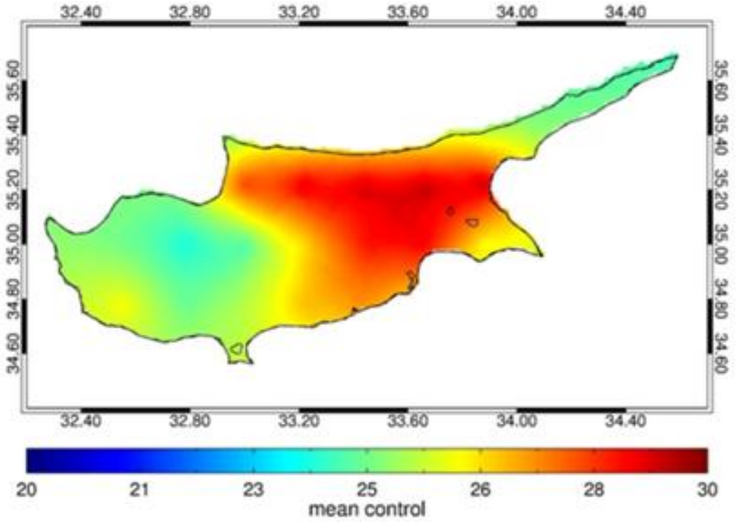


Figure 9-26: Average annual Humidex for the control period (1960-1990), PRECIS RCM model

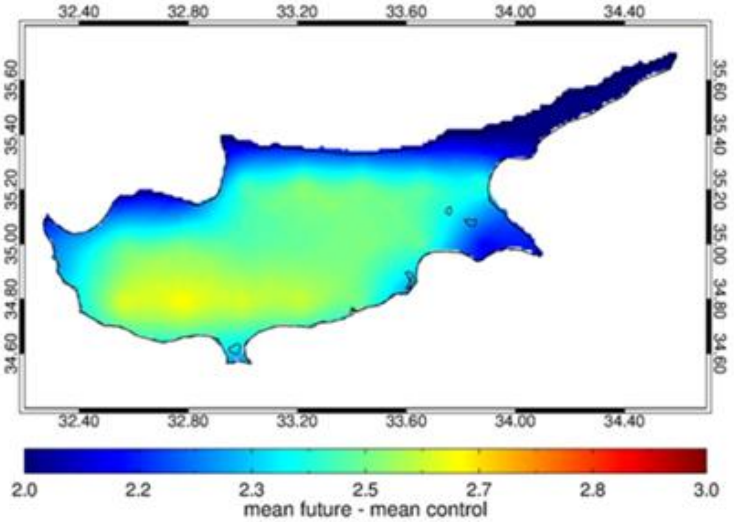


Figure 9-27: Change in average annual Humidex in the near future (Future – Control period), PRECIS RCM model

Apart from seasonal and annual distributions of humidex, three additional important parameters have also been studied i.e. the number of days with humidex > 38°C (high discomfort), the number of days with humidex > 40°C (great discomfort) and the maximum length of humidex > 38°C (consecutive days with high discomfort). Figure 9-28 depicts that in the present-day climate there are approximately 90 days with humidex > 38°C in inland and southeastern regions while in southern, western and mountain regions there are approximately 45 days. Regarding future changes, an important increase of about 40 – 42 days in mountain, southern and western regions is projected. In contrast, southeastern and inland regions present a smaller increase of the order of 33 days (Figure 9-29).

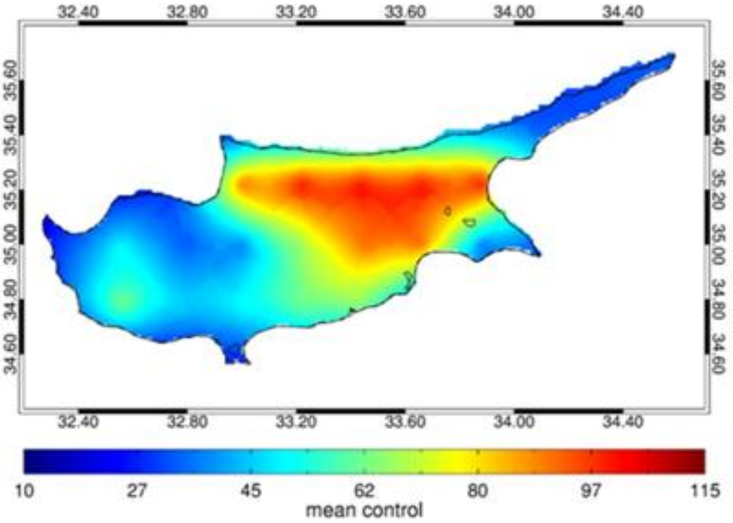


Figure 9-28: Number of days with Humidex > 38°C for the control period (1960-1990), PRECIS RCM model

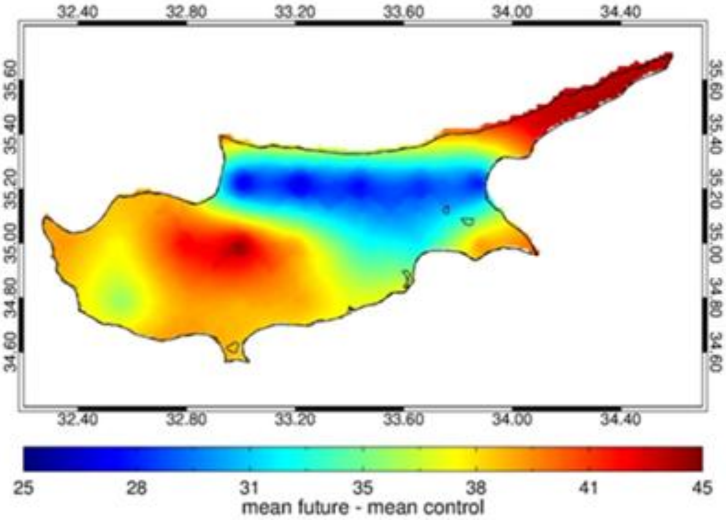


Figure 9-29: Number of days with Humidex > 38°C in the near future (Future – Control period), PRECIS RCM model

As regards the number of days with great discomfort for people, in other words with humidex > 40°C, Figure 9-30 illustrates that, inland and southeastern parts present the higher number of days of about 70 while mountain, southern and western parts show approximately 20-25 days. Concerning near future changes, PRECIS RCM projects an important increase of about 40-43 days in the wider area of the southeastern part of Troodos Mountain as well as in the coast area between Larnaca and Nicosia, while in the remaining areas the increase is between 34 and 38 days (Figure 9-31).

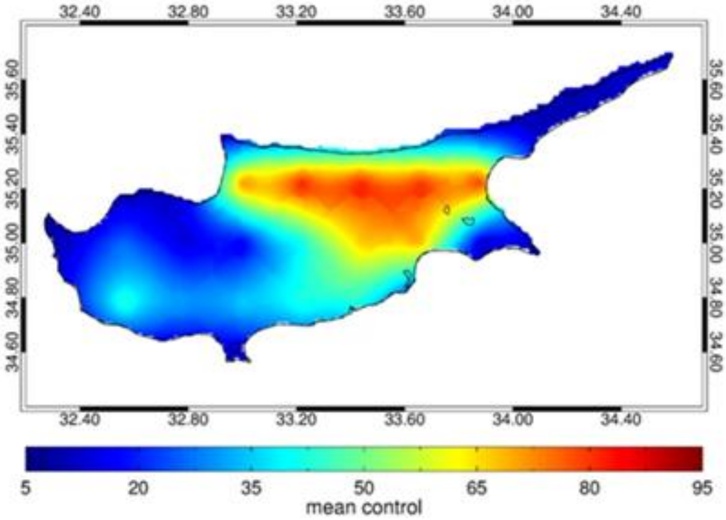


Figure 9-30: Change in the number of days with Humidex > 40°C for the control period (1960-1990), PRECIS RCM model

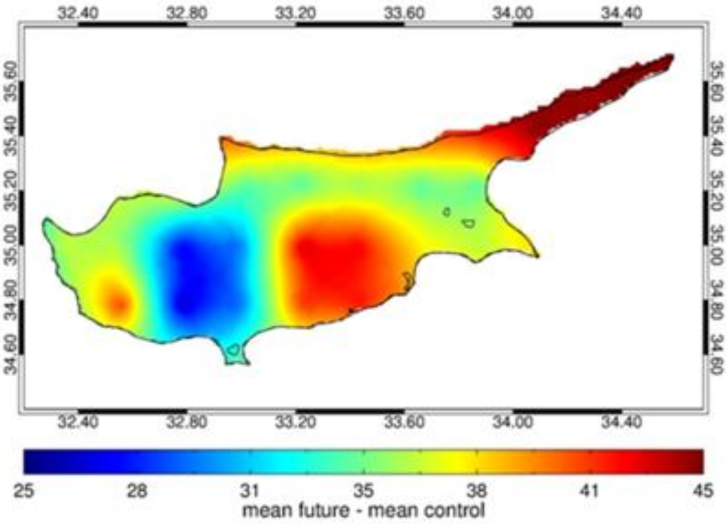


Figure 9-31: Change in the number of days with Humidex > 40°C in the near future (Future – Control period), PRECIS RCM model

Finally, the very important parameter of the maximum length of humidex above 38°C (consecutive days with high discomfort) is presented. PRECIS estimates for the control period (1960-1990) show a maximum length of about 60 days in inland and southeastern parts of Cyprus while southern, western and mountain regions present a maximum length of about 15 days (Figure 9-32). As for near future changes, a noteworthy increase of about 40 days, is projected in the inland and southern-southeastern regions. Also, western parts show a lower increase of about 35 days while Troodos Mountain shows the lowest increase of around 28 days (Figure 9-33).

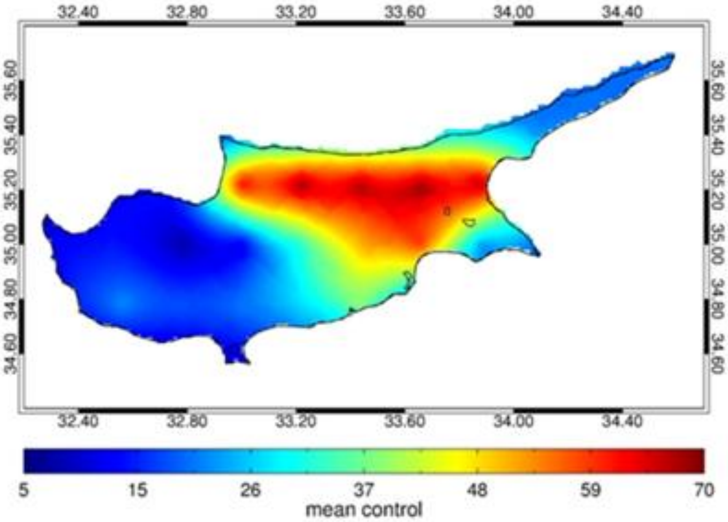


Figure 9-32: Maximum length of Humidex > 38°C for the control period (1960-1990), PRECIS RCM model

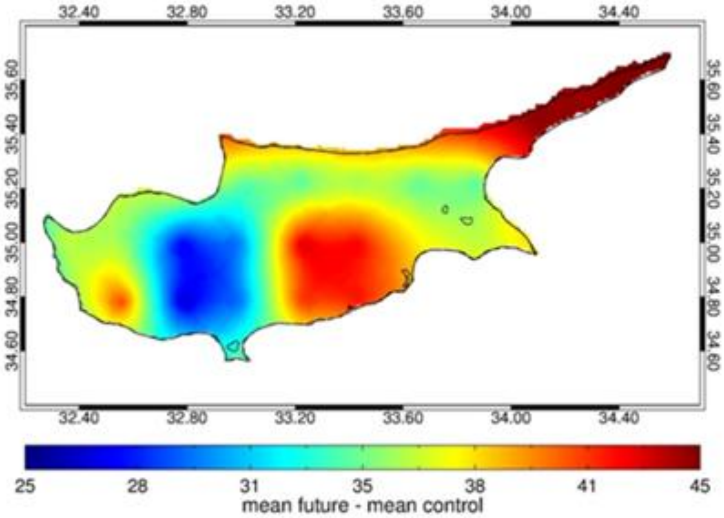


Figure 9-33: Maximum length of Humidex > 38°C in the near future (Future – Control period), PRECIS RCM model

The overall findings of the analysis regarding both present-day climate and potential near future changes due to climate change with negative or positive impacts on human life are summarized in Table 9-6 and Table 9-7.

Table 9-6: Values of indices with particular relevance to human life

	Western Regions	Mountain Regions	Inland Regions	Southern Regions	South eastern Regions
Average Summer HUMIDEX	36	37	41	37	40
Average Spring HUMIDEX	21	21	25	22	24
Average Fall HUMIDEX	27	27	31	28	31
Average Annual HUMIDEX	25	24	28	25	28
Nb of days with HUMIDEX > 38 deg	45	45	90	45	90
Nb of days with HUMIDEX > 40 deg	25	25	70	20	70
Max length of HUMIDEX > 38 deg	15	15	60	15	60

Table 9-7: Potential future changes in indices with particular relevance to human life

	Western Regions	Mountain Regions	Inland Regions	Southern Regions	South eastern Regions
Average Summer HUMIDEX	(+) 3.5	(+) 3.5-4	(+) 4	(+) 4	(+) 4

	Western Regions	Mountain Regions	Inland Regions	Southern Regions	South eastern Regions
Average Spring HUMIDEX	(+) 2	(+) 2	(+) 2	(+) 2	(+) 2
Average Fall HUMIDEX	(+) 2.5	(+) 2.5	(+) 2.5	(+) 2.5	(+) 2.5
Average Annual HUMIDEX	(+) 2.5	(+) 2.5	(+) 2.5	(+) 2.5	(+) 2.5
Nb of days with HUMIDEX > 38 deg	(+) 40	(+) 41	(+) 33	(+) 40	(+) 33
Nb of days with HUMIDEX > 40deg	(+) 36	(+) 38-40	(+) 38	(+) 34	(+) 38
Max length of HUMIDEX > 38 deg	(+) 35	(+) 28	(+) 40	(+) 35	(+) 40

Considering the above, the future exposure of public health to heat waves is characterized as **moderate to high**.

9.4.1.2. Assessment of adaptive capacity

The public health response of Cyprus in heat waves is based at forecasting heat waves, issuing warnings and providing advices for self protection from heat waves, through the mass media (television, radio, newspapers, public websites). In addition, during severe heat waves in Cyprus (as in summer of 2003), the government in order to protect its citizens from adverse health effects, recommends a curfew between the high risk hours of the day. Furthermore, working regulations prohibit outdoor labour work when temperature exceeds 40^{o}C. However, people frequently ignore curfews out of negligence, with all the adverse effects that may follow.

The majority of houses and indoor public areas as well as private trade facilities in Cyprus, are fully air-conditioned. Furthermore, there are communal centers fully air-conditioned to accommodate people with no access to an air-conditioned environment during days of elevated temperatures. However, the protection of the population from heat waves is not always possible.

As presented in Section 9.2.2, the ability of the health care system of Cyprus to respond to heat related incidents is sufficient. However, it is the rapid nature of some heat-related health effects such as heat strokes that people do not make it to the hospital.

Considering the above mentioned indicators, the adaptive capacity of Cyprus' public health to heat waves is characterized as **limited to moderate**.

Following, additional recommended adaptation measures (Shoukri and Zachariadis, 2012) that are considered to further enhance adaptive capacity towards this impact are presented indicatively. Nevertheless, their assessment and final selection for implementation will be made through the use of the Multicriteria Analysis (MCA) tool which will be developed and implemented in the framework of Actions 4 and 5 of the CYPADAPT project.

- Creation and protection of urban parks to reduce the urban heat island phenomenon and improve air quality
- Implement a coherent early warning system
- Establishment of a General Health Scheme and horizontal integration of the climate change adaptation priority in all sectors
- Development of contingency plans in health and social care systems to cope with increasing numbers of patients
- Preparation of an emergency plan in order to specify the responsibilities of various health and social service bodies
- Develop guidelines and proper training for medical doctors (private and public sector).

9.4.2. Flood-related deaths and injuries

9.4.2.1. Assessment of sensitivity and exposure

Sensitivity

The main population groups that are considered sensitive to deaths and injuries from floods and storms are (i) the elderly over 65 (13.3%) which cannot move easily and fast in case of a flooding event and (ii) infants and young children (16.1%) especially if they are not under the protection of an adult (CYSTAT, 2011).

The following figure illustrates the level of severity for public health of recorded flooding events in Cyprus during the period 1859-2011, according to historical records collected by the Water Development Department of MANRE (2011).

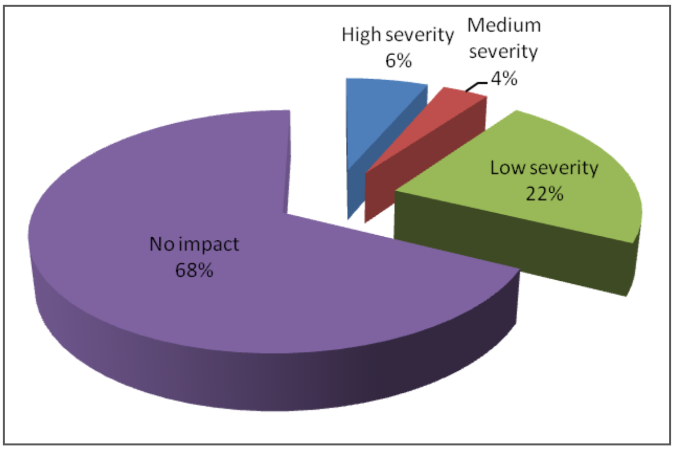


Figure 9-34: Impact of flooding events on public health (1859-2011)

Source: WDD, 2011

As shown in Figure 9-34, 6% of the recorded flooding events were characterized as of high severity for public health, 4% of medium severity and 22% of low severity, while the majority of flooding events did not have any impact on human health.

Taking into account the above, the sensitivity of Cyprus population to floods and storms is considered **limited to moderate**.

Exposure

The flood hazard distribution map of Cyprus (Figure 9-35) indicates that the risk ranges from high to very high levels at the regions close to Nicosia and Morphou while at the southern coastal areas of Paphos, Limassol and Larnaca the risk is medium. In the rest area of Cyprus particularly in the Troodos Mountains, where the population density is low, the risk is very low.

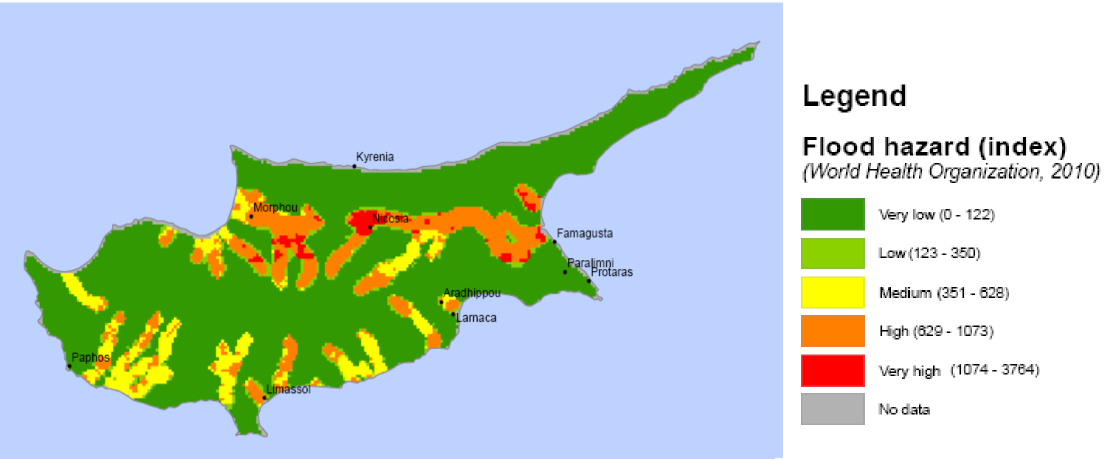


Figure 9-35: Flood hazard distribution map of Cyprus

Source: WHO, 2010. Available at: http://www.whoeatlas.org/europe/images/map/cyprus/cyp-flood.pdf

The total number and percentage of the population estimated to be exposed to floods in Cyprus by level of hazard are presented in the following table.

Table 9-8: Total number and percentage of the population exposed to floods by level of intensity in Cyprus

Hazard	Hazard intensity levels and number and percentage of people exposed					
	Very high No. exposed (%)	High No. exposed (%)	Medium No. exposed (%)	Low No. exposed (%)	Very low No. exposed (%)	No data No. exposed (%)
Flood	185,389 (21.07%)	183,380 (20.85%)	27,752 (3.15%)	77,684 (8.83%)	378,452 (43.02%)	27,066 (3.08%)

Source: The WHO e-Atlas of disaster risk for the European Region - Volume 1. Exposure to natural hazards (version 2.0)

According to Table 9-8, 52% of people is estimated to be exposed to low and very low intensity levels of floods, while 42% is estimated to be exposed to high and very high flood hazard intensity levels.

Regarding to the future climate changes, the climate projection model used for the case of Cyprus does not provide estimates for the frequency and intensity of floods in the future. Nevertheless, there is an indicator referring to the annual maximum total precipitation over one day indicating heavy rainfall, which could also be associated with flood risk. However, the PRECIS model showed that a slight increase of about 2-5 mm is anticipated in western, inland and mountain regions. Additionally, southern and southeastern areas present an increase of about 1 mm in annual max total rainfall over 1 day. Consequently, the future exposure of population to flooding events can be characterized as limited. It must be noted though that this indicator alone is not sufficient for estimating flood risk since other factors play an important role as well.

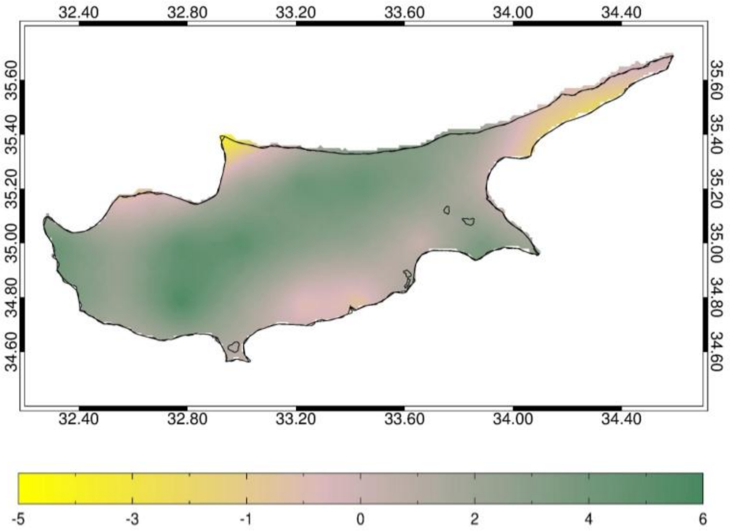


Figure 9-36: Changes in annual maximum total precipitation over 1 day between the future (2021-2050) and the control period (1961-1990)

Considering the above, the exposure of public health in Cyprus to floods can be characterized as **moderate**.

9.4.2.2. *Assessment of adaptive capacity*

For the protection of people during a severe flooding event, the civil preparedness and defense service of Cyprus is in place. In addition, the health care system of Cyprus cherishes injured people.

To prevent the occurrence of flooding events in Cyprus, a separate drainage system is being developed and expanded the last two decades in order to collect stormwater. So far, the drainage network in the majority of the big urban centres of Cyprus has been completed. Furthermore, the Sewerage Board of Limassol-Amathus in cooperation with the five municipalities of the Greater Limassol area as well as the wider area of Paphos began the implementation of Sustainable Urban Drainage Systems (SUDS). SUDS are actually a sequence of management practices, control structures and strategies designed to efficiently and sustainably drain surface water.

In Cyprus, 19 areas have been identified as areas for which Potential Significant Flood Risks exist or might be considered likely to occur, in accordance with the EU Directive on flood risk assessment and management. Furthermore, the directive states that Flood Risk Management Plans must be prepared by the end of 2015. It is expected that through the implementation of the Flood Risk Management Plans and the associated flood protection works, public health will be substantially safeguarded by the adverse effects of floods.

Considering the above, the adaptive capacity of Cyprus public health to floods is characterized as **moderate**.

9.4.3. Landslide-related deaths and injuries

9.4.3.1. *Assessment of sensitivity and exposure*

Sensitivity

The main population groups that are considered sensitive to deaths and injuries from landslides are (i) the elderly over 65 (13.3%) which cannot move easily and fast in case of a flooding event and (ii) infants and young children (16.1%) especially if they are not under the protection of adult (CYSTAT, 2011).

Taking into account the above, the sensitivity of Cyprus population to landslides is considered **limited to moderate**.

Exposure

According to the landslide hazard map produced by the World Health Organization (Figure 9-37), Cyprus population is not at risk from landslides, as in the greatest area of Cyprus the landslide hazard ranges from very low to low levels while only in the northern Turkish occupied part of Cyprus close to Kyrenia the hazard is medium.

Figure 9-37: Landslide Hazard Distribution Map of Cyprus

Source: WHO, 2010. Available at: http://www.who-eatlas.org/europe/images/map/cyprus/cyp-landslides.pdf

As shown in Table 9-9, the majority of the population in Cyprus (~97%) is exposed to low and very low landslide hazard, while only 0.01% is exposed to high landslide hazard.

Table 9-9: Total number and percentage of the population exposed to landslides by level of intensity for Cyprus

Hazard	Hazard intensity levels and number and percentage of people exposed					
	Very high (5)	High (4)	Medium (3)	Low (2)	Very low (0-1)	No data

Hazard	Hazard intensity levels and number and percentage of people exposed					
	Very high (5)	High (4)	Medium (3)	Low (2)	Very low (0-1)	No data
Landslide	0 (0.00%)	121 (0.01%)	182 (0.02%)	517,801 (58.86%)	332,476 (37.79%)	29,143 (3.31%)

Source: The WHO e-Atlas of disaster risk for the European Region - Volume 1. Exposure to natural hazards (version 2.0)

Regarding future climate changes affecting the impact of landslide-related deaths and injuries, the only indicator provided by PRECIS refers to the annual maximum total precipitation over one day. However, PRECIS showed that a slight increase of about 2-5 mm is anticipated in western, inland and mountain regions. Additionally, southern and southeastern areas present an increase of about 1 mm in annual max total rainfall over 1 day (Figure 9-36). Consequently, the future exposure of population to landslides can be characterized as limited. It must be noted though that this indicator alone is not sufficient for estimating flood risk since other factors play an important role as well.

Therefore, the exposure of public health in Cyprus to landslide related deaths and injuries is considered **limited**.

9.4.3.2. Assessment of adaptive capacity

For the protection of people from landslides, the civil preparedness and defense force of Cyprus is in place. In addition, the health care system of Cyprus cherishes injured people. For the protection of communities living in landslide prone areas from future landslides, entire settlements have been relocated to safer places. In places where landslides have occurred, technical structures were built in order to prevent human accidents and damages to infrastructure.

Currently, there is an ongoing effort to create a database with the recorded landslides. Furthermore, the Geological Survey Department of Cyprus has undertaken a research project entitled ‘Study of landslides in areas of Paphos District’, the main purpose of which is to promote a more secure urban development. However no action plans have been developed to date for the prevention and management of landslides.

Considering the magnitude of the impact of landslides on public health which is estimated as limited to moderate, the developed adaptive capacity to cope with the impact, is characterized as **moderate**.

9.4.4. Fire-related deaths and injuries

9.4.4.1. Assessment of sensitivity and exposure

Sensitivity

The main population group that is sensitive to fire-related deaths and injuries are the elderly aged over 65 (13.3%, see

Table 9-2) which cannot move easily and fast in case of a fire event. In addition, infants and young children (16.1%, see

Table 9-2) which have not yet developed the sense of risk and of self-protection, are sensitive, since if not under the protection of adults they will be trapped in the fire. Considering that the total share of population which is sensitive to fires is 29%, the sensitivity of the population in Cyprus to fire related deaths and injuries is characterized as **moderate**.

Exposure

Given that there are no data on the number of people killed or injured during fire events in Cyprus, the exposure will be estimated based on the fire risk areas in conjunction with the population density in these areas (Figure 9-41).

The areas exposed to “very high” fire risk in Cyprus are mainly the forest areas of Troodos’ mountains and the northern Pentadactylos range where the population density is very low. Moreover, in certain southern coastal areas close to Paphos and Limassol where the fire risk ranges from “moderate” to “low”, the population density is low (1-25 persons/km^2).

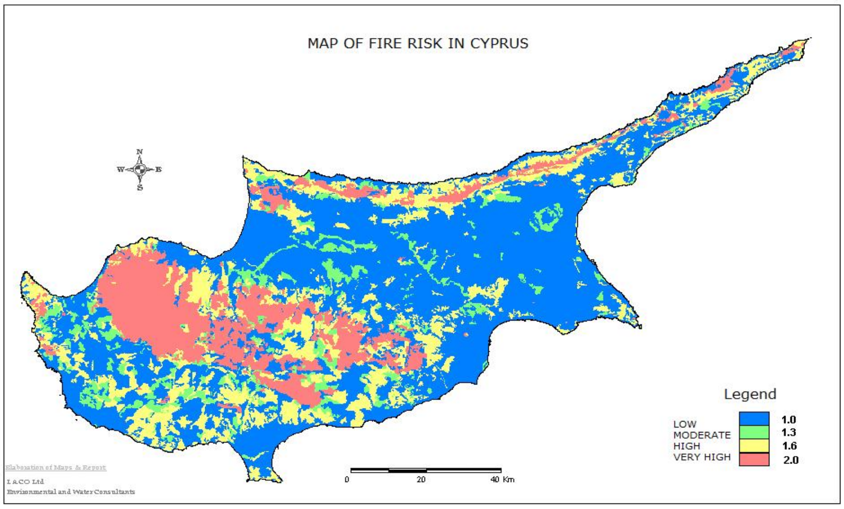


Figure 9-38: Map of fire risk in Cyprus

Source: Environment Service, 2007

In addition, according to the Fire Weather Index (FWI) which is also used for estimating fire risk as it was calculated by the PRECIS model, the highest values of fire risk are presented during summer and more specifically during the months of July and August. According to PRECIS, the FWI reaches extremely high values of about 50 (extreme high risk) in forested areas during July in the control period (1960-1990). Districts that present these excessive values are inland Limassol, Nicosia and Larnaca where FWI varies from 40 to 50. In Paphos District, FWI presents lower values of about 10 in coastal areas and 20-30 in the Paphos Forest in the northwestern part of Troodos Mountain. However, the areas with high FWI are mainly forested inland areas which are not densely populated (Figure 9-41) with the exception of Nicosia.

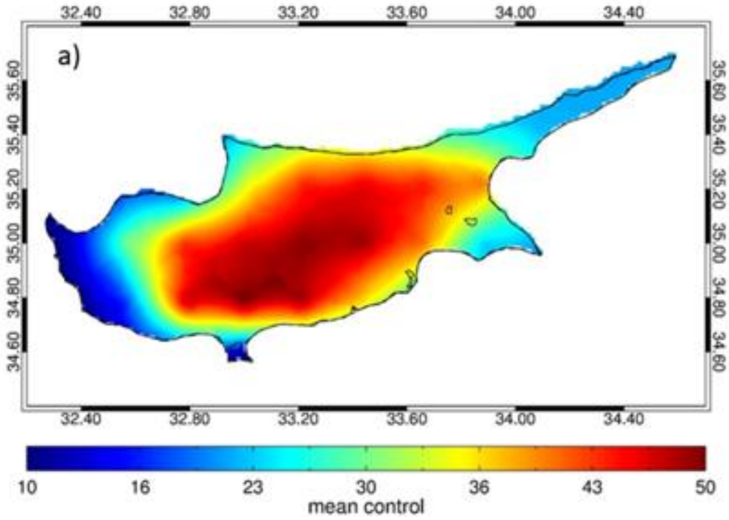


Figure 9-39: July average FWI in the control period (1960-1990)

As far as PRECIS near future (2021-2050) FWI projections are concerned, a small increase of FWI is estimated all over the Troodos Mountain of about 1-2 in low altitudes and 3-5 in high altitudes. In addition, a small increase in FWI of about 2 in forested areas of Limassol, Nicosia and Larnaca Districts is noted. However, from Figure 9-41 it can be seen that the areas with increases in FWI are mainly forested areas which are not densely populated.

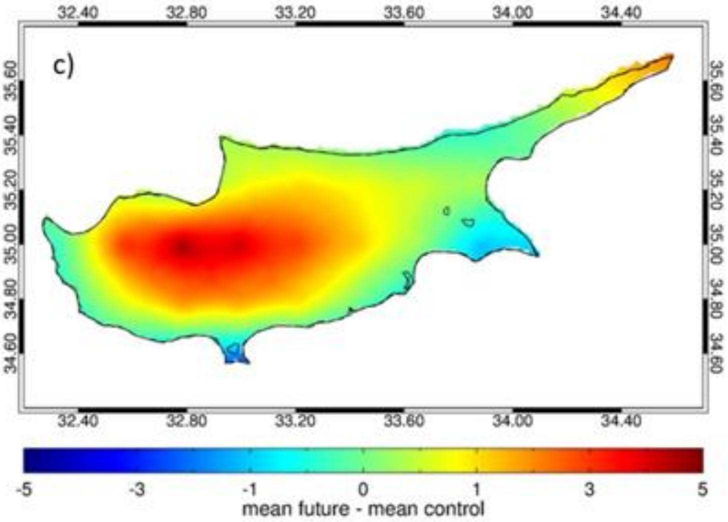


Figure 9-40: Changes in July average FWI in the near future (Future – Control period)

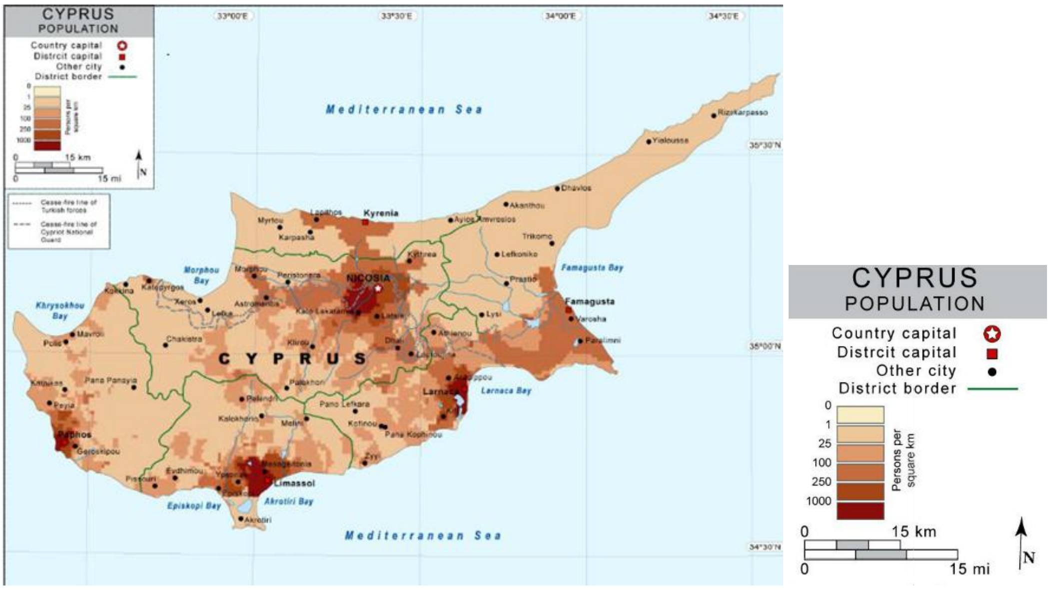


Figure 9-41: Population density in Cyprus

Source: http://www.bestcountryreports.com/Population_Map_Cyprus.php

Considering the geographic distribution of high fire risk areas as well as the population density of these areas, the exposure of the population in Cyprus to fire-related deaths and injuries is characterized as **limited to moderate**.

9.4.4.2. *Assessment of adaptive capacity*

In Cyprus, even though there are no specific adaptive measures for fires with regard to public health, the fire brigade, the civil preparedness and defense service as well as the health care system are in place in order to protect the population from fires.

Several measures are taken by the Forestry Department of Cyprus aiming to eliminate forest fires including prevention, pre-suppression, detection and suppression measures. The measures that directly concern public health are: information campaigns on fire prevention and protection, fire danger mapping, installation of fire protection systems in areas where large numbers of people may concentrate.

Therefore, the adaptive capacity of Cyprus public health to fire-related deaths and injuries can be characterized as **moderate**.

9.4.5. Vector-borne and rodent-borne diseases

9.4.5.1. *Assessment of sensitivity and exposure*

Sensitivity

Incidents of vector-borne and rodent-borne diseases are more likely to be detected in population groups with lower socio-economic status and lower access to sanitation. Population groups characterized by high risk of poverty in Cyprus amounted to 16% of the total population in the period 2005-2008 (see Table 9-1). Access to an improved sanitation system (public waste water network, septic tanks) is important, especially in urban areas where the risk of population contact with waste water is more frequent. In Cyprus 100% of the population living in urban and rural areas have access to sanitation (Figure 9-42).

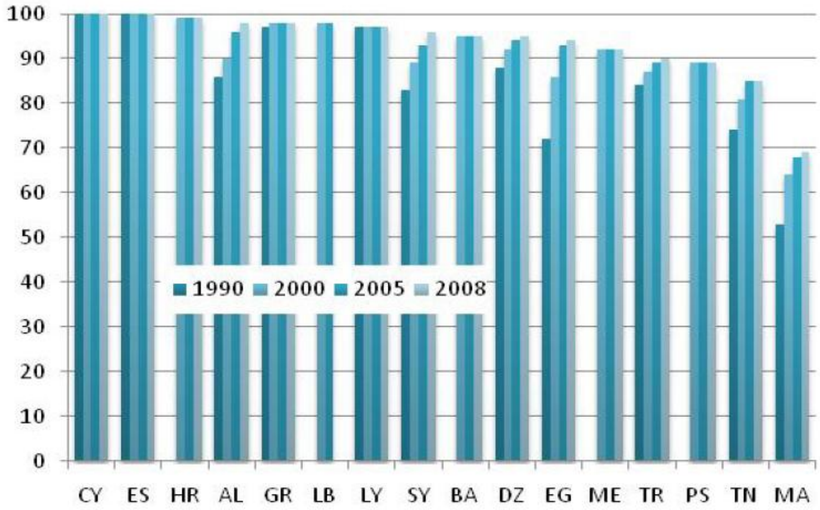


Figure 9-42: Share of population with access to an improved sanitation system, 1990 – 2006 (%)

Source: Plan Blue, 2011

Taking into consideration the above, it is estimated that the sensitivity of public health in Cyprus to vector-borne and rodent-borne diseases is **limited**.

<u>Exposure</u>

The exposure of public health to vector-borne and rodent-borne diseases is more possible during periods of increased temperatures, prolonged droughts or after floods as a result of the ideal conditions for the thriving of vector borne diseases (stagnation, contamination of small rivers). These conditions are a quite frequent phenomenon in Cyprus, especially during summers.

In 2007, the Cyprus Public Health Service has released a report on the mosquito surveillance program of the Republic of Cyprus conducted over the past 10 years. Twenty-three species belonging to 6 genera and 10 subgenera have been recorded to date, including species documented from earlier surveys. As a result of this program, new mosquito species for Cyprus have been recorded, including Anopheles marteri, Culex theileri, Cx. impudicus, Culiseta subochrea, and Uranotaenia unguiculata (Cosmatos, 2009).

However, Cyprus presents the lowest rate for vector-borne diseases among other countries. According to data provided by the United Nations Environment Programme UNEP, there have been no recent deaths in Cyprus due to malaria, although malaria did plague Cyprus for many years in the past. It was in 1946 when a well organized Anopheles eradication campaign started, while the official mosquito eradication completed on January 1950 (Cosmatos, 2009).

Projections for the period 2021-2050 according to the PRECIS model indicate that the average annual maximum temperature (TX) will increase by +1.0°C at the eastern and northern coasts and by +2.0°C in higher elevation areas and especially at the southwestern side of Troodos. The lowland and continental areas in the central part of the country present also notable changes in the average annual TX (mainly more than +1.5°C), followed by the western and southern coasts with a temperature increase limited to 1.3-1.7°C. It is considered that this indicator will have an impact on vector-borne and rodent-borne diseases in the future while its magnitude is not known yet.

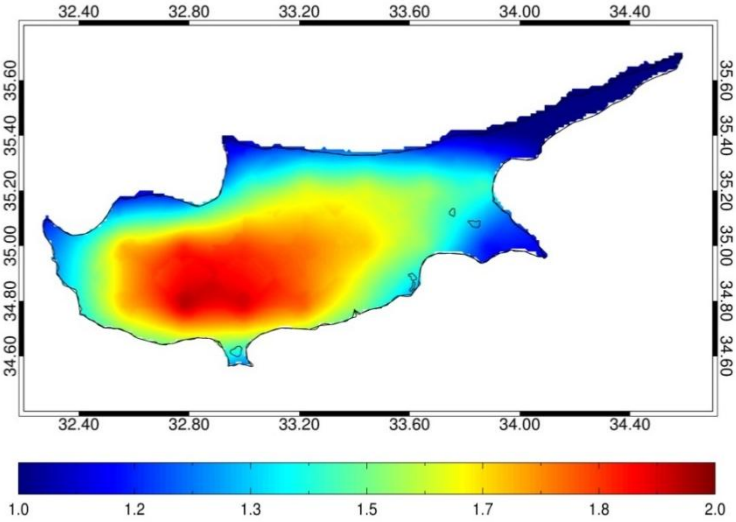


Figure 9-43: Changes in average annual maximum temperature between the future (2021-2050) and the control period (1961-1990)

As far as the length of drought periods in the future (2021-2050) is concerned, according to PRECIS (Figure 9-44), it is expected that the central part of Cyprus will face an increase of the maximum length of dry spell. In particular, the increase of this index will be about 15 days/year in the continental areas near Nicosia and Larnaca and approximately 20 days/year in the eastern part of Troodos (north from Limassol). On the other hand, the western coastal and higher elevation regions of Cyprus, as well as the area of Ayia Napa, is expected to have slight decreases or no changes in the maximum length of dry spell. It is considered that this indicator will have an impact on vector-borne and rodent-borne diseases in the future.

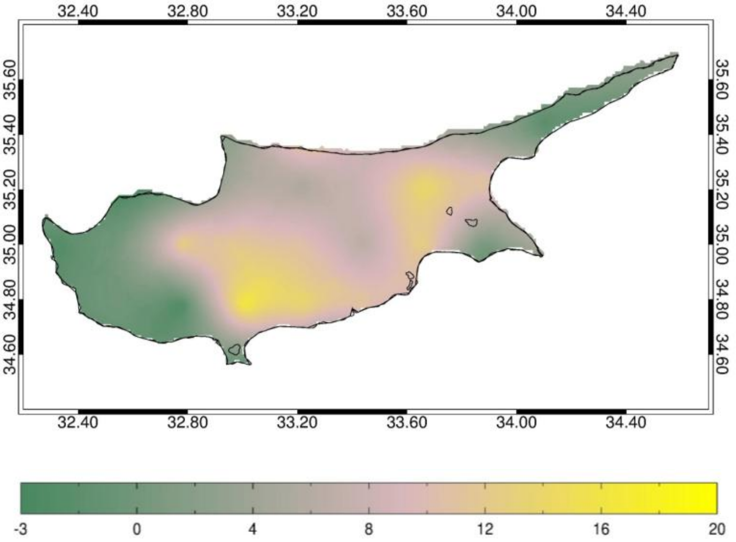


Figure 9-44: Changes in maximum length of dry spell (RR<0.5mm) between the future (2021-2050) and the control period (1961-1990)

The most relative indicator which PRECIS provides regarding flooding events, refers to the annual maximum total precipitation over one day. However, PRECIS showed that a slight increase of about 2-5 mm is anticipated in western, inland and mountain regions.

Additionally, southern and southeastern areas present an increase of about 1 mm in annual max total rainfall over 1 day (Figure 9-36). Thus, it is considered that this indicator will not have a significant impact on vector-borne and rodent-borne diseases in the future.

Considering the above, the exposure of public health in Cyprus to vector-borne and rodent-borne diseases is characterized as **limited to moderate**.

9.4.5.2. Assessment of adaptive capacity

Monitoring and identification of mosquito species is an important component of the Public Health Service's commitment to protecting the health of residents and preventing the spread of vector-borne diseases (Cosmatos, 2009).

The measures currently available to control vector-and rodent-borne diseases are disease-specific and can be broadly classified into diagnosis and treatment, vaccination, vector control, reservoir host control (spaying stagnant waters especially during summer), information and health education as well as disease surveillance and monitoring. In addition, the fact that 100% of the population in Cyprus has access to sanitation systems enhances Cyprus adaptive capacity.

Considering the above, the adaptive capacity of Cyprus public health to vector-borne and rodent-borne diseases can be characterized as **moderate**.

Following, additional recommended adaptation measures (Shoukri and Zachariadis, 2012) that are considered to further enhance adaptive capacity towards this impact are presented indicatively. Nevertheless, their assessment and final selection for implementation will be made through the use of the Multicriteria Analysis (MCA) tool which will be developed and implemented in the framework of Actions 4 and 5 of the CYPADAPT project.

- Strengthening public health system‘s ability to respond quickly to disease outbreaks
- Develop guidelines and proper training for medical doctors (private and public sector).
- Data collection and creation of inventories on vector borne diseases
- Increase monitoring and disease control
- Further research on disease control and prevention
- Implement a coherent early warning system
- Improve health infrastructure (hospitals, laboratories etc.)

9.4.6. Water-borne and food-borne diseases

9.4.6.1. Assessment of sensitivity and exposure

Sensitivity

Incidents of water-borne and food-borne diseases are more likely to be detected in population groups with lower socio-economic status, with lower access to sanitation and safe drinking water supply. Population groups characterized by high risk of poverty in Cyprus amounted to 16% of the total population in the period 2005-2008 (see Table 9-1). Access to an improved sanitation system (public wastewater network, septic tanks) is important, especially in urban areas where the risk of contact of the population with waste water is more frequent. In Cyprus 100% of the population living in urban and rural areas has access to sanitation (see Figure 9-42). Provided that many waterborne diseases are associated either directly or indirectly, to the quantity and quality of the water supply, people with limited access to clean water and adequate sanitation facilities are the most vulnerable. In Cyprus 100% of the population has access to safe water both in rural and urban areas (100%) (Figure 9-45).

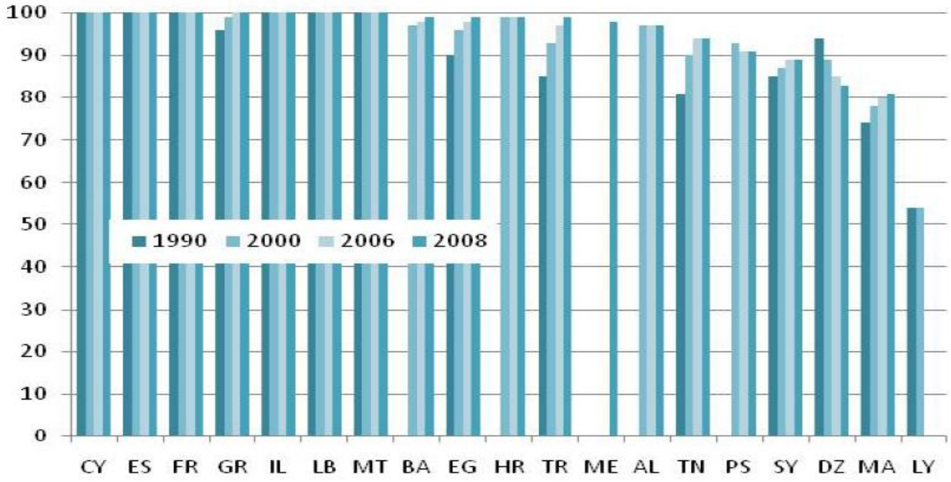


Figure 9-45: Share of population with access to an improved water source, 1990-2006 (%)

Source: Plan Blue, 2011

Taking into consideration the above, it is estimated that the sensitivity of public health in Cyprus to water-borne and food-borne diseases is **limited**.

Exposure

The data available on the actual exposure of public health in Cyprus to water-borne and food-borne diseases are limited, however these are presented next, indicatively. Twenty-six communicable diseases including cholera, dysentry, typhoid fever (all forms), infectious hepatitis A and food poisoning are notified in Cyprus under the Quarantine Law (WHO, 2003). An overview of the food-borne diseases notified in Cyprus during the period 1993 to 2000 is given in Figure 9-46.

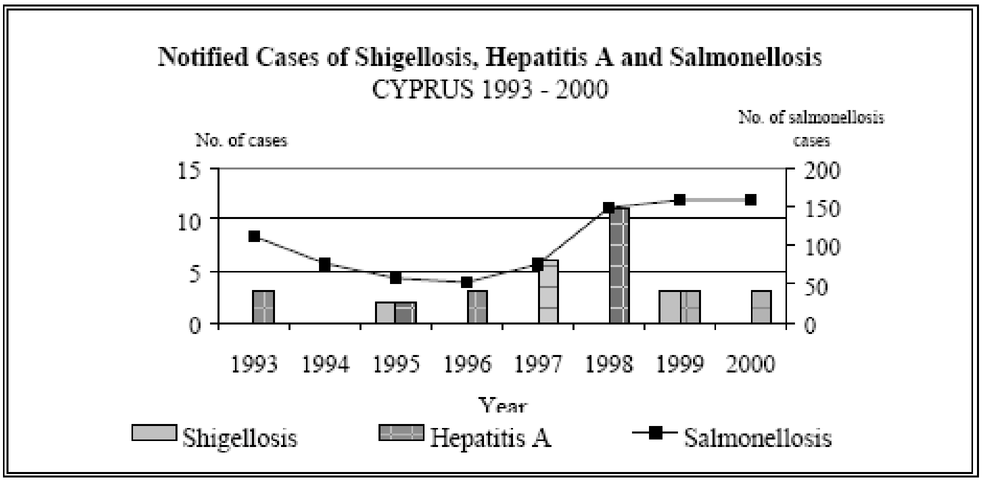


Figure 9-46: Notified cases of infectious diseases (1993-2000)

Source: WHO, 2003

Under the statutory notification system, a total of 168 and 164 cases of infectious diseases were notified in Cyprus in 1999 and 2000 respectively. More than 90% of the notified cases were salmonellosis.

Table 9-10: Number of notified cases and incidence rates of infectious diseases for the period 1999-2000

Disease	1999		2000	
	Number of notified cases	Incidence rate	Number of notified cases	Incidence rate
Salmonellosis	158	23.62	158	23.54
Staphylococcosis	0	0.00	0	0.00
Shigellosis	3	0.45	0	0.00
Cholera	0	0.00	0	0.00
Brucellosis	0	0.00	1	0.15
Hepatitis A	3	0.45	3	0.45
Echinononnosis	4	0.60	2	0.30

Source: WHO, 2003

Furthermore, taking into consideration the following facts:

- The estimated number of "healthy" life years lost (DALYs) attributable to water, sanitation and hygiene for 16 Member States of the EU27, shows that Cyprus is in the first place (reference year 2002)(see Figure 9-8);
- The recorded incidents of salmonellosis in Cyprus for the period 1984-2007 present a general increasing trend, although they remain quite below the average respective values in the EU (see Figure 9-9);

- The incidents of Hepatitis A in Cyprus are quite low (less than 1 incident/100,000 capita per year) for the period 1980-2007 while the respective value for the EU was significantly higher until recently when it declined (Figure 9-10),

the current exposure level of population to water and food-borne diseases can be characterized as limited to moderate.

The climate change factors that influence the exposure of public health in water-borne diseases through drinking water contamination are: decreased rainfall, increased temperature, increase in the frequency and intensity of droughts and floods. Following, the changes in the abovementioned factors in the period 2021-2050 compared to the period 1961-1990 for the case of Cyprus, are presented.

According to the PRECIS model, all north coasts and especially Karpasia peninsula are expected to receive less annual total precipitation in the future than that estimated for the recent past years 1961-1990. In all other parts of Cyprus, the annual total precipitation appears to have minor decreases or no changes at all with the exception of the area east from Paphos where an increase in total annual precipitation is noticed, minor though (up to 5mm). Thus, it is considered that this indicator will not have a significant impact on water-borne and food-borne diseases in the future.

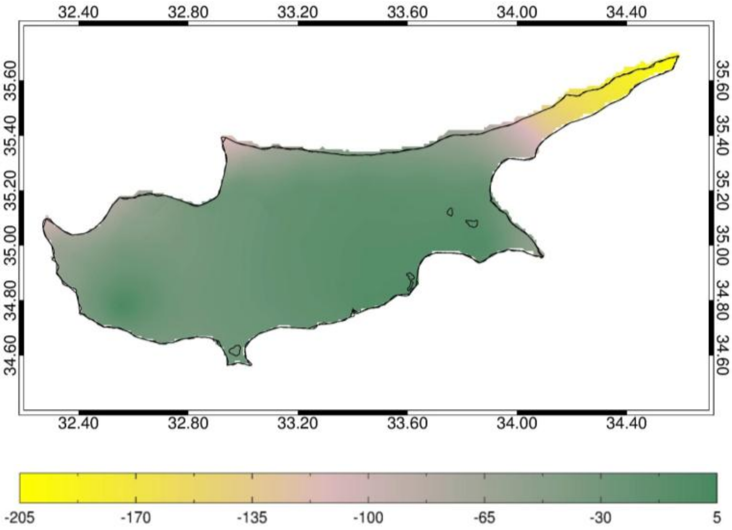


Figure 9-47: Changes in annual total precipitation between the future (2021-2050) and the control period (1961-1990)

Projections regarding the average annual maximum temperature (TX) indicate that there will be an increase of +1.0°C at the eastern and northern coasts and of +2.0°C in higher elevation areas and especially at the southwestern side of Troodos. The lowland and continental areas in the central part of the country present also notable changes in the average annual TX (mainly more than +1.5°C), followed by the western and southern coasts with a temperature increase limited to 1.3-1.7°C. It is considered that this indicator will have an impact on water-borne and food-borne diseases in the future while its magnitude is not known yet.

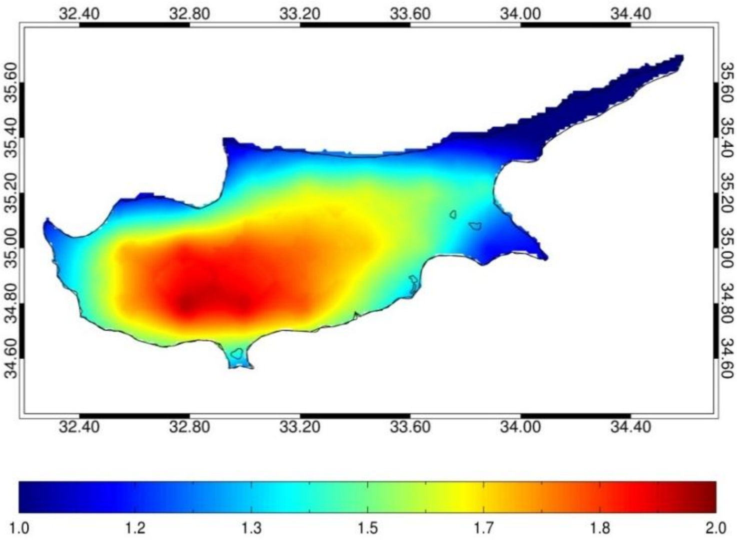


Figure 9-48: Changes in average annual maximum temperature between the future (2021-2050) and the control period (1961-1990)

As far as the length of drought periods in the future (2021-2050) is concerned, according to PRECIS, it is expected that the central part of Cyprus will face an increase of the maximum length of dry spell. In particular, the increase of this index will be about 15 days/year in the continental areas near Nicosia and Larnaca and approximately 20 days/year in the eastern part of Troodos (north from Limassol). On the other hand, the western coastal and higher elevation regions of Cyprus, as well as the area of Ayia Napa, is expected to have slight decreases or no changes in the maximum length of dry spell (Figure 9-44). It is considered that this indicator will have negatively affect water-borne and food-borne diseases in the future.

The most relative indicator which PRECIS provides regarding flooding events, refers to the annual maximum total precipitation over one day. However, PRECIS showed that a slight increase of about 2-5 mm is anticipated in western, inland and mountain regions. Additionally, southern and southeastern areas present an increase of about 1 mm in annual max total rainfall over 1 day (Figure 9-36). Thus, it is considered that this indicator will not have a significant impact on water-borne and food-borne diseases in the future.

Considering the current exposure level of population to water and food-borne diseases as well as the future climate changes that are associated with the impact, future exposure can be characterized as **limited to moderate**.

9.4.6.2. Assessment of adaptive capacity

The food-borne Disease Surveillance System in Cyprus (1999-2000) is illustrated in Figure 9-49. The system involves the collaboration between physicians and health care services. Notification of food-borne diseases by the attending physician is usually followed by laboratory confirmation of the infection. Because of this, it is not always possible to secure prompt action which would allow for the proper investigation and control of the disease.

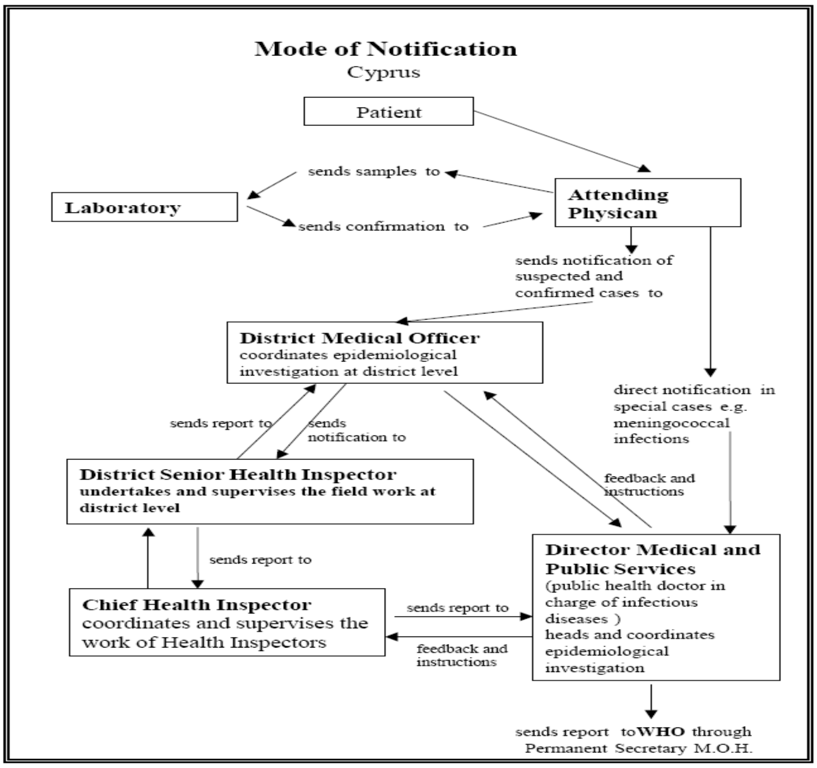


Figure 9-49: Cyprus notification mode of food-borne diseases

Source: WHO, 2003

The Ministry of Health, the Ministry of Agriculture, Natural Resources and Environment and the Ministry of Labour and Social Insurance jointly are responsible for environmental health. Their responsibilities include inter alia the monitoring of pollution levels and the monitoring of the environmental pollution level of drinking water supplies from pesticides and other micro pollutants. The General Laboratory of the Ministry of Health is responsible for performing controls on food and water samples for ensuring quality and safety. In addition, the National Committee for Nutrition which was established by the Ministry of Health in 1992 is responsible inter alia for monitoring compliance with state legislation on food safety and quality. In line with this a comprehensive list of controls is performed on food and water samples.

Finally, taking into account that (i) 100% of the population in Cyprus has access to sanitation, (ii) there is an effective food-borne surveillance system in place, (iii) there is continuous monitoring of water supply system and (iv) there is compliance with all food regulations, it is considered that the adaptive capacity of Cyprus to water-borne and food-borne diseases is **moderate to high**.

Following, additional recommended adaptation measures (Shoukri and Zachariadis, 2012) that are considered to further enhance adaptive capacity towards this impact are presented indicatively. Nevertheless, their assessment and final selection for implementation will be made through the use of the Multicriteria Analysis (MCA) tool which will be developed and implemented in the framework of Actions 4 and 5 of the CYPADAPT project.

- Strengthening public health system‘s ability to respond quickly to disease outbreaks
- Develop guidelines and proper training for medical doctors (private and public sector).
- Apply strict controls/health inspection in food industry and food service industry
- Data collection and creation of inventories on water and food borne diseases
- Increase monitoring and disease control
- Further research on disease control and prevention
- Implement a coherent early warning system
- Improve health infrastructure (hospitals, laboratories etc.)

9.4.7. Climate-related effects upon nutrition

9.4.7.1. Assessment of sensitivity and exposure

Sensitivity

Incidents of malnutrition are more likely to be detected in population groups with lower socio-economic status as well as to infants and young children. The population groups characterized by high risk of poverty in Cyprus amounted to 16% of the total population in the period 2005-2008 (see Table 9-1). The percentage of infants and young children amounts to 16.2% of the total population (see

Table 9-2).

Consequently, it is assumed that the sensitivity of public health in Cyprus to climate-related effects upon nutrition is **limited to moderate**.

Exposure

During drought years in Cyprus, the agricultural sector is the first to receive water cuts. As a consequence, significant reductions in farmers’ yields are recorded and especially in seasonal crops such as vegetables and potatoes.

In absence of data related to the quantities of damaged crops in Cyprus due to extreme climatic phenomena and their impact upon nutrition, the amounts of compensation provided to farmers for loss in their yields caused by frosts, droughts, heat waves, wind storms, hail and floods were used as indicators of current exposure, assuming that the amount of compensation provided is directly related to the crop areas destructed. As it can be seen from Figure 9-11 and Figure 9-12, the main climatic factors at which agricultural production is exposed are frosts and droughts.

Next, the future changes in the extreme climatic events causing damages to agricultural crops as these were calculated by PRECIS, are presented.

Frost nights (temperature below 0°C) cause serious damage to agricultural areas, especially where sensitive crops exist, such as orange and lemon groves. PRECIS projections (Figure 9-50) show that sensitive crops may benefit in future from climate warming since a decrease is anticipated in the number of frost nights of the order of 0-8 nights in Paphos, 2-8 nights in Limassol, 4-7 nights in Nicosia and 0-2 nights in Larnaca Districts. The model output shows that the highest decrease of frost nights reaches 6-9 days in the greater area around central and southern Troodos.

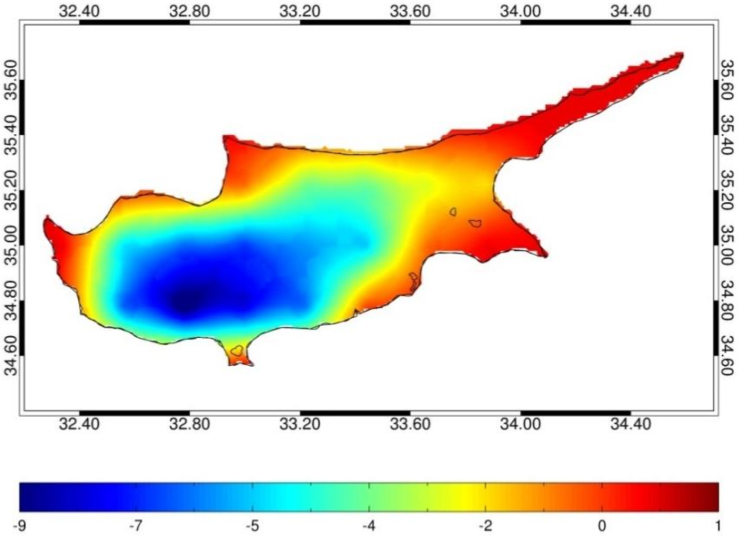


Figure 9-50: Changes in the annual number of frost nights (TN<0^{o}C) between the future (2021-2050) and the control period (1961-1990)

Dry spells highly influence sensitive plants to soil moisture content. According to PRECIS, it is expected that the central part of Cyprus will face an increase of the maximum length of dry spell. In particular, the increase of this index will be about 15 days/year in the continental areas near Nicosia and Larnaca and approximately 20 days/year in the eastern part of Troodos (north from Limassol). On the other hand, the western coastal and higher elevation regions of Cyprus, as well as the area of Ayia Napa, is expected to have slight decreases or no changes in the maximum length of dry spell (Figure 9-44). Thus, it is considered that this indicator will have a negative impact on agricultural losses in the future.

Under heat wave conditions, the productive stage of crops may be unfavourably affected. As PRECIS results testify (Figure 9-51), an increase of about 30 days is expected for the agricultural areas of Nicosia, Larnaca and Limassol Districts and 10 days for areas of Paphos

District. Consequently, the number of heatwave days over 35°C may reach in future 70 days in Nicosia, 60 days in Larnaca, 55 days in Limassol and 20 days in Paphos in contrast with current period where heatwave days are approximately 40, 30, 25 and 10 respectively.

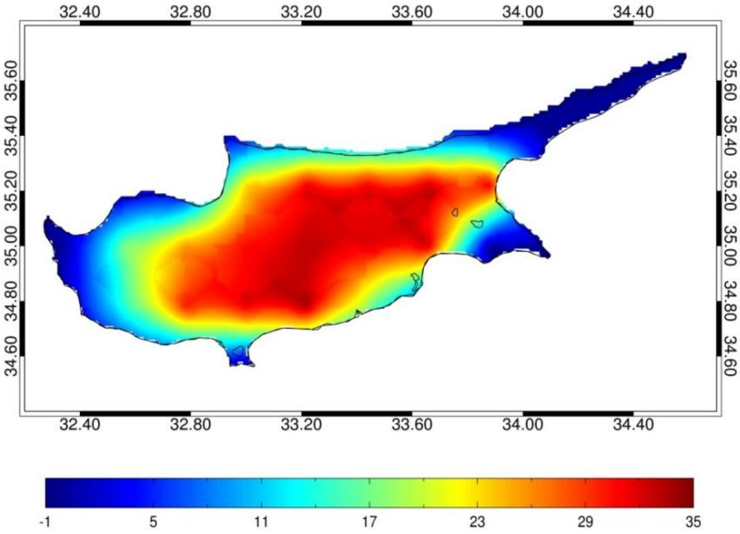


Figure 9-51: Changes in the average annual number of heat wave days (T>35°C) between the future (2021-2050) and the control period (1961-1990)

Extreme wind events are also associated with wind storms and damages to crops. Concerning future changes of extreme wind events according to PRECIS projections on the number of days with mean wind speed greater than 5 m/s, it is anticipated that in western, southeastern and inland areas a decrease of about 12 days will be noticed while in mountain areas the decrease will vary from 5 days to 10 days depending on the elevation. Also southern areas present a slight decrease of about 5 days. Consequently, the damages to crops due to extreme wind events are expected to decrease.

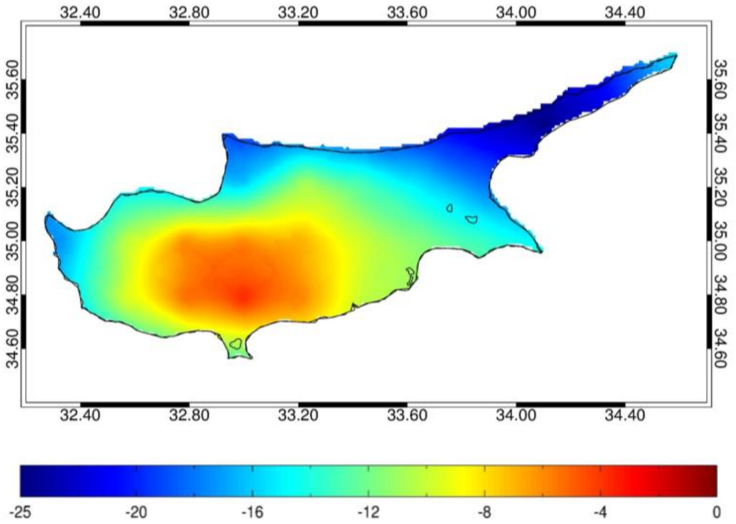


Figure 9-52: Changes in the number of days with mean wind speed > 5m/s between the future (2021-2050) and the control period (1961-1990)

Another important parameter associated with damages to agricultural crops is flooding. To get some insight into this threat, the maximum amount of rainwater that falls in a short period of time (1 day in this case) within the year is calculated. PRECIS projections show that a slight increase of about 2-4 mm is anticipated in western, inland and mountain regions. Additionally, southern and southeastern areas present an even minor increase of about 1 mm in annual max total rainfall over 1 day. It must be noted though that this indicator alone is not sufficient for estimating flood risk since other factors play an important role as well.

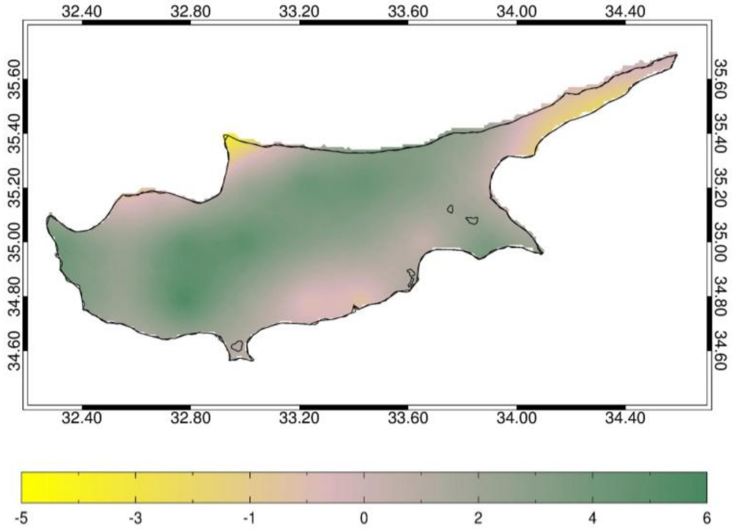


Figure 9-53: Changes in annual maximum total precipitation over 1 day between the future (2021-2050) and the control period (1961-1990)

However, the magnitude of the exposure on public health is also associated with the degree of dependence of the population on its agricultural production for satisfying its nutritional requirements. In Cyprus, nutrition is based on both agriculture and livestock national production but also on a great extent on imports, thus climate-related effects upon nutrition are considered to have **limited** exposure to public health.

9.4.7.2. Assessment of adaptive capacity

The measures to protect public health from undernutrition are associated with the measures to secure water availability for irrigation in periods of droughts (e.g. use of recycled water, increase water storage capacity, satisfaction of drinking water supply by desalination plants etc.) and the measures for the protection of crops from extreme climatic events (e.g. installation of hedgerows, green houses etc). Last but not least, the economic ability of Cyprus to secure food availability even when national productivity is reduced through imports of agricultural, meat and dairy products substantially enhances the adaptive capacity of Cyprus. It must also be noted that, the National Committee for Nutrition, is responsible inter alia for safeguarding the production and distribution of food products.

Consequently, the adaptive capacity of Cyprus public health to the climate-related effects upon nutrition can be characterized as **high**.

9.4.8. Air pollution-related diseases

9.4.8.1. Assessment of sensitivity and exposure

Sensitivity

Certain groups are potentially more vulnerable than others to air pollution. These include children, pregnant women, people over 65 years of age, and persons suffering from cardiovascular and respiratory diseases (e.g. asthma). Depending on their age, children may be more vulnerable than adults while elderly people may be particularly vulnerable to air pollution because the ability to eliminate chemicals from the body decreases with age. However, they may also be less sensitive to some effects such as irritation of the eyes and nose. Persons suffering from cardiovascular diseases are more vulnerable to particles and those suffering from respiratory diseases such as asthma are more vulnerable to several air pollutants. The data available on these population groups in Cyprus, show that the percentage of children under 14 years old is 16.1% of the total population in Cyprus (see

Table 9-2), the percentage of the elderly is 13.3% (see

Table 9-2) and that the percentage of admissions in hospitals with respiratory diseases diagnosed is approximately 8% of the total admissions while for the other population groups there are no sufficient data. Considering the above, it is estimated that a percentage above 30% is considered vulnerable to air population. Therefore, the sensitivity of Cyprus public health to air pollution is considered **moderate**.

Exposure

The ground-level ozone in Cyprus constitutes an overall transboundary problem. However, in the cities the ozone concentrations are lower than in the background because of the depletion by the primary emitted pollutants there. According to Figure 9-54, the ozone level in Cyprus shows high values in high elevated background areas like in Troodos Mountains while in the urban cities is low. Considering the fact that population density in the Troodos area is low, the exposure of population to ozone is limited.

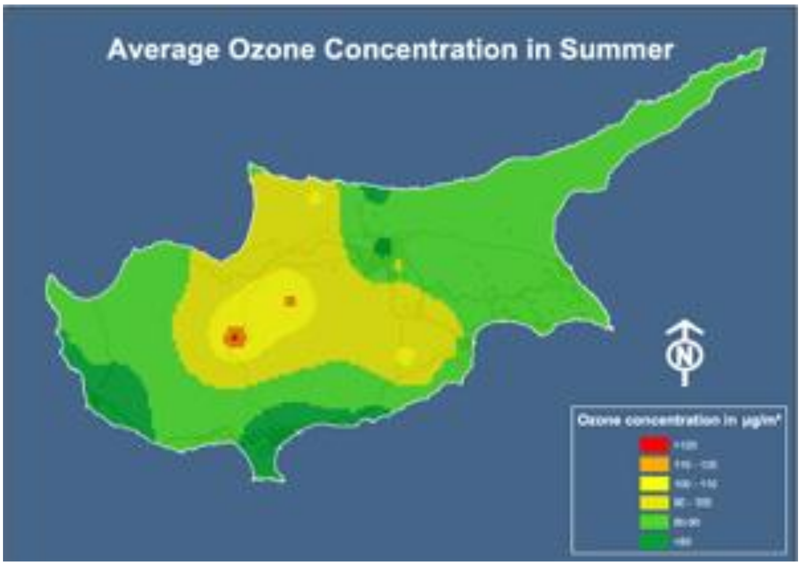


Figure 9-54: Average Ozone Concentration in Cyprus

Source: Department of Labour Inspection, Cyprus

According the results of “Preliminary Assessment of Ambient Air Quality and Drawing Up of Zones of Pollution in Cyprus" that was carried out in accordance with the EU Framework Directive 96/62/EC on ambient air quality assessment and management, the particulate matter (PM10) in Cyprus primarily originate from Sahara dust events and anthropogenic activities such as traffic and secondarily industrial activities. As it can be seen from Figure 9-55, the higher values of PM10 have been recorded in the main urban centers (reaching the EU limit values), where approximately 70% of the population leaves.

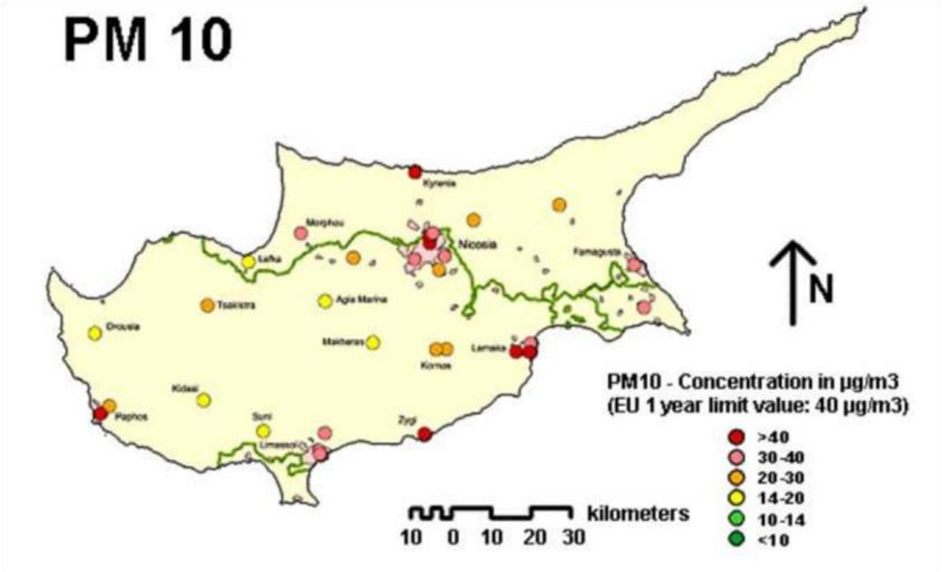


Figure 9-55: Annual PM10 concentrations in Cyprus including Sahara dust events

Source: Ministry of Labour and Social Insurance, 2007

As shown in Figure 9-56, the higher rates of nitrogen dioxide (30-40 and 40-54 µg/m^3 NO_2) are observed mainly in the urban areas and particularly in Nicosia, Limassol, Paphos and Larnaca, where approximately 70% of the population leaves.

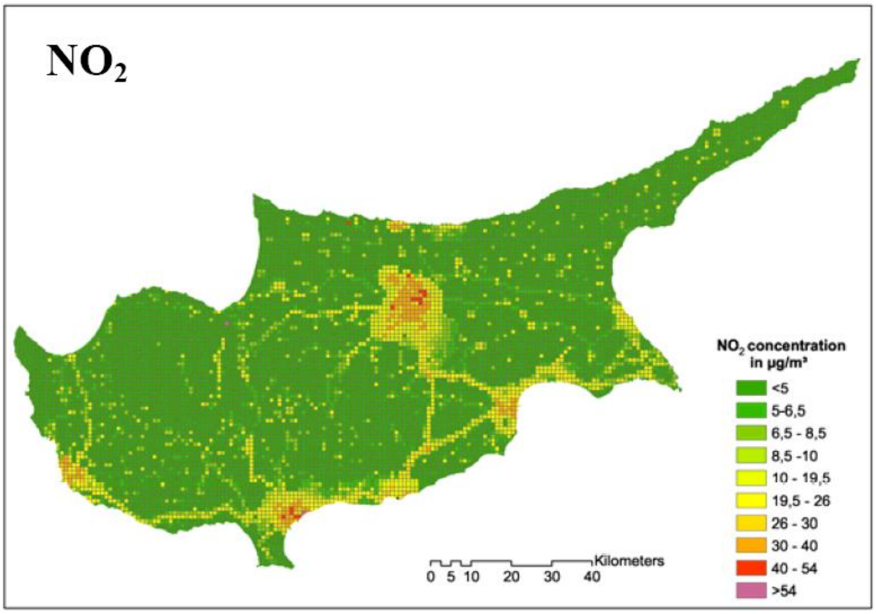


Figure 9-56: Spatial distribution of nitrogen dioxide (NO2) as an annual average during the years 2003-2004

Source: Ministry of Labour and Social Insurance, 2007

An increase in summer humidity would drastically increase the biological disease potential in the air. According to the Meteorological Service of Cyprus relative humidity of the air is on average between 65% and 95% in winter and between 40% and 60% in summer. Additionally, pollutants from forest fires in Cyprus can effect air quality for thousands kilometers.

According to the environmental burden of disease by category of air-related diseases of Cyprus, the country rates for cardiovascular diseases, asthma and respiratory infections are presented at the following table. Cyprus possesses low rates compared with world's rates (lowest and highest) while the rate of cardiovascular diseases is higher than those for asthma and respiratory diseases.

Table9-11: Environmental burden of disease for air-related diseases in Cyprus

Disease group	World's lowest country rate	Cyprus rate	World's highest country rate
Cardiovascular disease	1.4	3.6	14
Asthma	0.3	0.5	2.8
Respiratory infections	0.1	0.5	71

Source: WHO, 2009

The future changes (2021-2050) in climate which are associated with air-pollution related diseases are presented next.

According to the PRECIS model, the number of heat wave days (Tmax>35^{o}C) which are related to increases in the tropospheric ozone concentration, are expected to increase up to 20 days in coastal areas, with the exception of Famagusta, Larnaca and the coastal area between Larnaca and Limassol, where the increase in heat wave days will be more significant. It is also noted that the increase in the heat wave index, ranges from 30 to 35 days in the southeastern part of Troodos and in continental lowlands, especially near Nicosia (20 days) (Figure 9-18). By comparing spatial distribution of ozone concentrations (Figure 9-54) to changes in the frequency of heat waves in Cyprus, it can be said that ozone concentrations during summer are expected to substantially increase in the area of Troodos while an increase is also expected in the area of Larnaca.

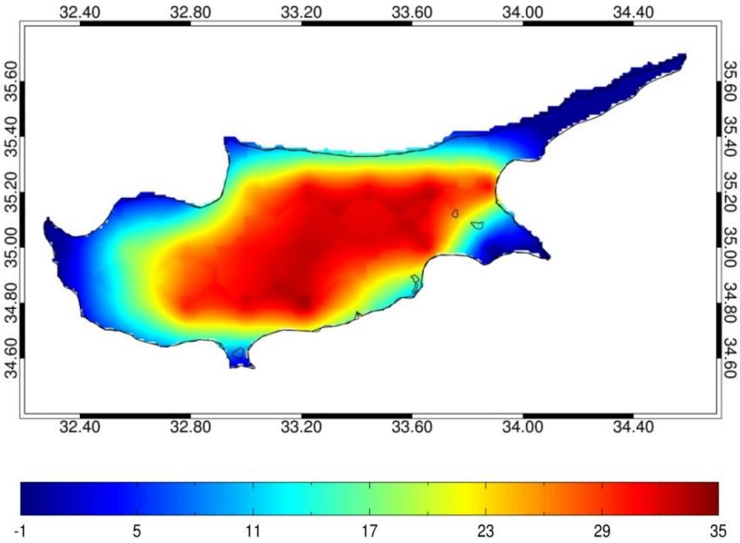


Figure 9-57: Changes in the number of heat wave days (T>35oC) between the future (2021-2050) and the control period (1961-1990)

As far as the length of drought periods in the future (2021-2050) is concerned, according to PRECIS (Figure 9-58), it is expected that the central part of Cyprus will face an increase of the maximum length of dry spell. In particular, the increase of this index will be about 15 days/year in the continental areas near Nicosia and Larnaca and approximately 20 days/year in the eastern part of Troodos (north from Limassol). On the other hand, the western coastal and higher elevation regions of Cyprus, as well as the area of Ayia Napa, is expected to have slight decreases or no changes in the maximum length of dry spell. Considering that the greatest concentrations of PM in Cyprus are located in the main city centers (Figure 9-55), the areas with the main increases in PM in the future are expected to be the wider area of Limassol, Larnaca and Nicosia.

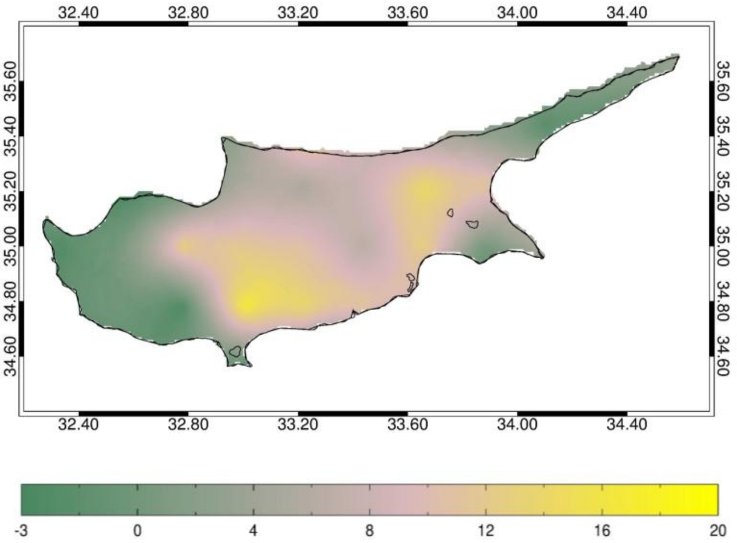


Figure 9-58: Changes in maximum length of dry spell (RR<0.5mm) between the future (2021-2050) and the control period (1961-1990)

Increased winds are also associated with increased PM concentrations in the air. PRECIS projections show that the future changes in the annual mean wind speed (Figure 9-59), in the highest mean wind speed and in the number of days with mean wind speed greater than 5 m/s will be negative for all the domain of the study. Thus, it is considered that the future PM concentration in the air will lower due to this indicator.

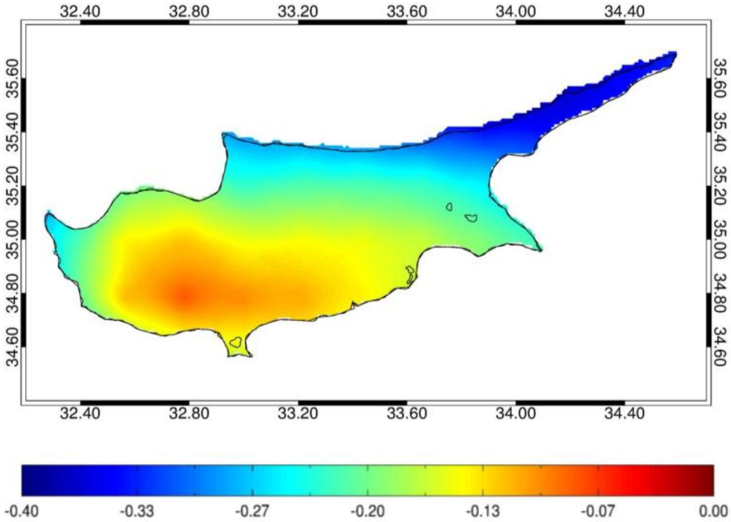


Figure 9-59: Changes in annual mean wind speed between the future (2021-2050) and the control period (1961-1990)

Regarding pathogen prevalence, this is enhanced by increased temperatures. Projections for the period 2021-2050 according to the PRECIS model indicate that the average annual maximum temperature (TX) will increase by +1.0°C at the eastern and northern coasts and by +2.0°C in higher elevation areas and especially at the southwestern side of Troodos. The lowland and continental areas in the central part of the country present also notable changes in the average annual TX (mainly more than +1.5°C), followed by the western and southern coasts with a temperature increase limited to 1.3-1.7°C. Similar patterns of spatial distribution are also expected to be experienced by pathogen prevalence in the future.

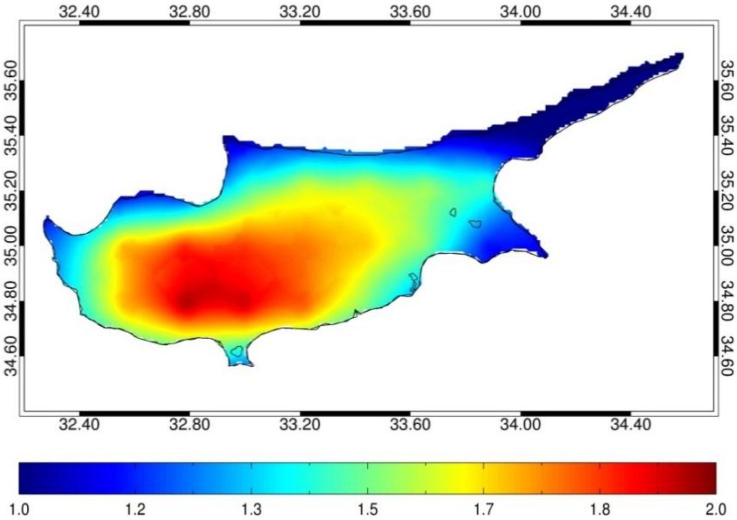


Figure 9-60: Changes in average annual maximum temperature between the future (2021-2050) and the control period (1961-1990)

Considering the above, the exposure of the public health of Cyprus to atmospheric pollution is characterized as **moderate**.

9.4.8.2. Assessment of adaptive capacity

The measures for controlling air-pollution related diseases are mainly related to the provision of medical services by the health care system of Cyprus for facing such diseases as well as measures for the prevention of such diseases, with the mitigation of air pollution. In specific, the Department of Labour Inspection of the Ministry of Labour and Social Insurance of Cyprus, operates a national network of nine stations for monitoring air quality (Ministry of Labour and Social Insurance, 2007).

The measures for air pollution mitigation applied in Cyprus are:

- ✓ Enforcement of air quality EU directive
- ✓ National and regional plans for air quality improvement
- ✓ Action Plan for the support of public transportation in Cyprus

Consequently, the adaptive capacity of Cyprus to deal with air pollution can be characterized as **moderate**.

9.4.9. Assessment of overall vulnerability

The principal aim of this chapter is to identify the key vulnerabilities of public health to future climate changes, as well as to assess the magnitude of these vulnerabilities. However, it must be noted that, as there were no sufficient data to evaluate all indicators further research is required.

In order to quantify the future vulnerability potential of public health against a climatic change impact, the values of sensitivity, exposure, adaptive capacity and vulnerability are quantified as follows:

Degree of sensitivity, exposure & adaptive capacity		Degree of vulnerability		Legend
None	0	None	V≤0	
Limited	1	Limited	0<V≤1	🟩
Limited to Moderate	2	Limited to Moderate	1<V≤2	🟨
Moderate	3	Moderate	2<V≤3	🟨
Moderate to High	4	Moderate to High	3<V≤4	🟧
High	5	High	4<V≤5	🟧
High to Very high	6	High to Very high	5<V≤6	🟥
Very high	7	Very high	6<V≤7	🟥
Not evaluated	-	Not evaluated	-	⬜

Since vulnerability is defined by the following formula:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity * \ Exposure$$

“Impacts” and “Adaptive capacity” should be evaluated on the same scale (1-7). For this to be achieved, the square root of “Sensitivity x Exposure” is used. The results of the future vulnerability assessment for the public health sector in Cyprus are summarized in Table 9-12.

Table 9-12: Overall vulnerability assessment of public health in Cyprus to climate changes

Impact	Sensitivity	Exposure	Adaptive Capacity	Vulnerability
Deaths and health problems related to heat waves and high temperatures	High (5)	Moderate to High (4)	Limited to moderate (2)	Moderate (2.5)
Flood-related deaths and injuries	Limited to Moderate (2)	Moderate(3)	Moderate (3)	None (-0.6)
Landslide-related deaths and injuries	Limited to Moderate (2)	Limited (1)	Moderate (3)	None (-1.6)
Fire-related deaths and injuries	Moderate (3)	Limited to Moderate (2)	Moderate (3)	None (-0.6)
Vector-borne and rodent-borne diseases	Limited (1)	Limited to Moderate (2)	Moderate (3)	None (-1.6)
Water-borne and food-borne diseases	Limited (1)	Limited to Moderate (2)	Moderate to High (4)	None (-2.6)
Climate-related effects upon nutrition	Limited to Moderate (2)	Limited (1)	High (5)	None (-3.6)
Air pollution-related diseases	Moderate (3)	Moderate (3)	Moderate (3)	None (0)

As it can be seen from the table above, the public health of Cyprus is not considered vulnerable to climate changes mainly due to the fact that it is characterized by a good adaptive capacity. The only vulnerability that was identified through the present study, is related to the deaths and health problems related to heat waves and high temperatures considering that heat waves are quite frequent during summer in Cyprus and that a significant percentage of the population in Cyprus is particularly sensitive to heatwaves (elderly people), while the adaptive capacity is not satisfactory enough given that the protection of the population from heat waves is not always possible.

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10 ENERGY

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Abbreviations and Acronyms

A/P	Airport
CDD	Cooling Degree Days
EEZ	Exclusive Economic Zone
HDD	Heating Degree Days
HFO	Heavy Fuel Oil
MCA	Multi-Criteria Analysis
PRECIS	Providing Regional Climates for Impact Studies
RCM	Regional Climate Model
RES	Renewable Energy Sources
RR	Precipitation
toe	tons of oil equivalent
tcf	Trillion cubic feet
TSO	Transmission System Operator
TX	Maximum Temperature

10.1. Climate change and energy

Cyprus is an island situated in the north-eastern part of the Mediterranean Sea. It constitutes an isolated energy system, the energy requirements of which are covered mostly by oil imports, making Cyprus a highly energy dependent island (Koroneos, 2005; Zachariadis 2010). Until recently, renewable energy was considered to be as the sole indigenous form of energy. However, recent studies have revealed that Cyprus has significant amount of fossil fuel resources in its Exclusive Economic Zone (EEZ) and in specific the initial evaluation work of Noble Energy Ltd indicates an estimated gross resource range of 5 to 8 trillion cubic feet (Tcf) of natural gas, with a gross mean of 7 Tcf (see Section 10.4.3.2). This is expected to change the energy mix profile and consequently to improve the energy security of the island.

On a worldwide basis, it is expected that the energy sector will experience different impacts due to climate change, including change of the heating/cooling degree days over year, reduction of the overall efficiency of the power stations associated with the increase in temperature of the cooling medium used in the energy production process, reduction in hydropower production etc.

According to EEA the Mediterranean basin has already been subjected to decreased precipitation something that is going to exacerbate as the climate change continues to persist and intensify. The decreased precipitation and stream flows will lead apart from low water availability, to decreased energy yield (regarding hydroelectricity). However, hydropower is not used in Cyprus and is not projected to be introduced to the energy mix of the island in the coming years, due to limited water resources and intermittent river flows.

The impact, vulnerability and adaptation assessment for the energy sector regarding climate changes that have occurred the recent years in Cyprus (CYPADAPT, 2012), showed that the energy sector of Cyprus in general is not considered very vulnerable to climate changes. In particular, the first vulnerability priority identified for the sector is related to the energy demand for cooling and heating, since it is directly affected by climate changes. However, given that there is potential for increasing energy supply in Cyprus in order to meet the increasing energy demand, the vulnerability towards this impact is characterized as limited to moderate. The second vulnerability priority is related to the efficiency of thermal power plants, which is not expected to be significantly affected by climate changes and thus the vulnerability was ranked as limited. With regard to the impact of climate changes on RES generation, no vulnerability was identified since the only type of RES which is expected to be significantly affected by climate changes is hydropower, which is not exploited in Cyprus due to the already limited water resources, while the impact of climate changes on the other types of RES is minor.

In the sections that follow, an attempt is being made to assess the impacts of future climate changes on the energy sector of Cyprus based on the climate projections output produced by the PRECIS (Providing Regional Climates for Impact Studies) regional climate model as well as on other socio-economic projections for the period 2021-2050. The reason why

PRECIS was selected to be used in the present study is that, unlike in other regional climate models, in PRECIS Cyprus lies at the center of the domain of the study. The future period 2021-2050 has been chosen, instead of the end of the twenty-first century as frequently used in other climate impact studies, in order to assist stakeholders and policy makers to develop near future plans.

10.2. Baseline situation

10.2.1. Energy demand

In order to obtain an understanding of the energy profile of a country, a number of aspects should be examined, including but not limited to the following:

- Primary energy production;
- Gross inland energy consumption;
- Final energy consumption; and
- Electricity consumption.

These figures are examined and analyzed in the following sections. It must be noticed that electrical consumption was examined separately due to its particular significance for the energy sector.

10.2.1.1. Primary energy production

As defined by Eurostat, primary production comprises any kind of extraction of energy products from natural sources to a usable form (e.g coal mines, crude oil fields, hydro power plants, fabrication of biofuels etc.). It must be noticed that any transformation of energy from one form to another, such as electricity or heat generation in thermal power plants, or coke production in coke ovens, is not primary production (Eurostat, 2007).

In Cyprus, there are no indigenous energy resources, apart from renewable energy sources (RES). To this end, in order to meet the energy requirements of the island, the vast majority of fuels (>95%) is imported, making Cyprus a highly energy dependent island. The primary energy production of the year 2010 totaled 84,000 tons of oil equivalent (*toe*), while according to the latest data provided by the Energy Service of the Ministry of Commerce, Industry and Tourism[1] the breakdown by RES source category is as follows:

- Solar thermal: 61,070 toe;
- PV systems (electricity): 550 toe;
- Biomass: 10,072 toe (6,215 toe thermal and 3,021 electricity);
- Biofuels (transport): 4,963 toe;
- Used oils (thermal): 5,466 toe;

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[1] Contact person: Eleni Topouzi, Energy Service, Ministry of Commerce, Industry and Tourism of Cyprus

- Tires and other fuels: 1,698 toe; and
- Geothermal: 753 toe

10.2.1.2. *Gross inland energy consumption*

As defined by Eurostat, the gross inland energy consumption[2] represents the quantity of energy necessary to satisfy inland consumption of the geographical entity under consideration and it covers: (a) consumption by the energy sector itself; (b) distribution and transformation losses; (c) final energy inland consumption by end users; and (d) statistical differences (between primary energy consumption and final energy consumption).

The total gross inland energy consumption in Cyprus totaled 1,728 ktoe in 2010 (excluding road and air transport which represent an additional 989ktoe, resulting to a total of 2,717ktoe) (Eurostat[3]).

10.2.1.3. *Final energy consumption*

According to Worldbank data, energy use in Cyprus expressed as kg of oil equivalent per capita for 2009 was 2,298 kg oil eq./cap, which was higher compared to the corresponding average value of 1,802.6 kg oil eq./cap on a worldwide basis.

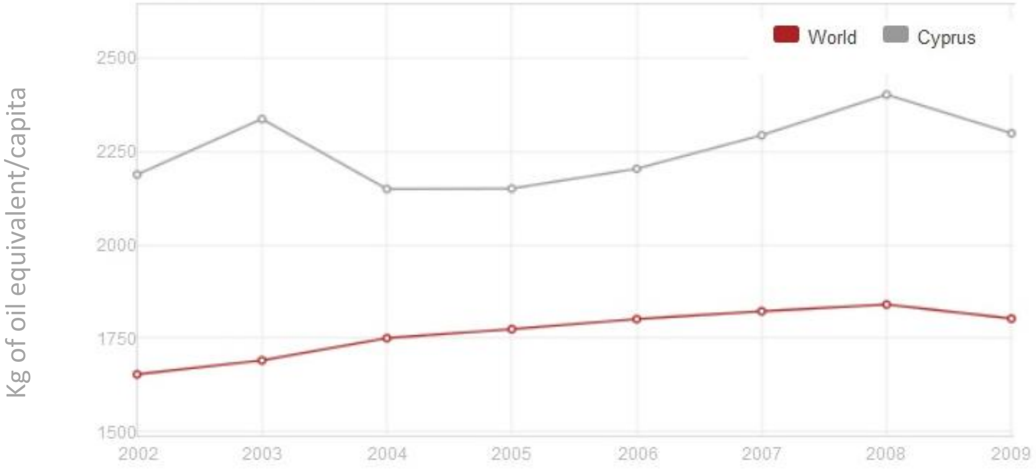

Figure 10-1: Energy use (kg of oil equivalent/capita) in Cyprus.

Source: http://data.worldbank.org/indicator/EG.USE.PCAP.KG.OE/countries/1W-CY?display=graph

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[2] It can be calculated by the following formula: primary production + recovered products + net imports + variations of stocks – bunkers. Sometimes it is referred to as "**primary consumption**".

[3] It must be mentioned that it is possible that an error message may appear when opening the page. Should this happen use the following link http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nrg_102a&lang=en and choose 'Final Energy Consumption' in the "INDIC NRG" field.

The final energy consumption[4] in Cyprus totaled 1,921 ktoe in 2010 and 1,926 in 2009 (including the transport sector). The major energy consumers along with their contribution to the final energy consumption are given below:

Table 10-1: Major energy consumers and their contribution to the final energy consumption of Cyprus

Energy consumers	2010[5]	2009 (EUROSTAT, 2011)
Transport	1,039 ktoe (54.1%)	1,019 ktoe (55.1%)
Households	295 ktoe (15.4%)	310 ktoe (16.8%)
Commerce & Services	235 ktoe (12.2%)	220 ktoe (11.9%)
Industry	236ktoe (12.3%)	260 ktoe (14.1%)
Agriculture & Fisheries	37 ktoe (2%)	37 ktoe (2%)

A more detailed picture of the final energy consumption and the energy sources balancing the energy requirements of each sector is presented in Figure 10-11.

The peak demand in 2010 amounted to 1,148 MW reflecting an increase of 4.6% from 2009 (1,098MW) while the minimum demand for the same year totaled 306 MW, as shown in Figure 10-2. In the same figure a diurnal variation of the power demand is presented.

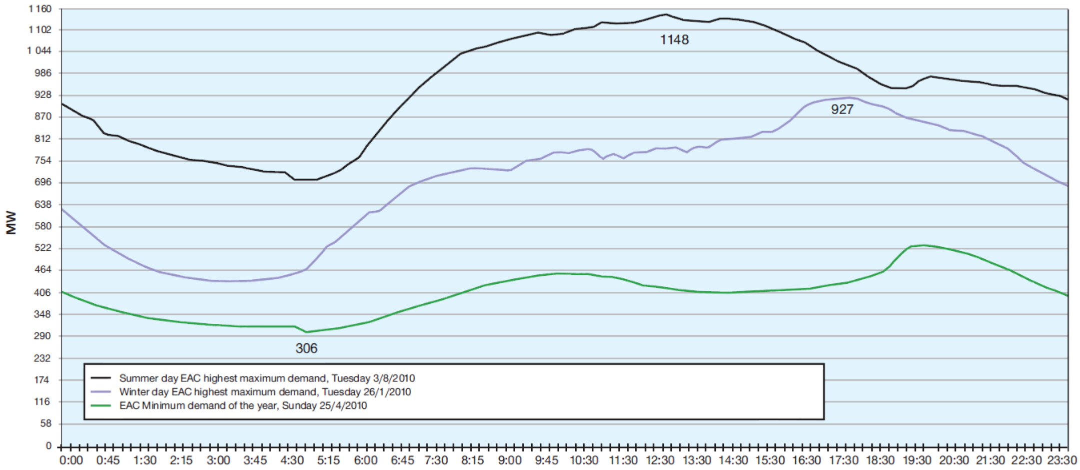

Figure 10-2: Peak and minimum demand in Cyprus in 2010

Source: EAC, 2011

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[4] Final energy consumption is the total energy consumed by end users, such as households, industry and agriculture and it excludes energy used by the energy sector, including energy transformation, transportation and deliveries.

[5] The information was obtained through communication with the Energy Service of the Ministry of Commerce, Industry and Tourism. Contact person: Eleni Topouzi.

Given that electrical supply plays a major role in the energy balance of an energy providing system, a comprehensive analysis of the electrical system is provided next.

10.2.1.4. Electrical demand

The total electrical requirements for the year 2010 were about 5,205,000 MWh, which represent a 28.71% increase compared to 2003 (7-year time period). A corresponding increase is expected by the year 2018, when a 33.14% (6,930,000 MWh) increase is estimated (EAC, 2010). The estimated maximum annual generation for the years 2011 to 2016 is presented in Table 10-2.

Table 10-2: Maximum Generation Demand

	2011	2012	2013	2014	2015	2016
Maximum Generation Demand (MW)	1,155	1,200	1,250	1,295	1,340	1,385

Source: TSO

The delivery of electricity to the different sectors of Cyprus for the year 2010 is presented in the following figure.

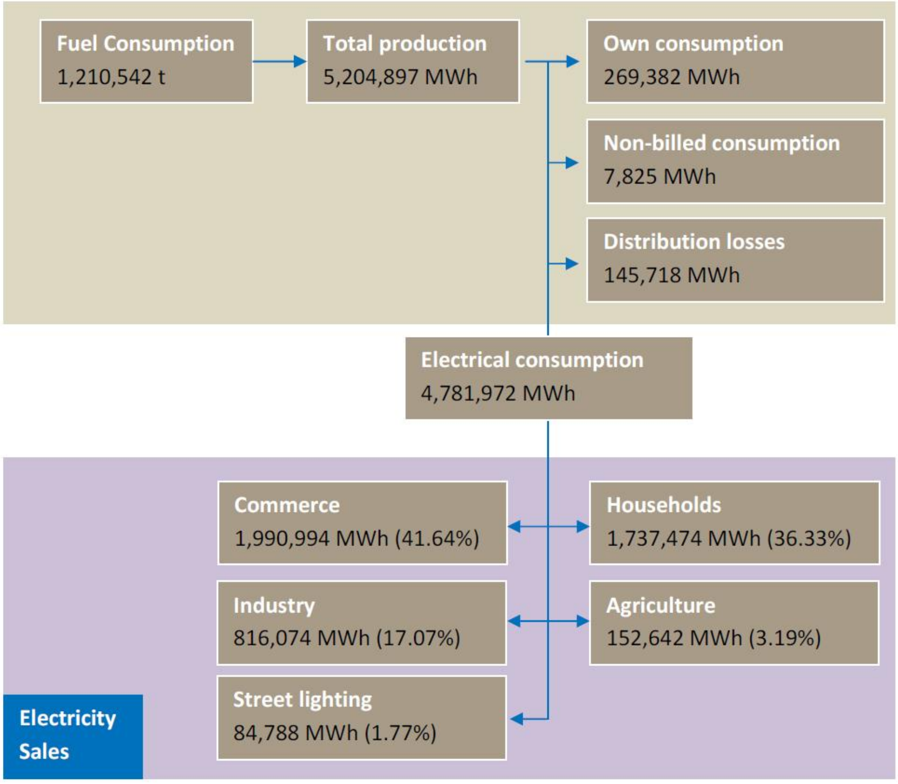

Figure 10-3: Share of different consumers in the electrical consumption in Cyprus

Source: EAC, 2011

10.2.2. Energy supply

As stated above, Cyprus has no indigenous energy resources (excluding renewable energy sources) and the energy requirements are covered to a great extent by oil imports. These amounts of petroleum products are used directly, as for heating purposes and indirectly, as for electricity production. In the following figure the final energy mix of Cyprus for the year 2010 is presented.

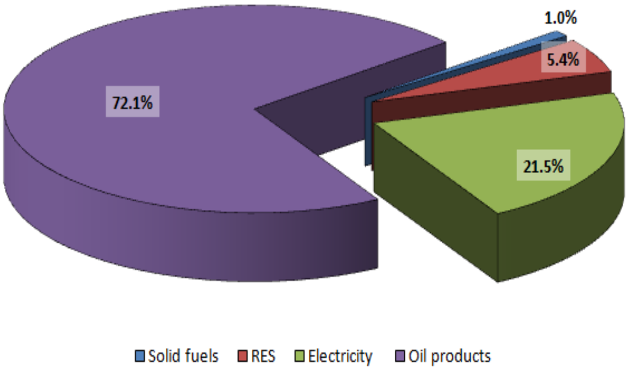

Figure 10-4: Final energy consumption, 2010 data

Source: Cyprus Energy Service

The share of conventional and renewable energy sources in the electricity production for the year 2012 in Cyprus is presented in the following figure. As it can be seen, 94.9% of electricity is produced from fossil fuels, 3.9% by wind parks, 0.8% by biomass and 0.4% by photovoltaics.

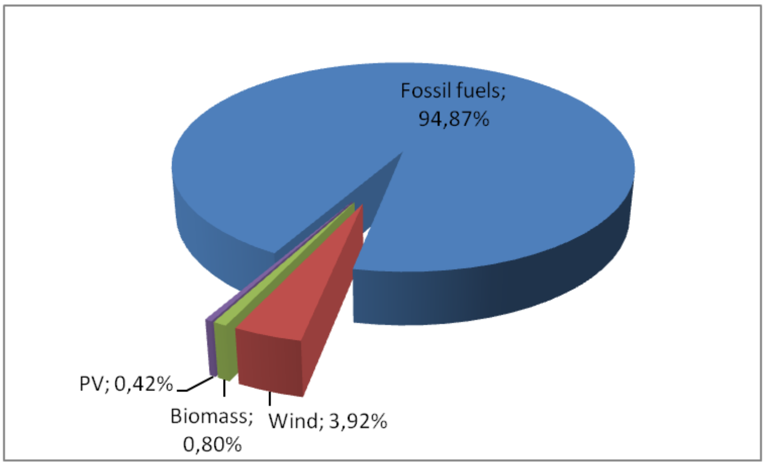

Figure 10-5: Share of conventional and renewable energy resources in the total electricity production in Cyprus (2012)

Source: Transmission System Operator, 2013; CERA, 2013

In regard with the indirect use of the fossil fuels for the production of electricity, different technologies are employed as discussed next.

10.2.2.1. Conventional electrical power supply

The electrical requirements of the island are provided by:

- three main power stations, namely: (a) Moni power station, (b) Vasilikos power station and (c) Dhekelia power station,
- self-producer installations (internal combustion units) whose total installed capacity reaches 21,6 MW (CERA, 2011).

Following a brief description of the public power stations is provided (EAC, 2011).

Moni Power Station

- **Location**: Southern coast of Cyprus
- **Total installed capacity**: 330 MW
    - 6x30 MW, steam turbine units burning heavy fuel oil. The last unit was commissioned in 1976, while the first two in 1966
    - 4x37.5 MW, oil fired gas turbines. The first two gas turbines were commissioned in 1992, while the other two in 1995
- **Thermal coefficient of efficiency**: (a) 24.56%, for the steam turbines and (b) 23,562%, for the gas turbines
- During 2010, Moni Power Station covered 4.98% (259,247 MWh) of the total electrical energy requirements

Vasilikos Power Station

- **Location**: Southern coast of Cyprus (25 km east of Limassol)
- **Total installed capacity**: 648 MW
    - 3x130 MW, steam turbine units burning heavy fuel oil (HFO)
    - 1x220 MW, Combined-Cycle Gas Turbines (CCGT)

  - 1x38 MW, diesel oil-fired gas turbine. This unit was commissioned in 1999 and mainly is used as a black start unit

- **Thermal coefficient of efficiency**: (a) 38.46%, for the steam turbines and (b) 22.73%, for the gas turbines, (c) 47.95% for the CCGT plant

- During 2010, Vasilikos power station covered 60.77% (3,162,958 MWh) of the total electrical energy requirements

Dhekelia Power Station

- **Location**: South east coast of Cyprus

- **Total installed capacity**: 460 MW

  - 6x60 MW, steam turbine units burning heavy fuel oil. The last unit was commissioned in 1993, while the first one in 1982

  - 2x50 MW, internal combustion units. The last unit was commissioned on the 1st of June, 2010.

- **Thermal coefficient of efficiency**: (a) 30.27%, for steam turbines and (b) 41.75%, for internal combustion engines

- During 2010, Dhekelias Power Station covered 34.25% (1,782,692 MWh) of the total electrical energy requirements

10.2.2.2. Renewable power supply

The share of renewable energy sources in the energy mix has increased quite recently in Cyprus under the Grant Scheme for the Promotion of Renewable Energy Sources (RES) and Energy Conservation. This increase is mainly attributed to the increase in the use of solar and wind energy. This policy measure received significant interest from the public, leading to a substantial increase in the number of applications and the amount of allocated funds (Figure 10-6) as well to the increase in the share of RES to the final energy consumption between 2006 and 2010. From a 2.5% share in total energy consumption in 2006, it reached 5.4% in 2010 (see Figure 10-7). By 2020, Cyprus has committed to the European Union that renewable energy will reach 13% (Kassinis, 2009; Kassinis, 2011).

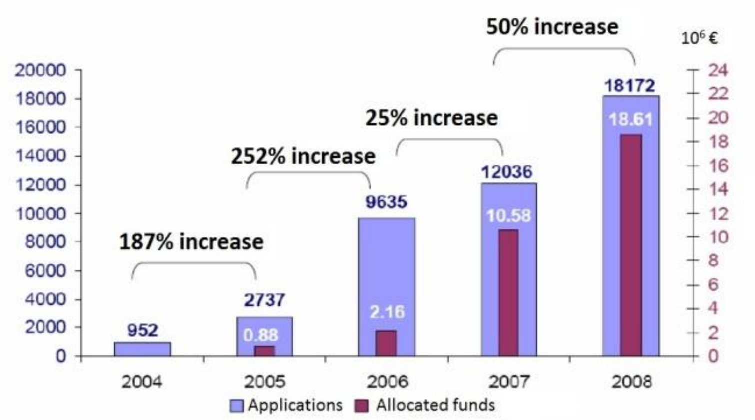

Figure 10-6: Applications and allocated funds for RES (2004-2008)

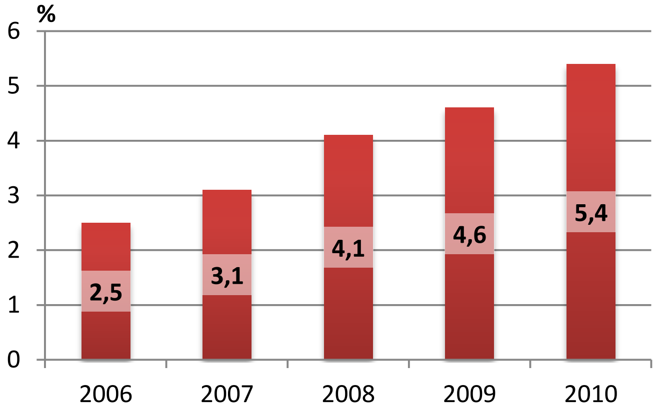

Figure 10-7: Penetration (share) of renewable energy sources in the final energy consumption

Source: Eurostat

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Solar energy

Cyprus is one of the most favorable areas worldwide in terms of solar potential. The solar energy potential of Cyprus is presented in Figure 10-8.

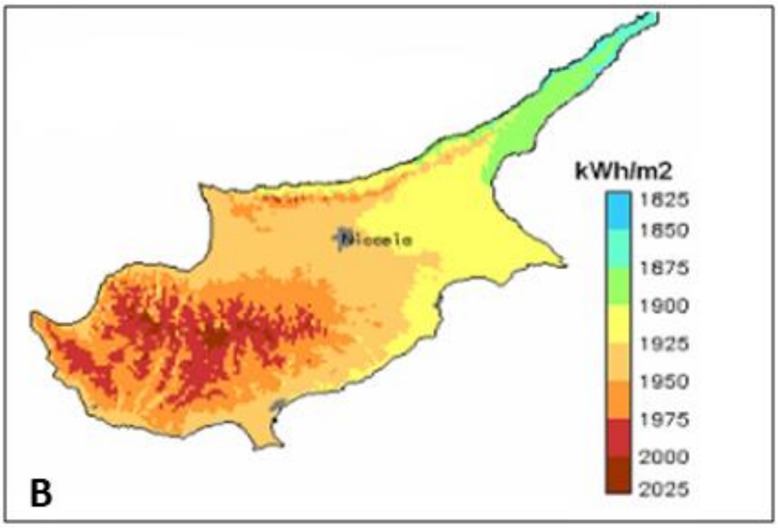


Figure 10-8: Yearly sum of solar irradiation in Cyprus received by optimally-inclined solar collectors

Source: Theodosiou, 2009

Various solar applications have already been installed, including:

- Power production systems
- Active solar systems.

At present, the only application for electrical power production in Cyprus from solar energy is the photovoltaic generator. Currently, the installed capacity has risen due to the supporting financial tool under the Grant Scheme for the promotion of RES. The installed capacity of photovoltaic systems currently amounts to 16.4 MW (CERA, 2013). Even though concentrated solar power (CSP) has not been developed until now, it is estimated that it will play a significant role in power production in the coming years.

In addition, active solar systems have been widely used in Cyprus with main representative application, the production of hot water. According to the Reviewed National Sustainable Development Strategy 2010 (MANRE, 2010), 92% of households and 53% of tourist accommodation units satisfy their hot water needs with renewable solar energy. In order for this energy conversion to be realized, solar thermal collectors are employed (mostly flat-plate collectors). Actually, Cyprus is a pioneer in this kind of applications, as it ranks first (see Figure 10-9) on a European level, in installed collectors per capita (~1m^2/capita).

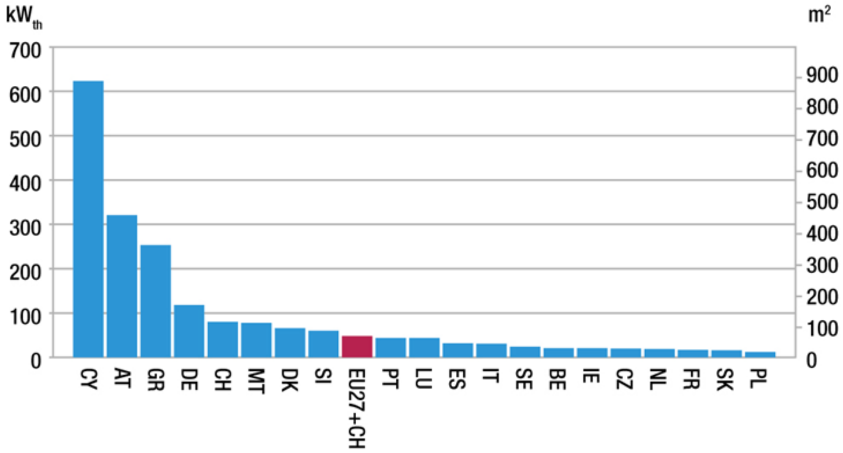


Figure 10-9: Solar thermal capacity in operation (per 1000 capita)

Source: ESTIF, 2011

Wind energy

Even though the potential for wind energy generation in Cyprus is relatively limited, there are regions with high wind potential that are suitable for the installation of wind farms. The average wind speed in some areas, which is suitable for the installation of wind farms, is about 5-6 m/s. The wind energy potential of Cyprus is presented in Figure 10-10.

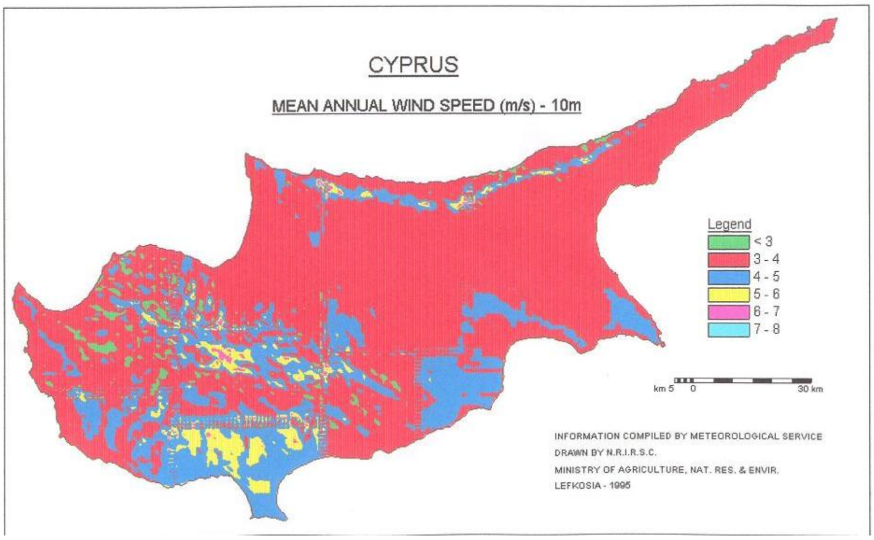


Figure 10-10: Spatial distribution of annual mean wind velocity in Cyprus

Source: Meteorological Service of Cyprus, 1995

According to the most recent information provided by the Cyprus Energy Regulatory Authority, five wind parks have been installed in Cyprus with a total capacity of 146.7 MW by the end of 2012 (CERA, 2013) and is expected to reach 165MW in the coming years (Kassinis, 2011).

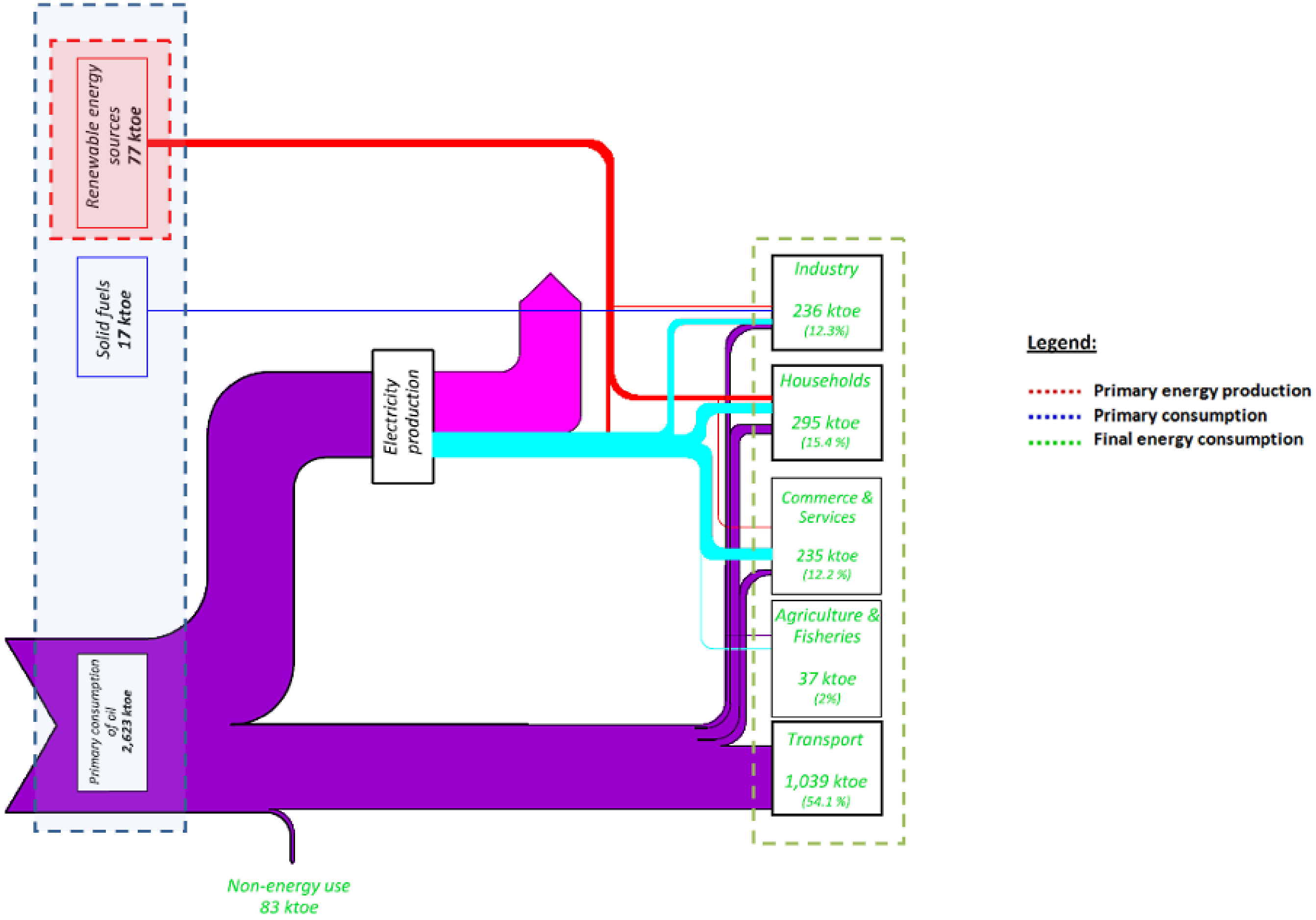
Hydroelectric energy

No hydropower plant exists until now in Cyprus while only two applications of 330 kW have been submitted to CERA (CERA, 2011).

Biomass energy

As regards the production of electricity from the use of biomass, by the end of 2012 there were 12 anaerobic digesters of farming wastes running with a total installed power of 8.8 MW (CERA, 2013). In addition, CERA has already issued 17 licenses for the construction of anaerobic digesters with total capacity of 14.9 MW and is examining two applications of 3.2MW total capacity.

Furthermore, bio-fuels have entered the market of transport fuels in Cyprus since 2007. According to a Ministerial Decision all suppliers of petroleum products are obliged to mix bio-fuels in conventional fuels so that the net annual amount of bio-fuels in the conventional fuels be at least 2.4% (around 6-7% biodiesel per volume in the conventional diesel). In Cyprus, only one company has been activated in the bio-fuel production sector, with 7,460 tn for the year 2008 (Kassinis, 2009), while according to more recent data the respective production for the year 2011 totaled 6,381tn.



Note: The primary energy consumption has been calculated on the basis of the formula described in Note 3, taking into account the following data provided by Eurostat: (a) Primary energy production: 84ktoe (out of which 77ktoe correspond to renewable energy), (b) recovered products: 1ktoe, (c) net imports: 2,924ktoe, (d) variation of stocks: -111ktoe and (e) international bunkers: 182ktoe. To this end, the primary energy consumption for the year 2010 equals to: 84+1+2,924-111-182≈2,717ktoe

Source: Own production (NTUA working team)

Figure 10-11: Energy balance for the year 2010 in ktoe

10.2.3. Pressures on the energy sector

10.2.3.1. Energy production cost

As analyzed in the following chapters, Cyprus shows particular vulnerability on the energy sector stemming from oil prices as the total amount of oil used is imported. The energy production cost depends on the following elements (EAC, 2011):

– Fuel oil:	63%
– Greenhouse gas emission rights:	0.9%
– Salaries and related costs:	15.6%
– Deficiency contribution to pension schemes:	1.7%
– Materials, services and other expenditure:	8%
– Depreciation:	10.8%

The energy production cost increased by approximately 26% from 2009 to 2010 (0.1159€/kWh and 0.14598€/kWh[6] respectively), mainly reflecting the increase (27.4%) in oil price (EAC, 2011). The price of oil shows a rising trend between 2009 and 2010, as depicted in Figure 10-12.

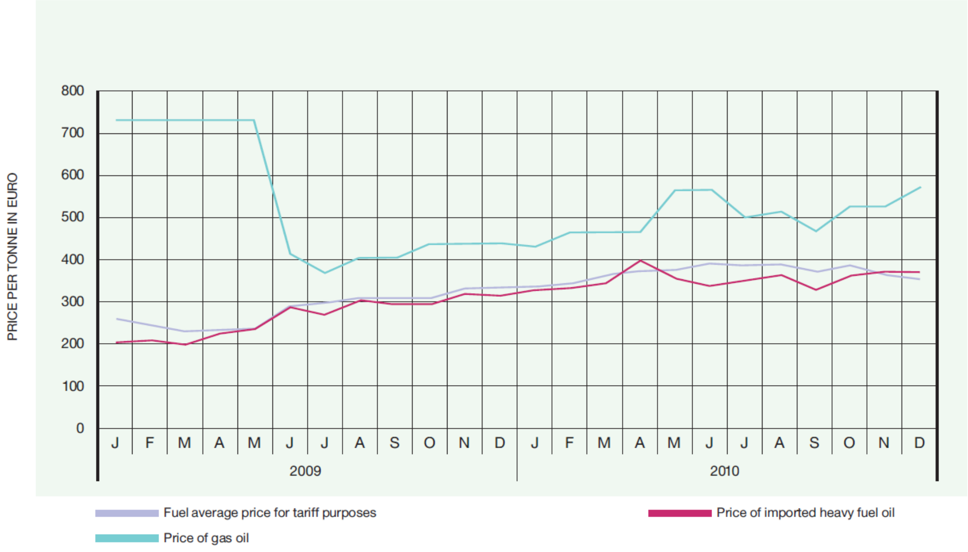


Figure 10-12: Fuel price between 2009 and 2010

Source: EAC, 2011

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[6] Energy produced (2009): 5,133.3 GWh (EAC, 2011; p.11), total operating cost (2009): 595,095€ (EAC, 2011; p.76)

10.2.3.2. Energy demand for water production from desalination plants

The rainfall decrease as well as the prolonged droughts has resulted in freshwater shortage in dams creating serious problems in terms of water availability in large urban and tourist centers as well as in agriculture. To reduce the dependence of drinking water on rainfall, the Government of Cyprus has resorted to operating seawater desalination plants which produce large amounts of fresh water to address the needs (WDD, 2011b).

Although seawater desalination seems to be a fairly satisfactory method of producing fresh water, it is a very energy-demanding process and therefore raises the issue of energy production required especially during the summer where energy demand is already at the highest level (due to air conditioners). The energy required to desalinate water is about 4.5 kWh/m^3 (Lange, 2011). Taking into account that a significant part of drinking water supply (46.862.000 m^3/year, ~65%) is based on desalination (MANRE, 2010) and, in specific, Reverse Osmosis (*RO*) plants, it is estimated that the aggregate electrical consumption for the operation of the three desalination plants in Cyprus totals 213,754.8 MWh/year (~4.4% of total electricity produced) (MANRE, 2010). Furthermore, it must be taken into consideration that desalination capacity has already substantially increased, thus increasing energy demand for that purpose in a great extent.

10.2.3.3. Energy demand for irrigation

It is expected that due to decreasing precipitation there will be longer irrigation periods. Since irrigated agriculture is based on pressurized irrigation systems and long conveyance pipe works, an increase in demand for electricity is expected.

10.3. Future impact assessment

In this section, the climate change impacts on the energy sector as these have been identified in Deliverable 1.2 "Climate change impact, vulnerability and adaptation assessment for the case of Cyprus" (CYPADAPT, 2012) will be reassessed in light of the climate projections for the future (2021-2050).

The climatic factors that are likely to induce impacts on the energy sector are the following: (a) temperature and relative humidity; (b) precipitation; (c) wind and cloud cover; (d) extreme events. The most significant climatic factors, with regard to the impacts on the energy sector, are temperature and humidity increase and decreased precipitation[7].

Following, the potential climate-induced impacts on the energy sector in general, and for the case of Cyprus in particular are recorded. To this end, the approach of this work is to provide, where possible, quantified results in order to measure to the greatest extent the impact on each energy sub-sector. In the context of the quantitative impact assessment the following indicators have been examined:

Table 10-3: Relationship between climate changes and impacts on the energy sector

Potential climate changes	Impacts
Increase in temperature and relative humidity	Increased cooling demand and decreased heating demand
	Decreased thermal efficiency in thermal power plants
Precipitation	Change in Hydropower generation
	Change in Bio-power generation
Wind speed	Change in Wind power generation
Cloud cover	Change in Solar power generation

In the following sections of this chapter, the future impacts of climate change on the energy sector are further analyzed where relative data and information are available. The impacts are presented according to their initial categorization in the current impact assessment (CYPADAPT, 2012), namely:

- Renewable energy yield;
- Efficiency of thermal power plants; and
- Energy demand.

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[7] Decreased precipitation is not considered as a significant climate factor, with regard to the impacts on the energy sector, as no hydro power plants exist in Cyprus (Section 10.2.2.2).

10.3.1. Renewable energy yield

As mentioned before, the primary energy production in Cyprus is limited only to renewable energy sources, while all fossil fuel resources used in the energy sector are imported from other countries.

According to the international bibliography, the renewable energy sources that are likely to be affected by climate change are the following: (a) hydropower; (b) wind power; (c) solar power and (d) bio-power (Kirkinen, 2005). The impacts observed on the aforementioned sources are discussed in the following sections.

10.3.1.1. Hydropower

The amount and seasonality of flow in most rivers can be affected by climate change, which in turn affects the power production by hydropower plants. According to the Environmental Energy Agency hydropower is expected to be significantly affected by climate-induced changes. However, hydropower production will vary across regions as different precipitation patterns and rates of hydropower deployment have been developed over time. More particularly, an increase in hydropower production by about 5% and more in northern Europe and a decrease by about 25 % or more in southern Europe is expected (EEA, 2010).

Situation in Cyprus

No hydropower plant exists until now in Cyprus, as the hydroelectric potential is very little to exploit. Consequently, no impact is regarded on the hydropower production in Cyprus.

10.3.1.2. Wind power

The maximum power that can be produced by wind can be estimated by the following formula:

$$\boldsymbol{P_w = \frac{\pi}{8} \cdot D^2 \cdot \rho \cdot U^3 P_w = \frac{\pi}{8} \cdot D^2 \cdot \rho \cdot U^3} \qquad \textit{(Equation 1)}$$

Where:

- D, the rotor diameter (m);
- ρ, the air density (kg/m^3); and
- U, air velocity (m/s).

The last two variables of the above equation (ρ, U) are dependent on climate changes. Moreover, it must be noted that even small changes in the air intensity can be translated into significant changes to the wind power produced, as the power is proportional to the third power of the wind velocity.

Moreover, a climatic factor that can affect the wind power produced and is not included in *Equation 1*, is the change in wind variability. For instance, if strong winds increase in frequency, wind power can be reduced, as there are specific cut-off wind velocities, depending on the type of the wind generator. As a result, even though in such a case the wind intensity rises, the produced power equals to zero. Finally, it is reported that wind power production can be affected indirectly by other factors such as rain and icing (Kirkinen, 2005).

Situation in Cyprus

Wind power was introduced to the Cypriot energy system in 2010. There are no available data for measuring the impact of climate change on wind power production in Cyprus.

Concerning future potential in wind power yield for the case of Cyprus, it must be mentioned that as projected by the PRECIS regional climate model, the annual mean wind speed will present decreasing trends in the range of -0.1 to -0.2 during the period 2021-2050. In addition, the highest mean wind speed is expected to decrease by 0.35 on average. Thus a decreasing trend in the already limited wind potential is anticipated, assuming that further development in wind power technology improving its efficiency will not take place.

Relative research for monitoring the impact of climate change to the wind potential and in turn to the wind power production is recommended. However, for the purpose of comparison with the impacts induced on the other sectors and only, it is suggested that:

- the impact on wind power can be characterized rather insignificant, since the contribution of wind power to the total electricity production is rather small (~4%) and in general, according to the international bibliography no significant changes are expected in wind potential on a worldwide basis.

10.3.1.3. Solar energy

The climate factors that can affect solar insolation are the following:

- Cloudiness;
- Atmospheric aerosol composition;

Generally, solar insolation drops with the increase of the above factors. However, due to the complex relationship between these factors and the unknown magnitude of the potential impact, it is unclear whether the effects of climate change will result in reduced solar insolation (Kirkinen, 2005).

In addition, photovoltaics, or solar panels, are affected by their operating temperature, which is primarily a product of the ambient air temperature as well as the level of sunlight. In specific, higher temperature results to reduced power production. The energy production efficiency of solar panels drops when the panel reaches hot temperatures which, on average, are about 20 degrees Celsius higher than the ambient air temperature. On the other hand, photovoltaic solar panel power production works most efficiently in cold temperatures. Cold, sunny environments provide optimal operating conditions for solar panels.

<u>Situation in Cyprus</u>

Cyprus is one of the most favorable areas worldwide in terms of solar potential. As a matter of fact, 92% of households and 53% of tourist accommodation units satisfy their hot water needs with the use of active solar systems while 1,039 PV units were installed by the end of 2012 all over Cyprus.

In order to study the observed impacts, if any, on the yields of the systems mentioned above it is essential to study first the observed and projected changes in solar potential due to climate change.

The composition of the atmosphere is being observed by the Meteorological Service of Cyprus since 1990. The number of days with dust in suspension presents an increasing trend over time as depicted by the following diagram.

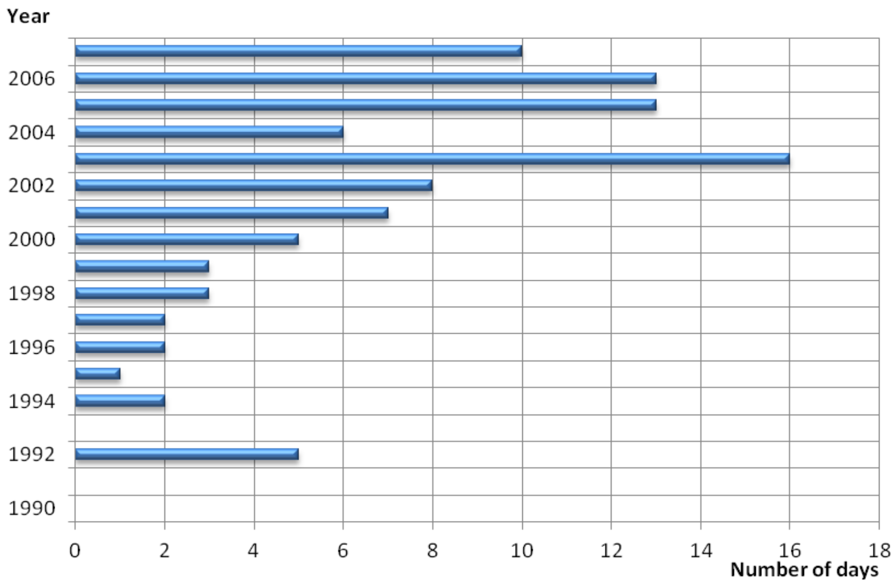
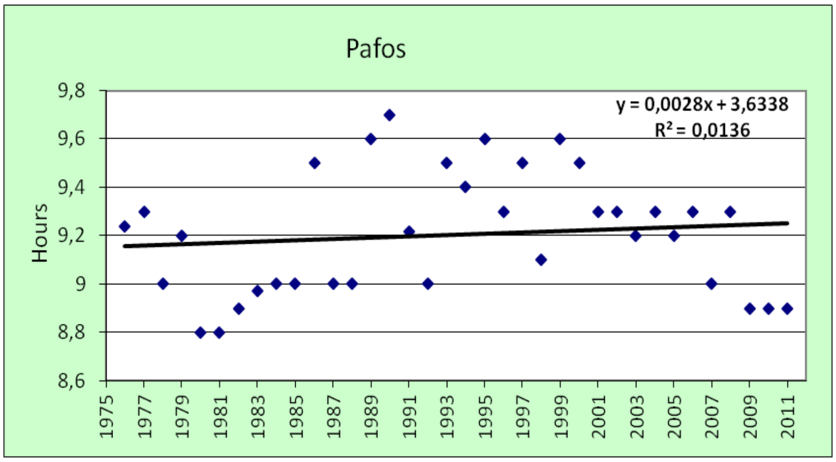


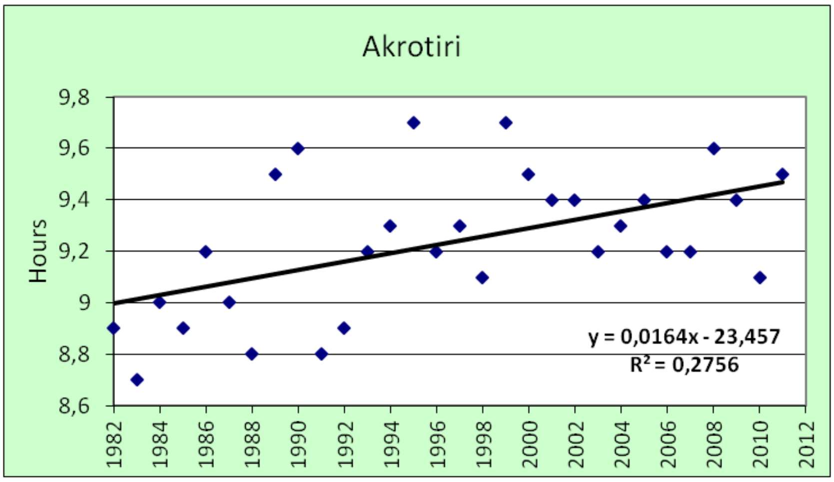
Figure 10-13: Number of days with dust in suspension in Cyprus between 1990 and 2007.

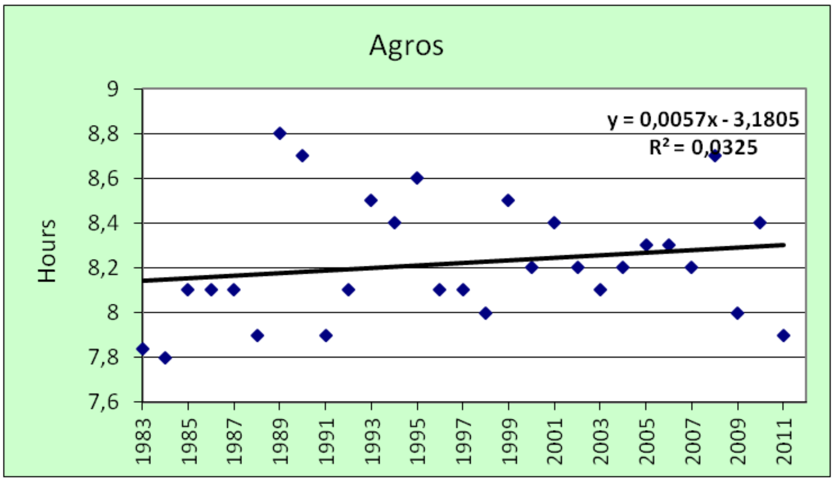
Source: Pashiardis, 2011

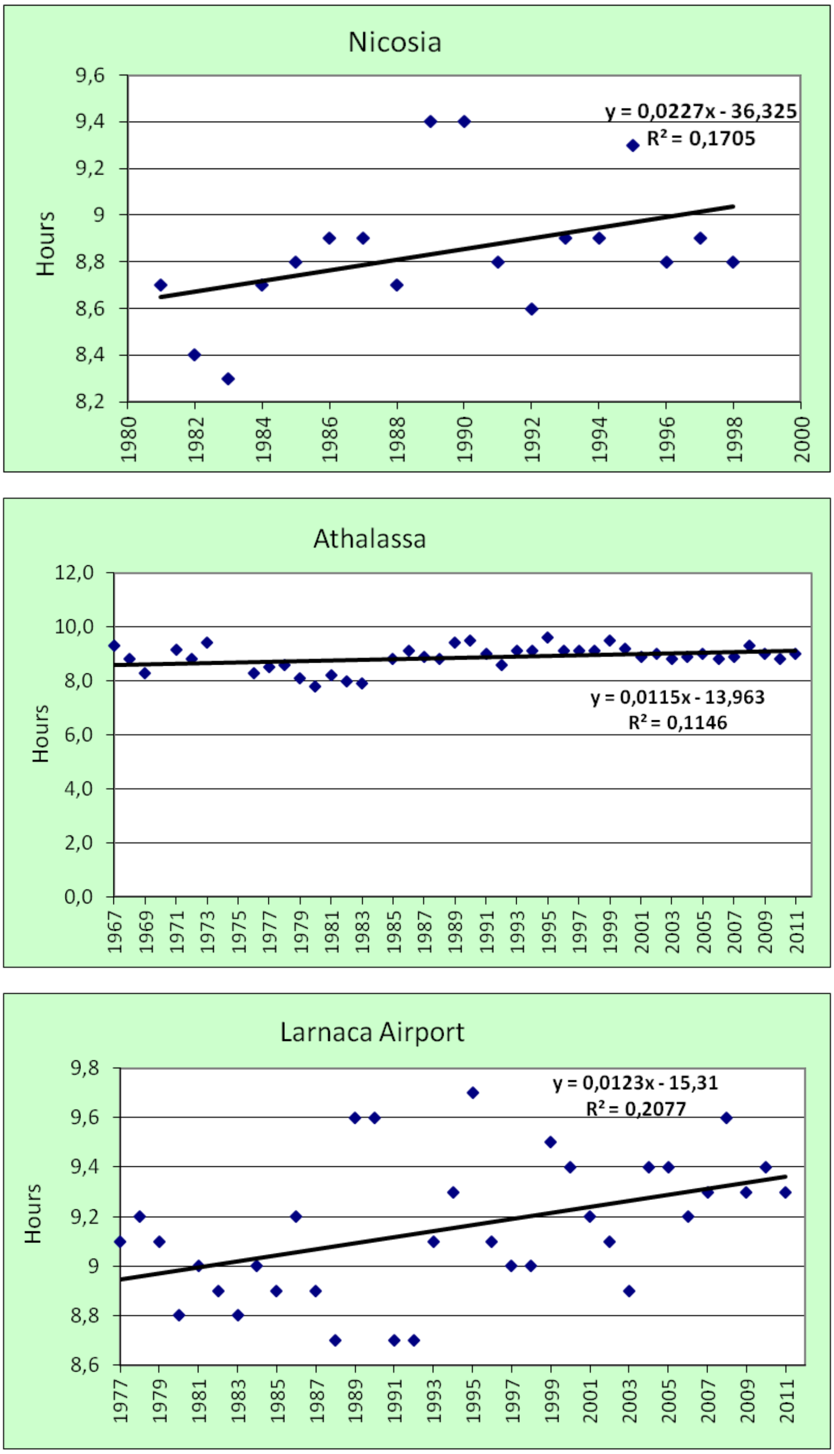
However, no changes in solar insolation have been linked with changes related to dust concentration in the atmosphere.

According to the Meteorological Service of Cyprus, the daily average sunshine has exhibited an increasing trend over the last decades (see Figure 10-14).









Source: The data were provided by the Meteorological Service of Cyprus (Contact Person: Stelios Pashiardis)

Figure 10-14: Yearly averages of daily sunshine duration observations between 1977 and 2011 in Cyprus

Next, the future climate changes in Cyprus that are considered to be associated with the future impact on solar energy yield, as these were projected with the use of regional climate models for the period 2021-2050, are presented in brief.

As mentioned above, the sunshine duration is considered to highly affect solar energy yield as solar insolation increases with the decrease cloudiness. For the projection of annual total sunshine duration in the future, other regional climate models were used as PRECIS does not provide projections for this parameter. In particular, the KNMI model projects a small increase of about 15-30 hrs in sunshine duration for the domain of the study while ENSEMBLE model mean presents an increase of 60-160 hours. Considering the above, it is expected that solar energy potential will increase due to the increase in sunshine duration.

On the other hand, high temperatures are expected to hinder to some extent solar energy potential. According to PRECIS, it is expected that the number of hot days per year when maximum temperature exceeds 30^{o}C will increase all over Cyprus in the period 2021-2050, with the range of changes being between +17 and +24 days per year. However, it is not known whether a change of this magnitude will have an adverse effect on the solar energy potential.

No impacts have been observed on solar power production due to climate change. As relative research is still lacking, further work in the field is recommended. Similarly to what was noticed for wind power production, it seems that:

- the impact of climate change on solar power can be characterized <u>rather insignificant</u>.

10.3.1.4. Bio - energy

Biomass energy is commonly used for non-food purposes such as electricity production, heat generation and transportation fuel. The main forms of biomass for non-food purposes are:

a) agricultural by-products which can be:
    a. residual agricultural crops (maize strains, cereal straw etc.);
    b. waste processing agricultural products (fruit pits, olive pits, rice hulls, etc.)
b) animal farming wastes;
c) wood biomass;
d) energy crops and industrial plants (reed, miscanthus, sweet sorghum, eucalyptus, etc.); and

e) the organic fraction of municipal solid waste.

The forms of biomass that could potentially be affected by climate change are the energy crops and wood biomass used for space heating. For energy crops, climate change impacts are focusing on changing factors related to decreased availability of irrigation water due to decreased precipitation and droughts, increased occurrences of weeds, diseases and insect pests, as well as to the increase in extreme weather events, all of which will negatively affect yields and growth. As for wood biomass, increased fires due to reduced fuel moisture, increased dieback of trees due to extended drought periods, increased insect infestations and the proliferation of invasive species are also anticipated to affect wood biomass availability for heating purposes.

In addition, a positive effect of global warming is noted in the case of anaerobic digestion of biomass for the production of biogas. Since the process of anaerobic digestion requires energy input for the provision of heat for certain reactions to take place, increased temperatures will reduce heat provision requirements and thus will save energy.

Situation in Cyprus

Transportation fuel:

In Cyprus, the potential for the production of biofuels from energy crops is low due to the limited availability of suitable agricultural land and water scarcity, which is expected to be aggravated in light of future climate changes.

There is no cultivation of crops for use as energy sources and no change is expected in the foreseeable future. Cereals production is inadequate (self-sufficiency in good years does not exceed 1/3 for barley and 1/6 for wheat) and any by-products are used as animal feed due to the scarcity of grazing land. The Agricultural Research Institute studied the feasibility of energy plant cultivation in Cyprus. The study estimated the land area and the water required for the irrigation of the plants. Regarding land, the area required far exceeds the supply while the water required is not possible as the available water is hardly enough to cover the household needs. In view of the above the possibility of producing biodiesel from oils is problematic, especially in view of future climate changes. In addition, it should be noted, that it costs considerably more to produce the oils needed for the production of biodiesel than to import them. Currently, only one Cypriot company (Ambrosia) is active in this area, which however uses imported oils for the production of biodiesel (Ioannou & Theocharides, 2009).

Heat production:

Results of a recent research study showed that 35% of the households in the mountainous communities in Cyprus utilize traditional fireplaces for space heating. Although some forest biomass is used for heating houses in mountain areas, in Cyprus there is no potential for forest biomass because no fast-growing trees are grown and the cutting down of forest trees is prohibited. The origin of wood biomass for heating purposes in the mountainous communities is mainly agricultural residues such as vine prunings (60%), forest prunings (16%) or both (12%) (CEA, 2012). As climate changes are expected to affect agricultural and forestry production, agricultural and forest residues are expected to be affected too. However, since the use of wood biomass for heating is limited in the mountain areas, no significant effect is regarded.

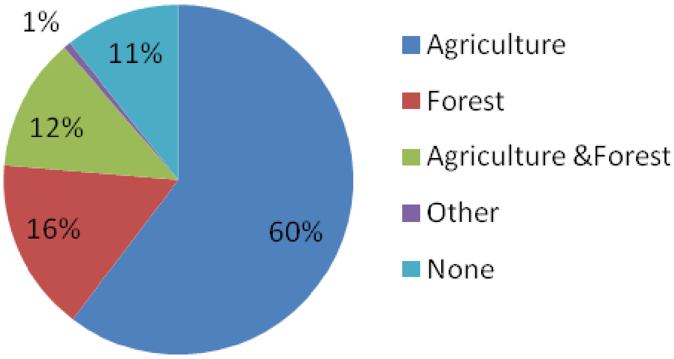


Figure 10-15: Origin of wood biomass in Cyprus

Electricity production:

In Cyprus there are 12 anaerobic digesters of farming wastes. Increased temperatures are expected to reduce heat provision requirements during the process and thus will result in energy savings. Thus it is expected that climate changes in Cyprus will have a positive impact on biogas production.

Considering the above, the impact on the sector induced by bio-power seems to be rather insignificant.

10.3.2. Efficiency of thermal power plants

In order to obtain a better understanding of the correlation of temperature with the power plants efficiency, the thermodynamic efficiency of the Carnot cycle can be used:

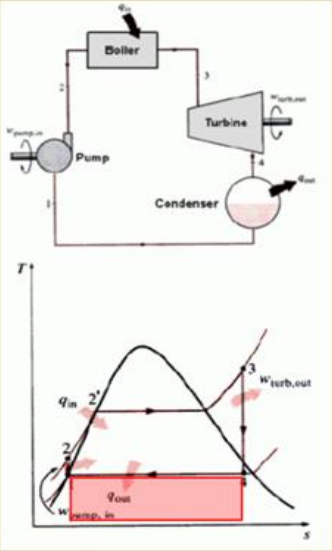
$$n_{th,Carnot} = 1 - \frac{T_b}{T_a} n_{th,Carnot} = 1 - \frac{T_b}{T_a} \qquad \textbf{(2)}$$

Where:

- T_b, the temperature where the heat rejection occurs; and

- T_a, the temperature (K) at which heat is transferred to the working media.

From the equation, it can be easily deduced that with increased cooling temperatures (T_b) the thermodynamic efficiency of the power generation cycle decreases. It must be noticed that the reduction of the coefficient of efficiency is not dependent on the type of cooling technology employed. However, in order to minimize this impact, the selection of the appropriate technology must be made on a case specific basis. The BREF document regarding the best available techniques on the large combustion plants, provides concrete data for such a selection (EC, 2006; pp. 46-47).



Box 3.1: Heat rejection of an ideal Rankine cycle
(steam power cycle, see also Figure below)

According to the second law of thermodynamics the heat flux can be expressed by:

$$Q = \int_{s_1}^{s_2} T \cdot ds$$

Given, that in the heat rejection section latent heat is rejected (the temperature remains constant) the equation is simplified as follows: $Q = T \cdot (s_2 - s_1)$. This product represents the area which is highlighted in the figure on the left. That is to say, the higher the temperature, the higher the corresponding area of the diagram, translating to higher energy losses.

Moreover, in order to attain the same cooling effect with increased temperatures, larger quantities of the cooling medium have to be used. This is translated into higher pumping requirements which lead to decreased net power plant capacity. As it can be seen from Figure 10-17, the net electricity offered to the public network equals to the gross electricity produced minus the own electrical consumption of the power plant. To this end, the capacity of the power plants is expected to decrease.

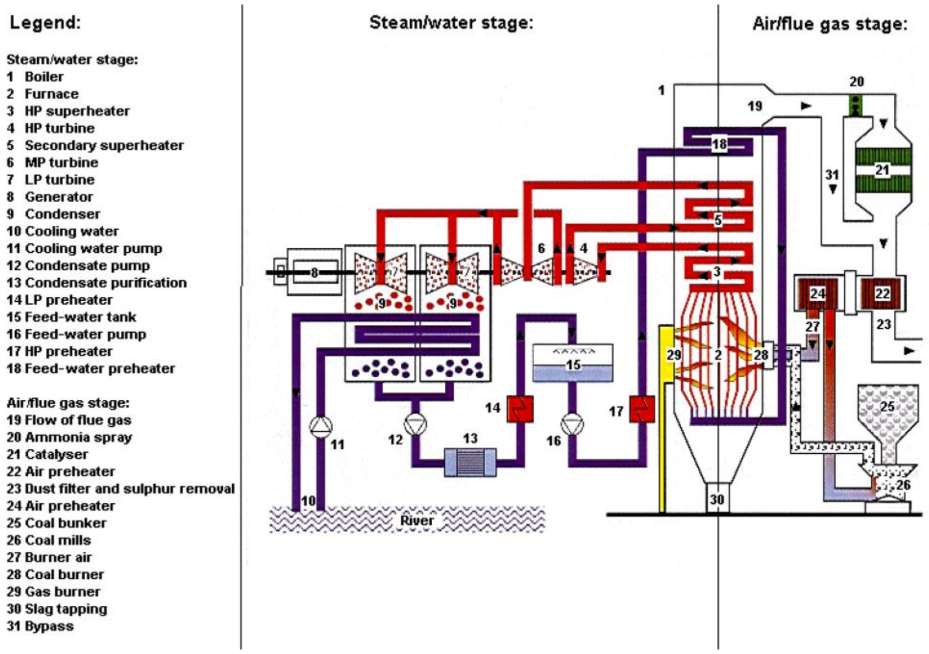


Figure 10-16: Possible configuration of a steam plant

Source: EC, 2006

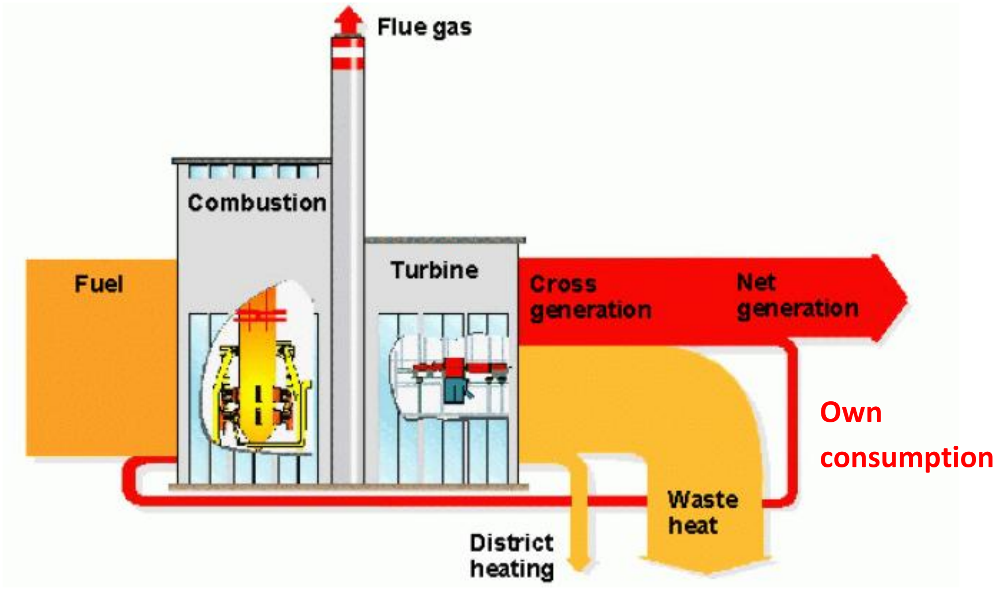
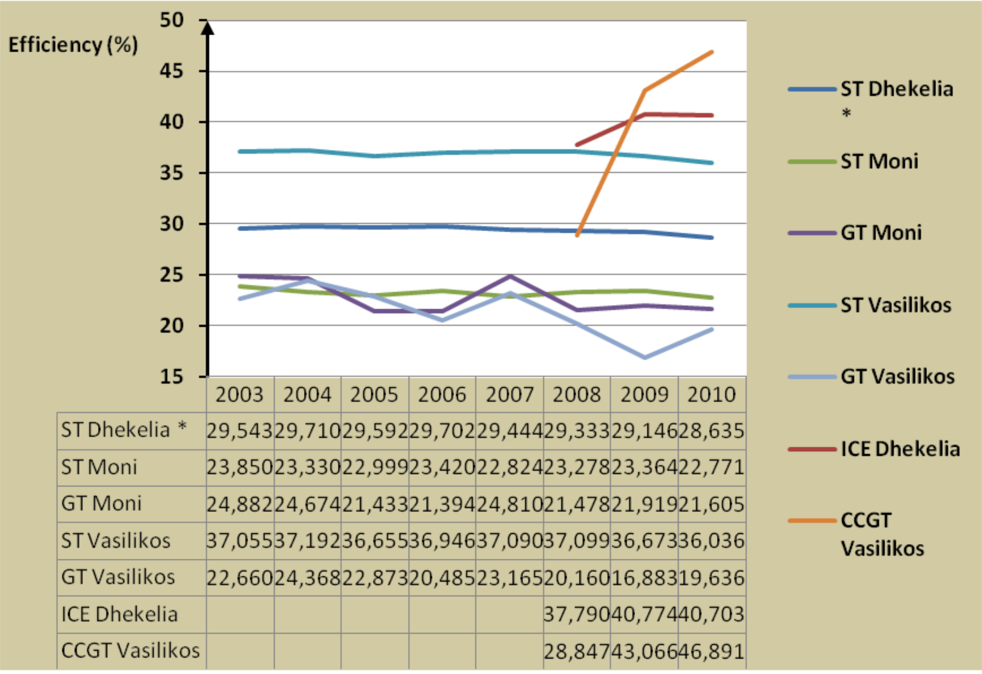


Figure 10-17: Energy conversion in a typical thermal power plant

Source: EC, 2006

Situation in Cyprus

Apart from the mean value of thermal coefficient of efficiency (36.1%), the efficiency of each unit should be monitored. The changes that have been recorded in the efficiency of the different thermal power plants are presented in Figure 10-18. As it can be seen, the efficiency of the thermal power plants drops over time. However, from the communication with the EAC's competent department[8], it was deduced that there is no clear relation between climate change (temperature increase) and drop of the thermal coefficient of the power plants in Cyprus, as the latter would still drop over time due to ageing of the power units.



	2003	2004	2005	2006	2007	2008	2009	2010
ST Dhekelia *	29,543	29,710	29,592	29,702	29,444	29,333	29,146	28,635
ST Moni	23,850	23,330	22,999	23,420	22,824	23,278	23,364	22,771
GT Moni	24,882	24,674	21,433	21,394	24,810	21,478	21,919	21,605
ST Vasilikos	37,055	37,192	36,655	36,946	37,090	37,099	36,673	36,036
GT Vasilikos	22,660	24,368	22,873	20,485	23,165	20,160	16,883	19,636
ICE Dhekelia						37,790	40,774	40,703
CCGT Vasilikos						28,847	43,066	46,891

Figure 10-18: Observed changes in the efficiency of thermal power plants in Cyprus

*Note: (1) CCGT: Combined Cycle Gas Turbine, ST: Steam Turbine, GT: Gas Turbine, ICE: Internal Combustion Engine, (2) the increase in CCGT and ICE units are related with the installation of new units

It must be noted that the data presented have been obtained through communication with the Electricity Authority of Cyprus (EAC) and have not been published yet.

Regarding future changes in the efficiency of thermal power plants, future changes in temperature may be used as an indicator. According to PRECIS projections for the future period 2021-2050, the average annual temperature in Cyprus is expected to increase by 1 - 2°C with respect to the control period 1960-1990. However, it is not known whether a change in temperature of this magnitude will have an impact on the efficiency of thermal power plants.

As relative research is still lacking, further work on the field is recommended. No impacts

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[8] Contact person: Menelaou Charalambos (Assistant Generation Manager), Tel: 00357 22 201513, CMenelao@Eac.com.cy

have been observed on the efficiency of thermal power plants due to climate change.

10.3.3. Energy demand

Weather fluctuations have a significant impact on different sectors of the economy. One of the most sensitive is the energy market, because power consumption is linked to several weather variables (mainly air temperature). Consumption of energy is particularly sensitive to weather, since large amounts of energy cannot be stored and thus energy that is generated must be instantly consumed.

Although energy requirements are linked to climate conditions, the relationship of energy demand and temperature is not linear. The variability of ambient air temperature is closely linked to energy consumption, whose maximum values correlate with the extreme values of air temperature (maximum or minimum) (Giannakopoulos et al., 2009).

Daily energy consumption in countries throughout the world shows a clear seasonal pattern. Average daily energy consumption in most European countries, historically shows a single peak during winter months. Only the European Mediterranean countries show an additional peak during summer months (Giannakopoulos and Psiloglou 2006). Consumption patterns with only summer peaks may be found outside of Europe.

In the Mediterranean basin, the expected change in energy demand is expected to change by 2050 as follows (Alcamo, 2007):

- 2 to 3 fewer weeks per year will require heating; and
- additional 2 to 5 weeks will require cooling.

Situation in Cyprus

Due to the observed warming in Cyprus in our days, energy consumption may change as energy requirements for heating during winter will fall while during summer energy demand for cooling will grow largely due to high temperatures. This constitutes the most important impact of climate change in relation to energy, since the energy consumption has increased in recent years (see Figure 10-19), further increasing demand for energy during summer should somehow be offered. This means there will be a need to install additional generating capacity over and above that needed to cater for the underlying economic growth.

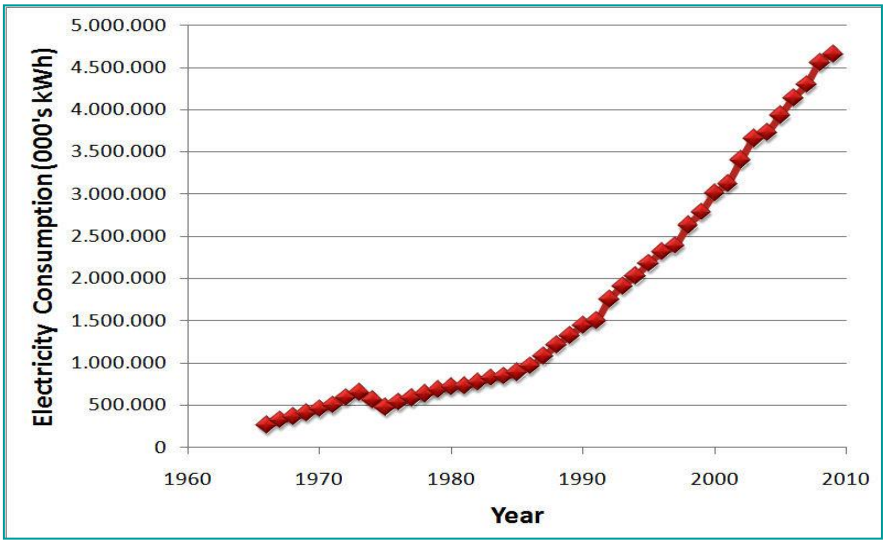

Figure 10-19: Increase in mean monthly electricity consumption in Cyprus for the period 1966-2009

Source: Lange, 2011a

Heating and Cooling Degree Days

In order to allow the impact on energy demand to be measured, counteracting effects should be carefully taken into account such as cooling and heating degree days. Countries at low latitudes as Cyprus will be significantly affected in terms of cooling demand, resulting in an increase of cooling degree days and a decrease of heating degree days with increased temperature.

The observed changes in heating and cooling degree days between 1980 and 2004 are presented in: (a) Figure 10-20 to Figure 10-22, for heating degree days and (b) Figure 10-23 to Figure 10-25 for cooling degree days. The data presented in the figures have been obtained through contacts with the Meteorological Service of Cyprus[9]. More specifically, the data were selected by three meterological stations which are situated in different elevation levels. These stations are: (a) Prodromos Station (mountainous area); (b) Athalassa (low land area); and (c) Larnaca Airport (A/P) Station (coastal area). The data will allow to obtain a better understanding of the relation between change in heating/ cooling demand and climatic zones (mountainous, low land and coastal areas).

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[9] Contact person: Stelios Pashiardis, e-mail: spashiardis@ms.moa.gov.cy

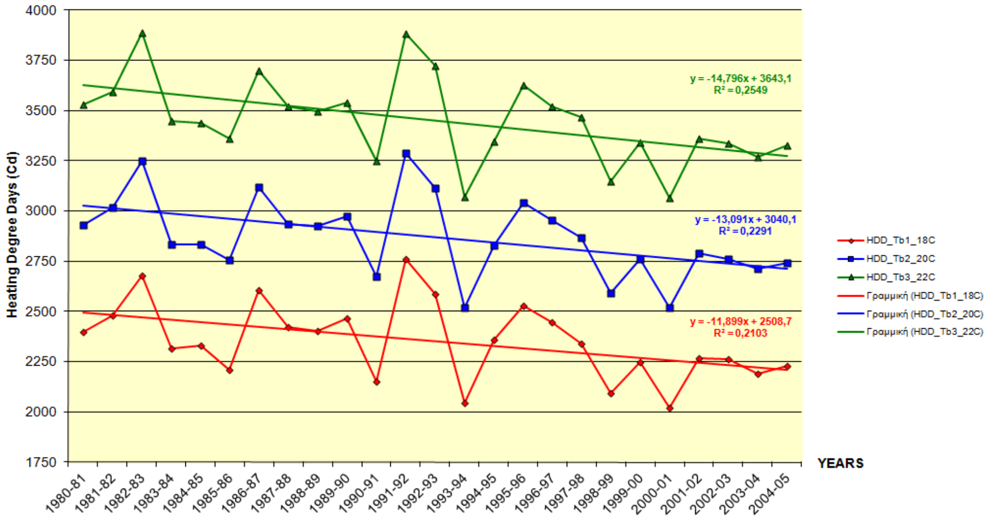


Figure 10-20: Observed changes in heating degree days between 1980 and 2004. Station: Prodromos

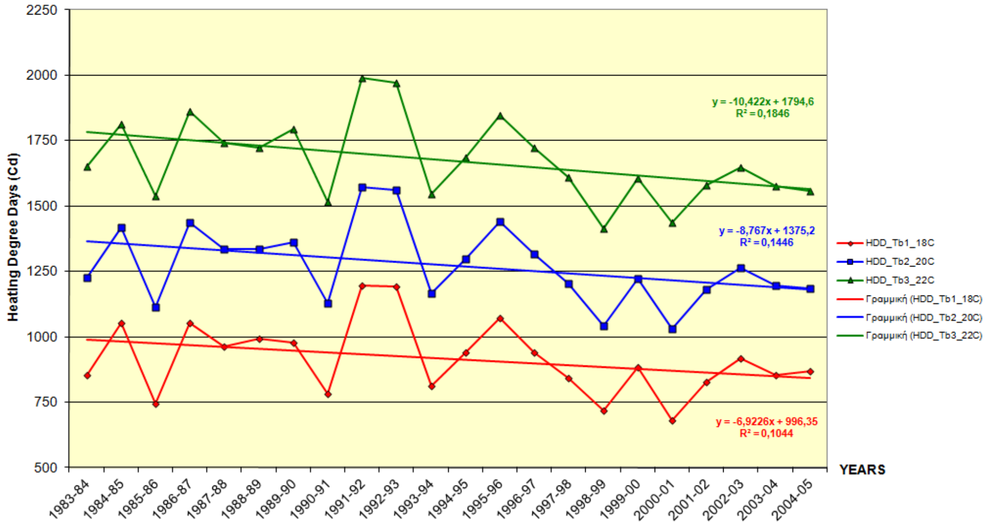


Figure 10-21: Observed changes in heating degree days between 1983 and 2004. Station: Athalassa

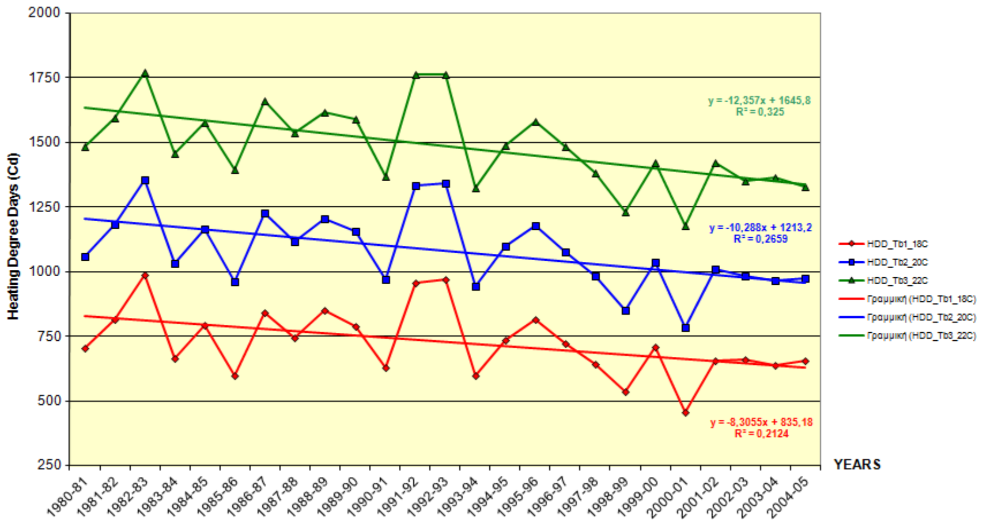


Figure 10-22: Observed changes in heating degree days between 1980 and 2004. Station: Larnaca

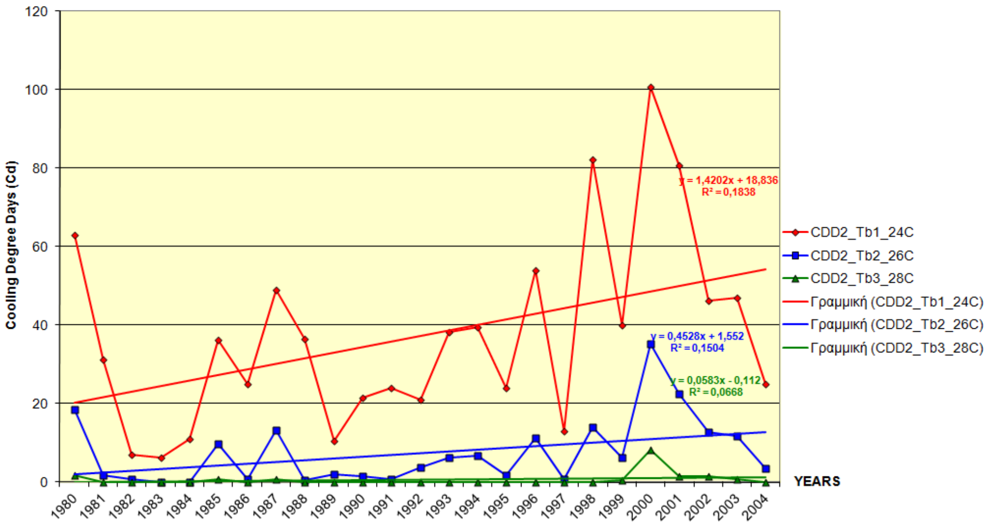


Figure 10-23: Observed changes in cooling degree days between 1980 and 2004. Station: Prodromos

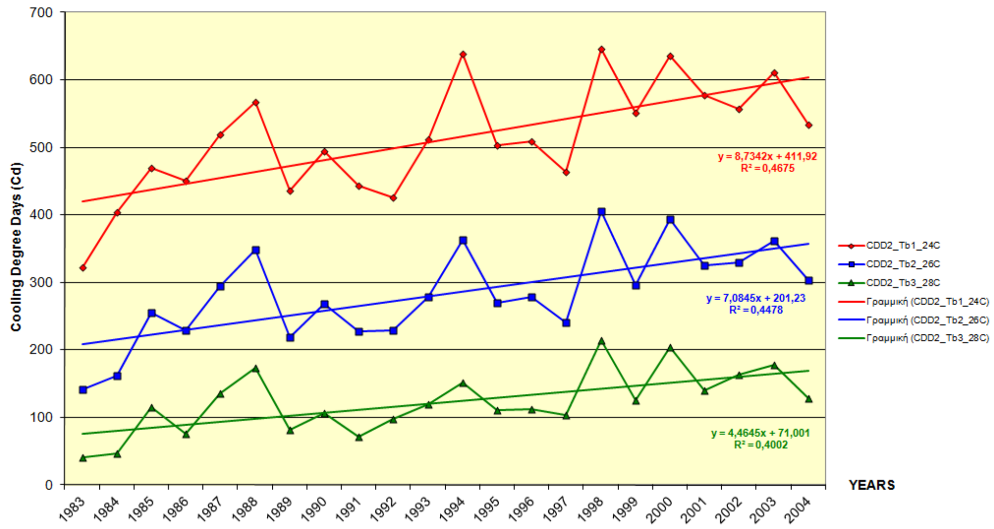


Figure 10-24: Observed changes in cooling degree days between 1980 and 2004. Station: Athalassa

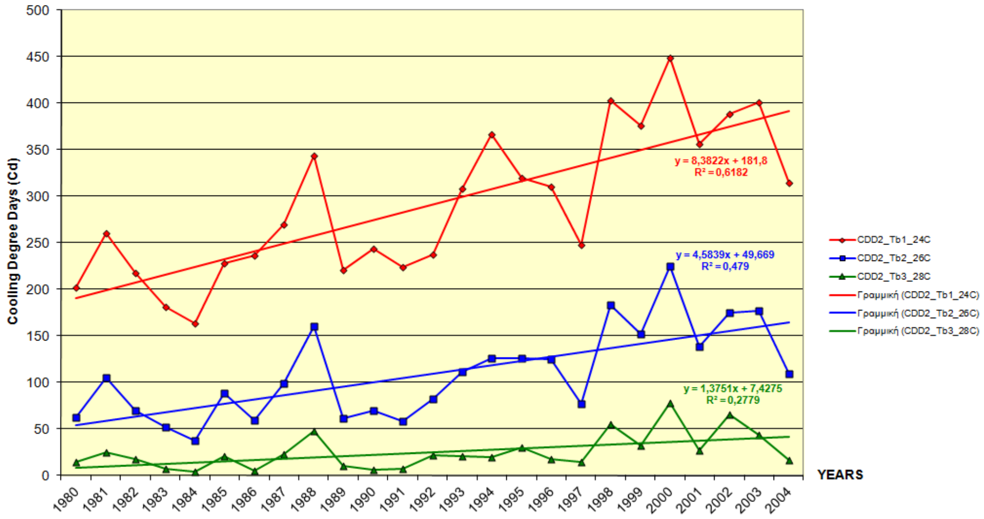


Figure 10-25: Observed changes in cooling degree days between 1980 and 2004. Station: Larnaca

A further increase in the maximum and minimum temperature in the future in Cyprus is expected to affect both cooling and heating demand. In particular, it is projected according to PRECIS that the mean annual maximum temperature will increase by 1.3-1.9^{o}C during the period 2021-2050 and the mean annual minimum temperature will also increase by 1.3-1.8^{o}C on average for all the domain of the study. Consequently, an increase in cooling demand and a decrease in heating demand is expected.

10.4. Future vulnerability assessment

In this section, the future vulnerability of the energy sector to climate change impacts is assessed in terms of its sensitivity, exposure and adaptive capacity based on the available quantitative and qualitative data for Cyprus and the climate projections for the period 2021-2050. In particular, sensitivity is defined as the degree to which the energy sector will be affected by climate changes, exposure is the degree to which the energy sector will be exposed to climate changes and its impacts while the adaptive capacity is defined by the ability of the energy sector to adapt to changing environmental conditions as well as by the effectiveness of the relative existing and planned adaptation measures.

For the assessment of future vulnerability, the same indicators used in the current vulnerability assessment (CYPADAPT, 2012) were used, wherever the necessary data were available. These indicators are summarized in Table 10-4.

Table 10-4: Indicators used for the vulnerability assessment of climate change impacts on the energy sector of Cyprus

Vulnerability Variable	Selected Indicators
Renewable energy yield	
Sensitivity	– Relationship between solar energy potential and sunshine – Relationship between solar energy potential and high temperature – Relationship between wind energy potential and wind speed – Relationship between hydropower potential and water availability – Relationship between bio-power potential and water availability – Share of hydropower in total power production – Share of bio-power in total power production – Dependence of produced bio-power in Cyprus on bio-crops – Share of wind power in total power production – Share of solar power in total power production – Increase in share of bio-power in total power production (2020) – Increase in share of wind power in total power production (2020) – Increase in share of solar power in total power production (2020)
Exposure	– Change in renewable energy potential – Change in renewable power production – Future changes in sunshine duration – Geographic distribution of active solar systems – Future changes in the number of days with maximum temperature >30^{o}C – Geographic distribution of solar panels – Future changes in wind speed – Geographic distribution of wind parks

Vulnerability Variable	Selected Indicators
Adaptive capacity	– Promotion of RES: Directive 2009/28/EC – Other measures undertaken (administrative, legal, economic, social measures)
Efficiency of thermal power plants	
Sensitivity	– Sensitivity of thermal coefficient of efficiency to changes in temperature
Exposure	– Geographical distribution of power plants in Cyprus – Future temperature changes in the areas where power plants are located
Adaptive capacity	- Adaptation measures implemented
Energy demand	
Sensitivity	– Yearly, monthly, daily and hourly relationship between energy demand and temperature – Effect of higher temperatures in summer on peak energy demand – Share of tertiary sector in the final energy consumption – Welfare loss associated with the additional electricity requirements
Exposure	– Future energy consumption levels for the cold period – Future energy consumption levels for the warm period – Current and future Heating Degree Days across regions – Current and future Cooling Degree Days across regions – Net change in energy demand for heating and cooling across regions – Share of population in the mostly affected regions
Adaptive capacity	– New power stations ○ Maximum output capacity (2016) ○ Peak demand (2016) ○ Energy capacity (2020) – Energy efficiency measures – Promotion of renewable energy power production – Natural gas introduction

The relationship between sensitivity, exposure and adaptive capacity is based on the following qualitative equation:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity * Exposure$$

Sensitivity, exposure and adaptive capacity are evaluated on a 7-degree qualitative scale ranging from “none” to “very high”.

To assess the vulnerability of the energy sector, the following impacts were considered:

1. Renewable energy yield;
2. Efficiency of thermal power plants;
3. Energy demand.

It must be noted that, there are no sufficient scientific evidence and data to evaluate or correlate all impacts and indicators to future climate changes. Consequently, further research is required in order to provide concrete information for a more detailed and descriptive assessment of the future vulnerability of the sector. Nevertheless, an attempt was made to provide a preliminary assessment of the future vulnerability. In case additional data are provided by the competent authorities of Cyprus, the future vulnerability of the sector could be re-assessed.

10.4.1. Renewable energy yield

10.4.1.1. Assessment of sensitivity and exposure

<u>Sensitivity:</u> Renewable power production is considered sensitive to climate changes due to the reduction in renewable energy potential such as wind, solar, hydropower and biomass. Following, the aforementioned types of renewable energy will be examined in terms of their sensitivity to climate changes as well as in terms of their share to the current and future (planned) share to the total power production in Cyprus which indicates the specific sensitivity of the country towards this impact.

Hydropower is sensitive to climate changes as reduced precipitation and increased evapotranspiration due to increased temperatures lead to reduction in the amount and seasonality of flow in most rivers, which in turn affects the power production by hydropower plants. According to the Environmental Energy Agency hydropower is expected to be significantly affected by climate-induced changes. However, given the already limited availability of surface water resources in Cyprus, no hydropower plant are installed until now in Cyprus, as the hydroelectric potential is very little to exploit. In specific, the share of both current and future (2020) hydropower in total power production is 0%, thus it is considered that there in no sensitivity of the hydropower potential to climate changes in the case of Cyprus.

Wind power is considered particularly sensitive to changes in wind speed given that, according to *Equation 1* (below) for the calculation of the maximum power that can be produced by wind, even small changes in the air intensity can be translated into significant changes to the wind power produced, as the power is proportional to the third power of the wind velocity.

$P_w = \frac{\pi}{8} \cdot D^2 \cdot \rho \cdot U^3 P_w = \frac{\pi}{8} \cdot D^2 \cdot \rho \cdot U^3$ *(Equation 1)*

Where:

D, the rotor diameter (m);
ρ, the air density (kg/m^3); and
U, air velocity (m/s).

By taking into account the share of wind power in total power production (3.9%) as well as the expected value for the year 2020 which is 6.8%, it is considered that the sensitivity of wind power potential to climate changes in the case of Cyprus is moderate.

Solar energy potential is considered sensitive to climate changes and in particular to changes in sunshine duration. In general, solar insolation drops with the increase of the cloudiness. In addition, photovoltaics, or solar panels, are sensitive to higher temperatures as the energy production efficiency of solar panels drops when the panel reaches hot temperatures. Considering that the current share of solar power in total power production is 0.4% and will reach 7.2% in 2020, it is considered that the sensitivity of solar power potential to climate changes in the case of Cyprus is moderate.

Biomass power production and especially energy crops and wood biomass used for space heating are sensitive to climate change and especially to reduction in precipitation, increases in temperature and increased frequency and intensity of extreme weather events which reduce their production rates. Given that energy crops which are most dependent by climate change are not used in Cyprus as well as that the use of wood biomass for heating purposes is limited to mountain communities, the impact on the sector induced by bio-power seems to be rather insignificant.

Considering the above, it can be said that the sensitivity of RES energy production to climate changes can be characterized as **limited to moderate**.

Exposure: In order to assess the exposure of RES power production to climate change the following indicators were used:

- Change in renewable energy potential (based on climate parameters); and
- Change in renewable energy production.

As discussed in detail in Sections 10.3.1.2, 0 and 10.3.1.4, relative research for monitoring the impact of climate change on wind, solar and bio-power production is still lacking and no conclusive information is available at present.

Next the climate changes considered to affect wind and solar power potential are presented. The energy potential of hydropower and bio-power will not be investigated since no sensitivity to climate changes for the case of Cyprus was detected.

To begin with, to assess the exposure of wind power to climate changes, the future changes of wind speed projected with the use of PRECIS model for the case of Cyprus are presented. In particular, the annual mean wind speed changes in the near future are projected show a slight decrease of about 0.20 m/s in western, southeastern and inland regions while in southern and mountain regions a lower decrease of about 0.1 m/s is expected (Figure 10-26). Given that the majority of wind parks is installed at the southeastern, eastern and central lowland part of Cyprus (see Figure 10-28), they will be exposed to decreases in the annual mean wind speed up to -0.25 m/s, while the wind parks mostly affected are located in eastern part (Agia Napa) followed by the wind parks located at the central and lowland areas of Cyprus (near Nicosia).

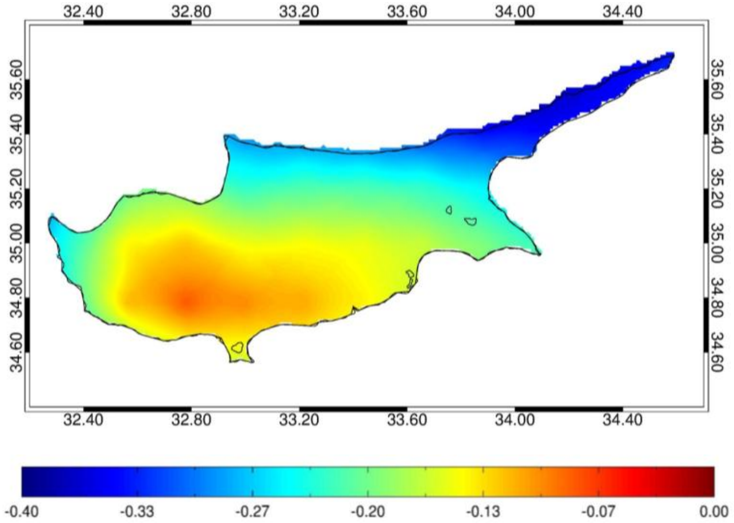


Figure 10-26: Changes in annual mean wind speed between the future (2021-2050) and the control period (1961-1990)

Furthermore, as far as the future changes in highest mean wind speed are concerned, Figure 10-27 illustrates that PRECIS projections show a small decrease of about 0.1 m/s in western and southeastern areas, reaching almost 0.4 m/s in Famagusta District. In mountain regions a decrease of about 0.1 m/s in northern parts is anticipated while no change is expected in central and southern parts. Given that the majority of wind parks is installed at the southeastern, eastern and central lowland part of Cyprus (see Figure 10-28), they will be exposed to decreases in the highest mean wind speed up to -0.5 m/s, while the wind parks mostly affected are located in eastern part (Agia Napa) followed by the wind parks located at the central and lowland areas of Cyprus (near Nicosia).

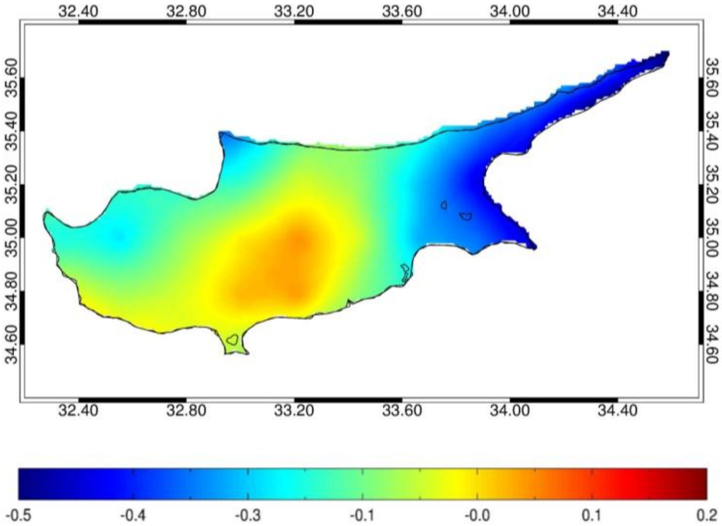


Figure 10-27: Changes in highest mean wind speed between the future (2021-2050) and the control period (1961-1990)

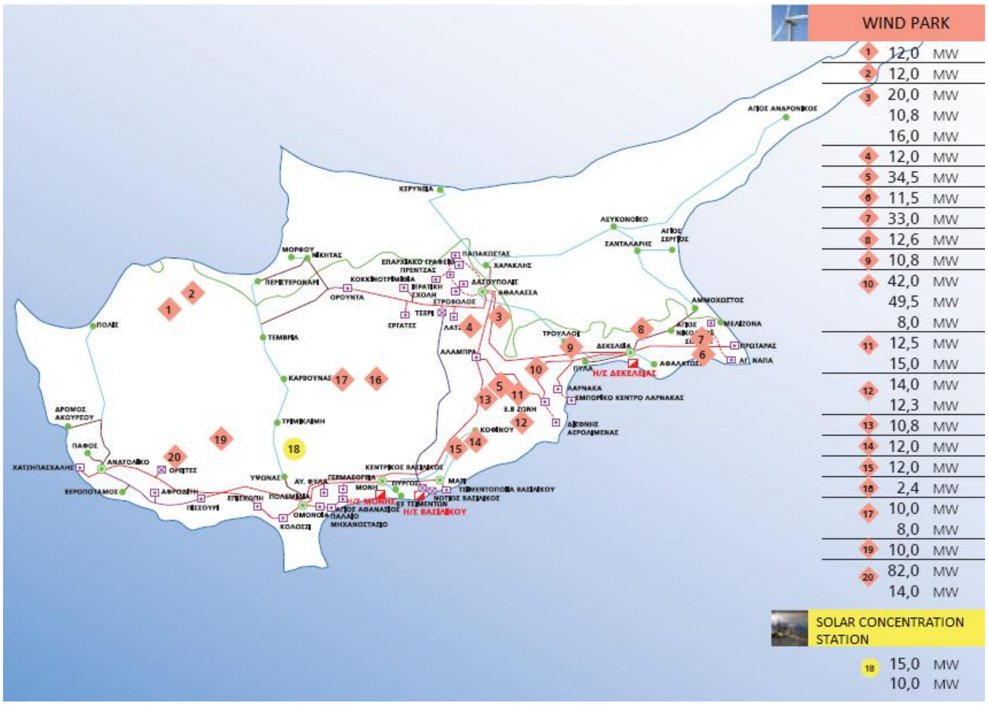


Figure 10-28: Licensed wind farms and solar concentration stations for electricity generation (31/12/2010)

Source: CERA, 2011

Although the magnitude of the impact on the actual wind power production is not known, it is anticipated that a general decreasing trend will be observed in the future.

As for the current climate changes affecting solar power potential, the only available information concerns the observations of the meteorological service of Cyprus regarding the composition of the atmosphere and the values of yearly average sunshine duration at different locations in Cyprus.

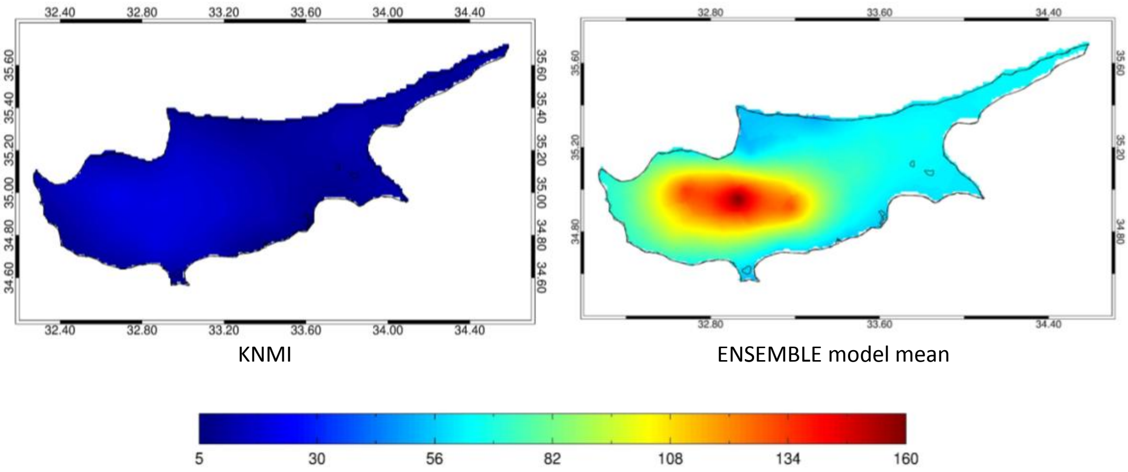
The observed changes in the daily sunshine duration are exhibiting a slightly increasing trend, something that indicates that the solar energy yields are expected to be slightly increased. The largest increase has occurred at the region of Athalassa, where the sunshine duration has increased from 8.66h (1967 data) to 9.16h (2011 data), exhibiting an increase of approximately 0.51h (see also Table 10-5).

Table 10-5: Observed changes in daily sunshine duration at different regions in Cyprus

Region	Increase in daily sunshine duration
Pafos	0.1h (increase from 1975 to 2011)
Akrotiri	0.5h (increase from 1982 to 2012)
Agros	0.16h (increase from 1983 to 2011)
Nicosia	0.45h (increase from 1980 to 2000)
Athalassa	0.51h (increase from 1967 to 2011)
Larnaca	0.42h (increase from 1977 to 2011)

Source: Meteorogical Service of Cyprus

For the projection of annual total sunshine duration in the future, other regional climate models were used as PRECIS does not provide projections for this parameter. In particular, the KNMI model projects a small increase of about 15 hrs for the greater area of Paphos, Famagusta, Larnaca and Nicosia, 25 hours for the area of Limassol and 30 hours for the Troodos mountains. Respectively, the ENSEMBLE model mean shows a more notable increase of 60-75 hours for all the domain of the study, while for the mountain areas, an even higher increase is projected ranging between 100-140 hours (Figure 10-29). Considering the above, it can be said that the solar power potential is expected to further increase in the future due to the increase in annual total sunshine duration.



KNMI

ENSEMBLE model mean

Figure 10-29: Changes in mean annual sunshine duration between the future (2021-2050) and the control period (1961-1990)

As regards the future changes in high temperatures which are considered to be associated with reduced solar power potential in photovoltaics, or solar panels, it is expected according to PRECIS that these will increase throughout Cyprus. In specific, in the near future the hot day index (number of days with maximum temperature >30^{o}C) seems to increase by 5–12 days over the northwestern and southwestern coasts and 20–24 days in continental lowlands, higher elevation areas and Karpasia peninsula. In addition, Troodos mountains present even higher increase of about 26-28 days. However, the strongest increase (about 1 month) appears over the coastal area between Larnaca and Limassol (Figure 10-30). In particular, it can be said that the solar concentration station installed north from Limassol (see also Figure 10-28) will experience an increase towards this indicator of about 17-22 days. However, it must be mentioned once again that it is not known whether a change of this magnitude will have an adverse effect on the solar energy potential.

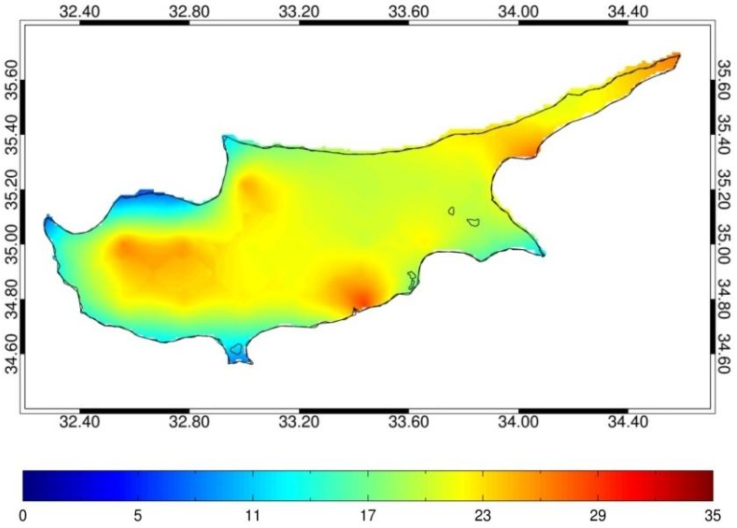


Figure 10-30: Changes in the number of hot days (TX>30^{o}C) between the future (2021-2050) and the control period (1961-1990)

Considering that the potential of the renewable energy sources in Cyprus, is not expected to present worth-noticing changes. To this end, the exposure was ranked as **limited**.

10.4.1.2. Assessment of adaptive capacity

Increase of RES installed capacity

The main policy measure related to renewable energy deployment in Cyprus is the Directive 2009/28/EC on the promotion of the use of energy from renewable sources. According to this Directive, each Member State has a specific target for the overall share of renewable sources in the gross final energy consumption, as well as it is obliged to form a national renewable action plan in order for these targets to be achieved.

For the case of Cyprus, the target for the share of renewable energy in the final energy consumption has been set at 13% for 2020[10], while the trajectory specified by Cyprus is presented in Figure 10-31. It must be noticed that the design of the trajectory involves a diversified renewable energy mix, meaning that in case climate change impacts will be observed in a specific renewable power category, the whole renewable power production sector shall not be significantly affected.

Finally, potential impacts on renewable energy potential can be counterbalanced by the promotion of additional RES in terms of capacity: if the rate of renewable power deployment (measured at kW installed) offsets the reduction of kWh due to reduced RES potential, the yearly total kWh produced by RES will grow over time.

Moreover, an indicative list of measures (administrative and economic) undertaken up to the present for the promotion of renewable energy sources is given below:

Administrative measures

- Support Scheme Plans (2004-2008 & 2009-2013)
- Establishment of the “Energy office for the citizens of Cyprus” (9/2/2009)
- Adoption of the “One Stop Shop” principle (2002)

Legal measures

- L. 174/2006: “Promotion of Combined Heat and Power”
- Obligation of the Electricity Authority of Cyprus (EAC) to purchase electricity using RES (2002)
- Licensing exemption (from CERA) for the construction and operation of wind power systems up to 30kW, and photovoltaic systems and biomass systems up to 20 kW

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[10] Whereas the corresponding share of RES in the electricity production sector is set at 16%

Economic measures

- Special fund for the promotion of RES and energy conservation (August 2003), the revenue of which comes from an additional charge per kWh consumed by all electricity consumers categories (0.0022€/kWh)
- Reduced application fee of very small PV, wind and biomass units

Social measures

- Organization of information campaigns, seminars and workshops on renewable power production.

Regarding the economic incentives, it can be said that the subsidy for RES installed at household level was up to 55%[11], while for larger scale systems there exists a feed-in tariff system 'subsidizing' the price of sold electricity (€/kWh).

Given the variety of measures taken for fostering renewable power penetration to the energy production sector, the adaptive capacity is considered to be **moderate**.

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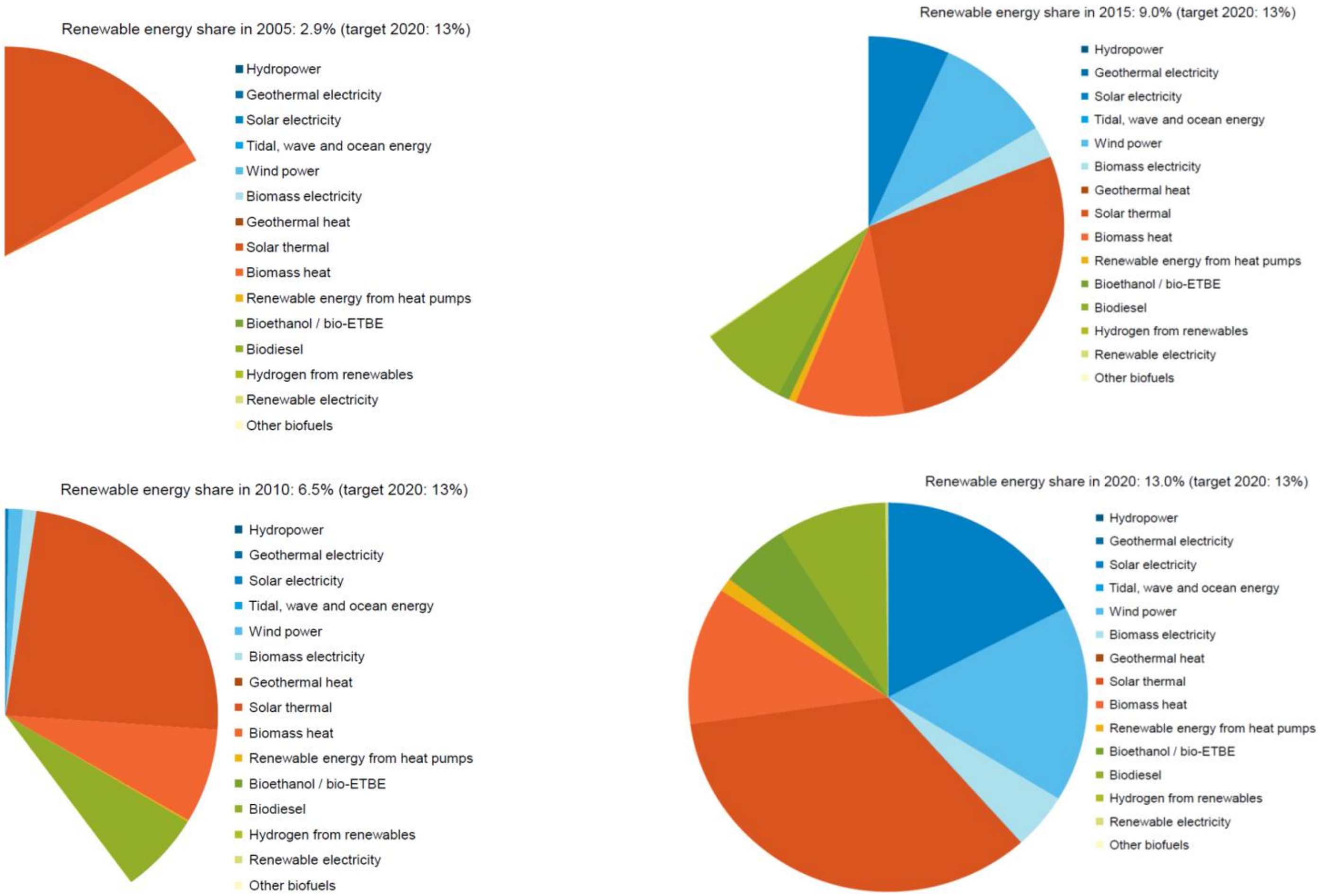
[11] The government is revising this policy


Renewable energy share in 2005: 2.9% (target 2020: 13%)

Renewable energy share in 2015: 9.0% (target 2020: 13%)

Renewable energy share in 2010: 6.5% (target 2020: 13%)

Renewable energy share in 2020: 13.0% (target 2020: 13%)

Figure 10-31: Indicative trajectory for the shares of energy from renewable sources in the final energy consumption until 2020

Source: MCIT, 2010

10.4.2. Efficiency of thermal power plants

10.4.2.1. Assessment of sensitivity and exposure

Sensitivity: As discussed in Section 10.3.2, the required condensing power is sensitive to temperature increase (air and water) as such a change is expected to lead to reduced thermal efficiency of power plants. In order to assess the magnitude of sensitivity of thermal efficiency of the power plants to climate change the following indicator was used:

- Change of thermal coefficient of efficiency of power plants over time.

In order to obtain a global picture of the impact, the thermal efficiency of each power plant should be monitored and regularly recorded. This has already been realized for the power plants of Cyprus by the Electricity Authority of Cyprus (*EAC*), however no correlation of the decreased efficiency of the units has been attributed to climate change; rather, it is attributed to the ageing of the units.

EAC considers that, in essence, the efficiency has low sensitivity to temperature changes[12]. This is in accordance with studies that have been elaborated on a worldwide basis, which imply a drop in the efficiency in the order of 1% (0.2 - 0.3% has been reported) (Kirkinen, 2005; UNEP, 1998). Considering that the energy produced and delivered to balance the energy demand would slightly be affected, the sensitivity was ranked as **limited**.

Exposure: For the assessment of the exposure of thermal power plants in Cyprus to increased temperature in the future which could reduce their thermal efficiency, the geographical distribution of power plants in Cyprus in conjunction with the future temperature changes for the period 2021-2050 in these areas according to the PRECIS model were used as indicators.

As it can be seen in Figure 10-32, the three main power stations in Cyprus, i.e. (a) the Moni power station, (b) the Vasilikos power station and (c) the Dhekelia power station (highlighted with purple squares) are located in the southern and southeastern coasts of the island. In addition, there is a number of self-producer installations located inland (highlighted with green triangles), whose capacity however is minor (CERA, 2010).

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[12] Contact person: Menelaou Charalambos (Assistant Generation Manager), Tel: +357 22 201513, CMenelao@Eac.com.cy

Figure 10-32: Location and installed capacity of power stations in Cyprus

Source: CERA, 2011

From Figure 10-33, which presents the average annual maximum temperature change projections for the period 2021-2050 according to the PRECIS model, it can be seen that the southern coastal area east from Limassol where the two main power plants are located is characterized by a temperature change of about +1.7°C while the southeastern coastal area between Limassol and Larnaca where the third main power plant is located, is characterized by a lower increase in temperature change of about 1.3°C. As for the changes in water temperature, these are related to the changes in air temperature and are also expected to increase with a lower rate though.

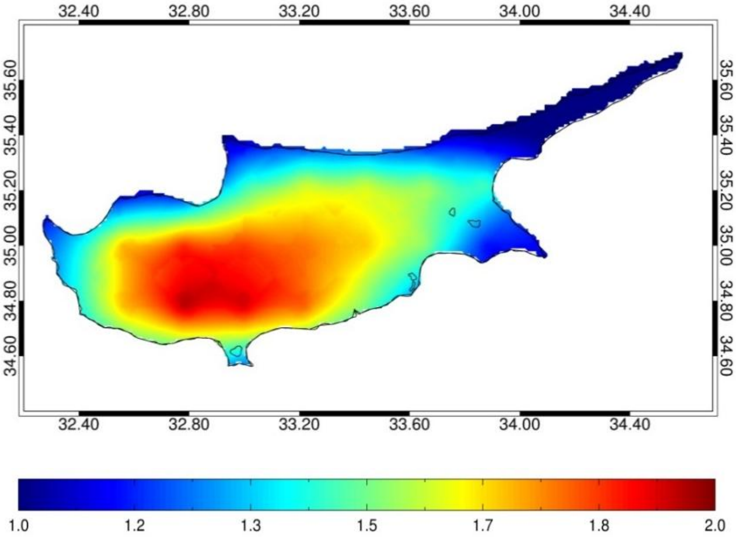


Figure 10-33: Changes in average annual maximum TX between the future (2021-2050) and the control period (1961-1990)

Considering the above, it is expected that the exposure of power plants to future increases in temperature is **moderate**.

However, as also mentioned previously further research is needed in order to estimate the magnitude of the impact caused by climate changes.

10.4.2.2. Assessment of adaptive capacity

In order to offset this impact, more careful design of the thermal power plants can be made, implementing a series of proper modifications in the typical configurations which are used at present, most of which relate to the selection of proper sitting of the units or better operation of the equipment. However, no such measures have been taken in Cyprus for climate change adaptation purposes, nor it is projected to take place in the short-term. On the other hand, the modernization and replacement of old equipment and the implementation of the necessary maintenance activities are expected to increase or stabilize thermal coefficient efficiency of the plants. To this end, the adaptive capacity is ranked as **limited to moderate**.

10.4.3. Energy demand

10.4.3.1. Assessment of sensitivity and exposure

Sensitivity: The energy consumption is sensitive to climatic conditions and it is expected that with warmer weather, decreased consumption should be typical in winter and increased consumption should be typical in the summer. Moreover, the effect of higher temperatures mainly in summer is likely to be considerably greater on peak energy consumption than on net consumption, suggesting that there will be a need to install additional generating capacity over and above that needed to cater for underlying economic growth.

In order to assess the sensitivity of energy demand to climate changes the relationship of energy demand with changes in air temperature was investigated for the case of Cyprus.

Hourly energy consumption data together with mean daily air temperatures for the island of Cyprus were made available by the Transmission System Operator of Cyprus. These data refer to total hourly residential and commercial energy consumption (MWh) spanning the period from January 1999 to December 2009.

Daily variation in air temperature and energy consumption for the period 1999–2009 for the island of Cyprus is depicted in Figure 10-34. Energy consumption shows a clearer upward trend compared to air temperature. The increase in energy consumption is largely due to economic growth and also to greater usage of air conditioners in residential and commercial situations. The link between hot weather and increased energy consumption is also evident in other warm countries where use of air conditioners has increased. It is obvious that there are two components in energy load variations: seasonal and yearly. The former is mainly influenced by the prevailing weather conditions and the latter by economic, social and demographic factors.

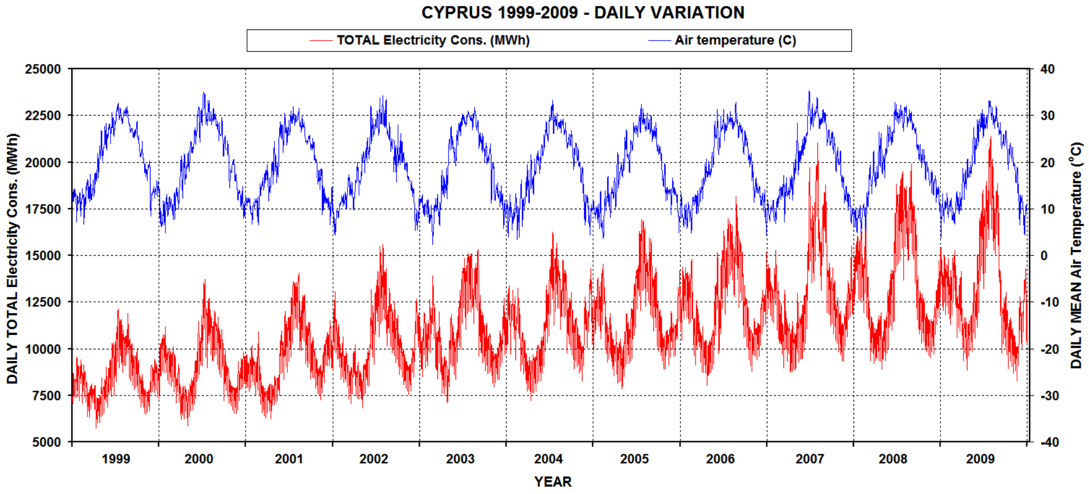
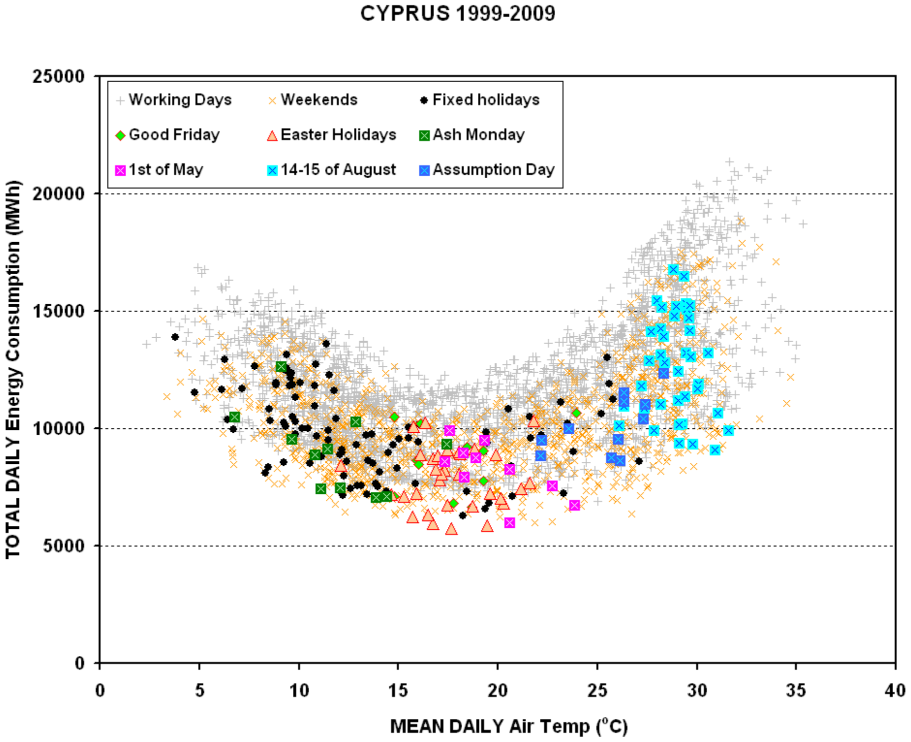


Figure 10-34: Daily variation in air temperature (^{o}C) and energy consumption (MWh) for the period 1999–2009 for the island of Cyprus

Variation in daily energy consumption and mean daily air temperature for the examined period 1999-2009 is shown in Figure 10-35. Energy consumption is closely linked to mean daily air temperature; the maximum values of the former coincide with extremes of the latter. In January, energy consumption peaks during the lowest temperatures. In the transitional season (March–April) when air temperatures are constantly rising but remain comfortable, energy consumption levels are approximately constant. Energy use is greatly reduced during weekends and holidays compared to working days. The lowest values of energy consumption occur during the long Easter weekend (Good Friday to Easter Monday) and other fixed holidays (Christmas, bank holidays, Assumption Day), irrespective of daily mean air temperature. The relationship between energy consumption and air temperature is not linear, but presents a single minima and double maxima. Above this minima, energy consumption increases with higher temperatures (due to air conditioning). Below this minima, energy consumption increases with lower temperatures (due to space heating).



Working days and weekends/holidays have been plotted using different shape figures.

Figure 10-35: Scatter plot of daily energy consumption versus daily mean air temperature for the period 1999–2009 for the island of Cyprus

Temporal variability of energy consumption

An analysis was carried out to investigate whether energy consumption follows a monthly, diurnal or hourly cycle. The nature of such a cycle can be assessed using seasonal variation indices (Giannakopoulos and Psiloglou, 2006). The Monthly Seasonal Variation Index (MSVI), can be defined as:

$$MSVI_{ij} = {}^{E_{ij}}\!/_{\overline{E_j}}$$

where $MSVI_{ij}$ is the index value for month i in year j, E_{ij} is the monthly energy consumption for month i in year j and E_j is the mean monthly consumption for year j (mean of 12 values of E_{ij} for year j). The average value of MSVI represents the mean annual energy consumption whereas maximum and the minimum values of MSVI reveal deviations from mean consumption pattern. Figure 10-36 shows the monthly values of MSVI for the island of Cyprus. The maximum values of energy consumption are related to the maximum monthly temperatures, mainly in July and August, indicating the need for space cooling. Energy consumption falls as autumn approaches and increases again during the festive Holiday season in December and in January related to colder temperatures. MSVI then gradually decreases until May.

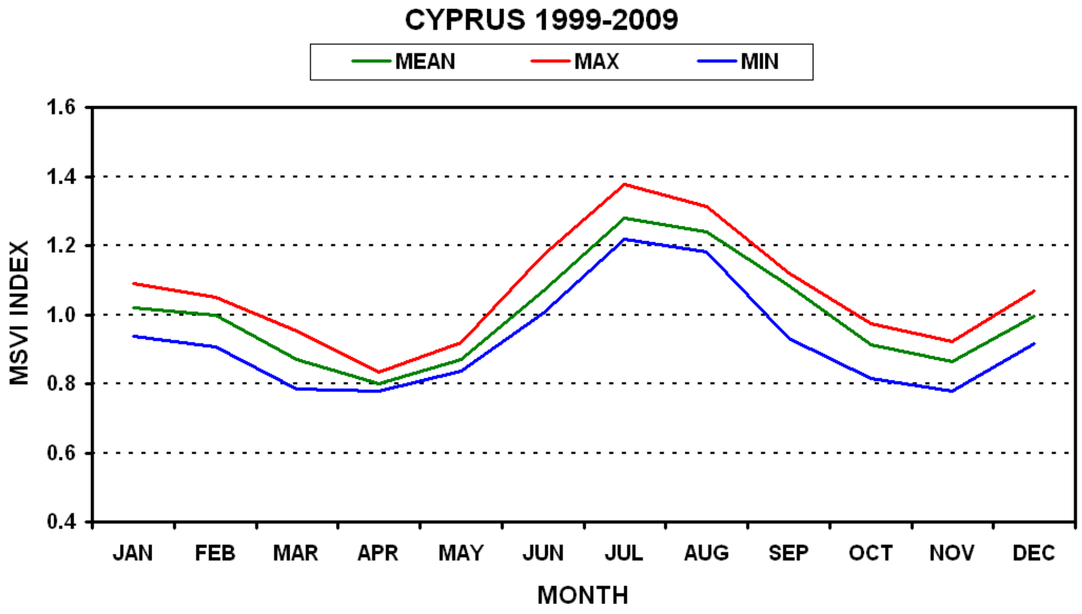


Figure 10-36: Monthly variation of energy consumption using them MSVI index in Cyprus for 1999-2009

The daily fluctuation of energy load was subsequently investigated based on the Daily Variation Index (DSVI) which is defined as:

$$\mathrm{DSVI}_{ijk} = \mathrm{E}_{ijk} \Big/ \overline{\mathrm{E}_{jk}}$$

where DSVI$_{ijk}$ is the value of the index for day *i* of week *j* of year *k*, E$_{ijk}$ is the energy consumption for the particular day, and $\overline{\mathrm{E}_{jk}}$ is mean daily consumption for week *j* of year *k*. In Cyprus, energy consumption is significantly lower during the weekends (especially on Sundays) due to reduced economic activities over this period. Small fluctuations are evident in the other days of the week. Winter and summer months tend to have similar behavior with summer weekdays having higher energy levels and summer weekends having lower energy levels than the winter ones (Figure 10-37).

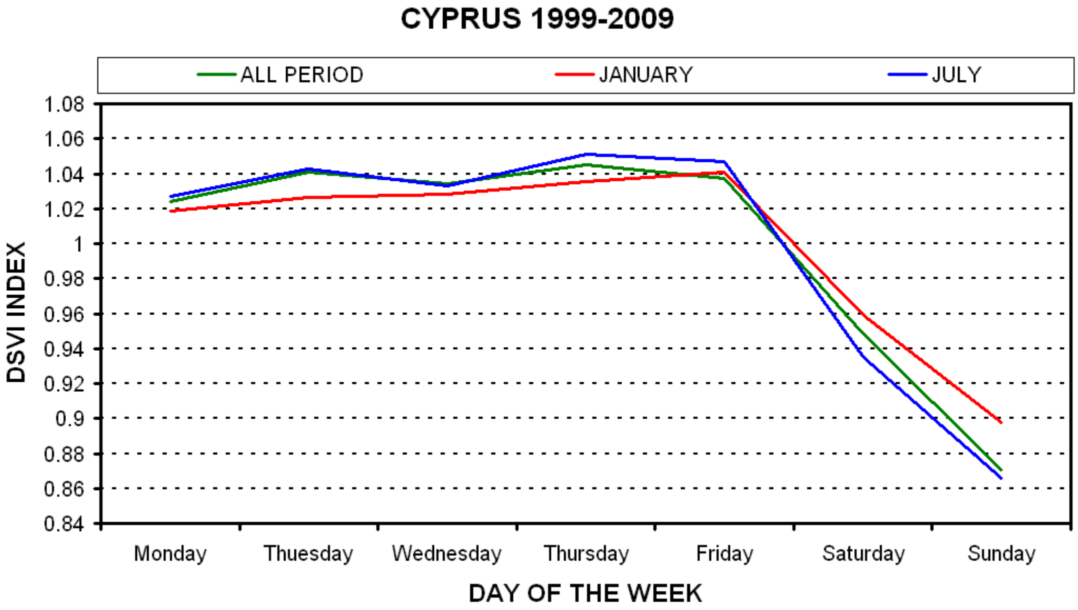


Figure 10-37: Daily variation of energy consumption using the DSVI index in Cyprus for 1999-2009

Finally, hourly values of energy consumption were utilized to calculate the Hourly Seasonal Variation Index (HSVI), which shows diurnal variation in energy consumption. The average diurnal variation for each month (24 average hourly values each month) was estimated based on the hourly values, and thus an average 24 h period become available for each month. Hence, for each year, 12 such 24 h periods have been derived. The HSVI is defined as:

$$\mathrm{HSVI}_{ijk} = {}^{\mathrm{E}_{ijk}}\!\big/_{\overline{\mathrm{E}}_{jk}}$$

where HSVI$_{ijk}$ is the value of the index for hour *i* of the average 24 h period of month *j* in year *k*, E$_{ijk}$ is the energy consumption for a certain hour, and $\overline{\mathrm{E}_{jk}}$ is mean monthly energy consumption for month *j* in year *k*.

Figure 10-38 presents the hourly variation during a 24 h period in Cyprus for the period 1999-2009. Energy values rise after 9am when people start work and remain at high levels until 9pm with a small decline soon afterwards and a larger decline from 2am-8am. January presents lower energy values during the day and higher during the evening/night than July. A small peak exists around 7-8pm in January reflecting the need for additional heating in the evening hours as people tend to stay indoors and engage in home activities.

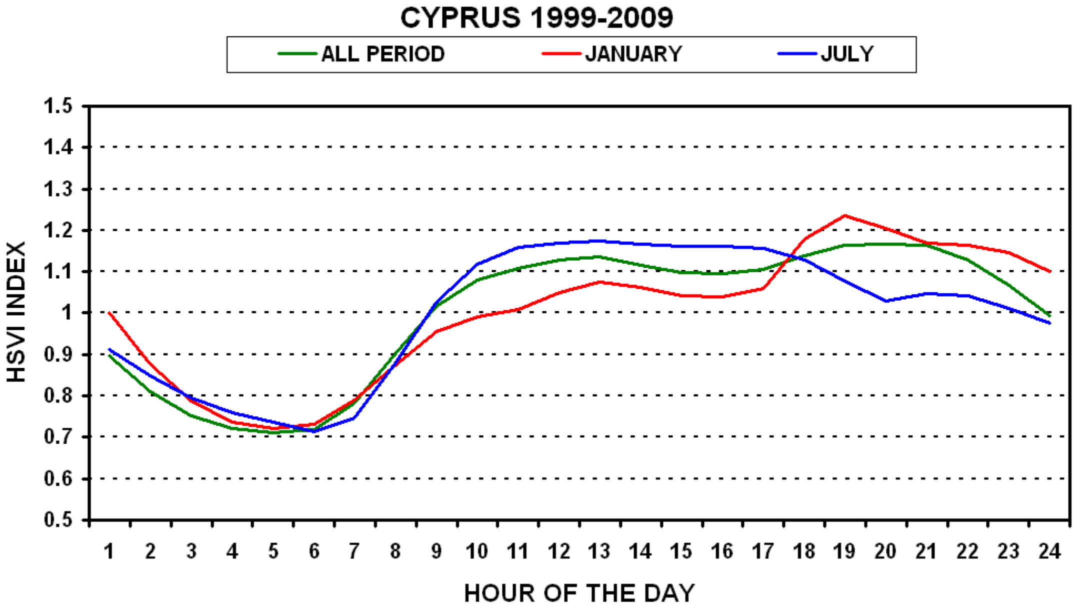


Figure 10-38: Hourly variation of energy consumption using the DSVI index in Cyprus for 1999-2009

The sector of Cyprus which is considered more likely to experience increase in energy demand due to increased temperature, is the tertiary sector which includes households and commerce & service sectors. The aggregate share of these two sectors for Cyprus totals 78% (see Figure 10-3), confirms that the demand for power is very sensitive to changes in temperature.

What is more, preliminary results from a recent study (Zachariadis, 2010) indicate that the welfare loss associated with the additional electricity requirements can reach 15 million € in 2020 and 45 million € in 2030. The burden induced per household is estimated around 30€/year in 2020 and 80€/year in 2030 (at constant prices of year 2007).

Conclusively, the demand for power has been estimated to present **Very high** sensitivity to temperature changes.

Exposure: For the assessment of the exposure of energy demand to climate changes, the future changes in overall energy consumption based on temperature changes as well as the changes in the heating and cooling demand will be estimated.

Overall energy consumption

In order to assess the future exposure of the overall energy consumption to temperature rise, temperature data from the PRECIS RCM as well as the six ENSEMBLES RCMs are used for two 30 year periods: the 'control period' 1961–1990 and the 'future period' 2021-2050, employing the A1B scenario. To be able to project energy consumption under future climatic conditions, the same technology use is assumed between the control and the future period.

Moreover, we split our examined period into ‘cold’ and ‘warm’ period. The ‘cold’ period covers the months November-April and the ‘warm’ period the months May-October.

The variation of energy consumption in the ‘cold’ period follows a non-linear decreasing pattern as temperatures rise and the mathematical formula used for the extrapolation under future climatic conditions appears in Figure 10-39. Figure 10-40 presents patterns of energy consumption related to maximum air temperature for the observations (1999-2009), the control period 1961-1990 and the future period using the extrapolation formula of Figure 10-39. For the ‘cold’ period of the year (November to April), a decreasing trend in energy consumption is evident as warmer conditions dominate by 2050. Moreover, it is clear that observations lie closer to the levels of consumption typical in the 2021-2050 than in 1961-1990, indicating that a certain degree of decrease in energy consumption levels in the ‘cold’ period of the year has already occurred by 2009. There are variations among the various examined models but the signal of decrease around 5% compared to the control period in energy consumption levels remain.

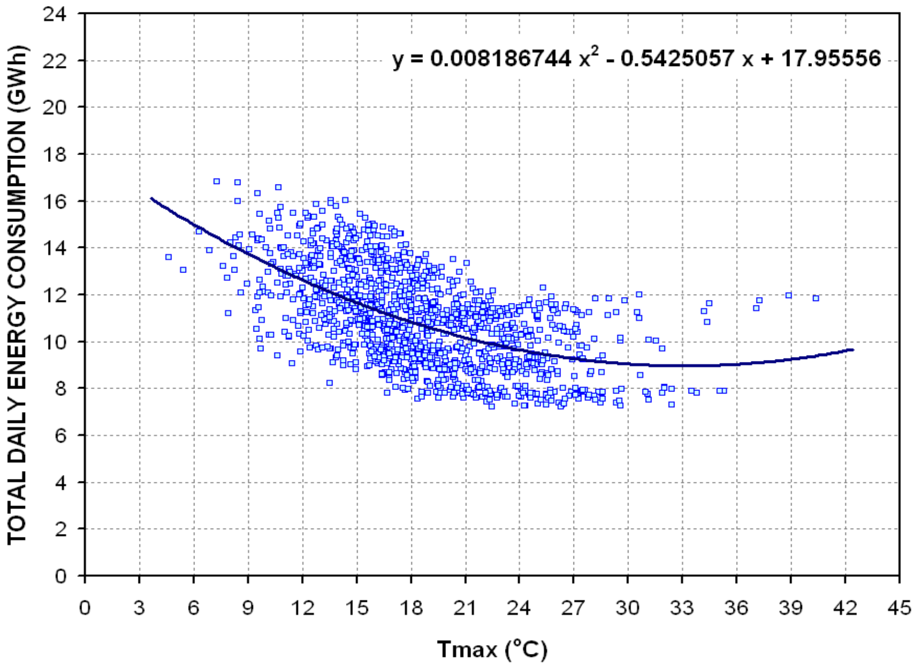


Figure 10-39: Relation of daily energy consumption with daily maximum air temperature for the ‘cold’ period of the year for the period 1999-2009 in Cyprus

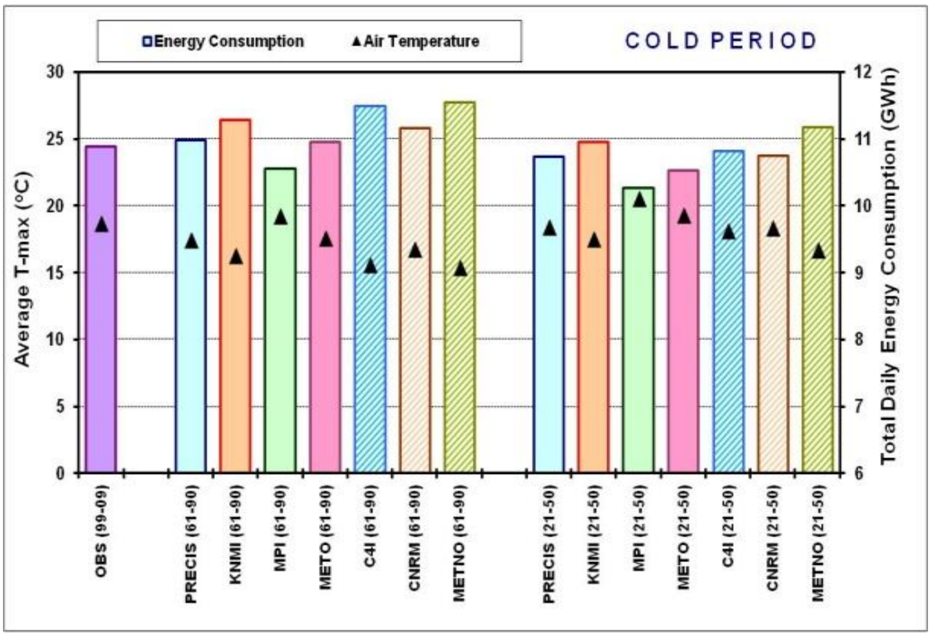


Figure 10-40: Cyprus energy consumption (bars, right axis) and daily maximum air temperature (triangles, left axis) for the 'cold' period of the year for the observations period 1999-2009, the various models for the control period 1961-1990, and the future period 2021-2050

The variation of energy consumption in the 'warm' period follows a non-linear increasing trend as temperatures rise and the mathematical formula used for the extrapolation under future climatic conditions appears in Figure 10-41. Figure 10-42 presents patterns of energy consumption related to temperature for the observations (1999-2009), the control period 1961-1990 and the future period using the extrapolation formula of Figure 10-41. For the 'warm' period of the year (May-October), an increasing trend in energy consumption is evident as warmer conditions dominate by 2050. Moreover, it is clear that observations lie closer to the levels of consumption typical in the 2021-2050 than in 1961-1990, indicating that a certain degree of increase in energy consumption levels in the 'warm' period of the year has already occurred by 2009. There are variations among the various examined models but the signal of increase around 10% compared to the control period in energy consumption levels remain. It is worth noting here that the increase in the 'warm' period of the year doubles the energy decrease (saving) in the 'cold' period of the year.

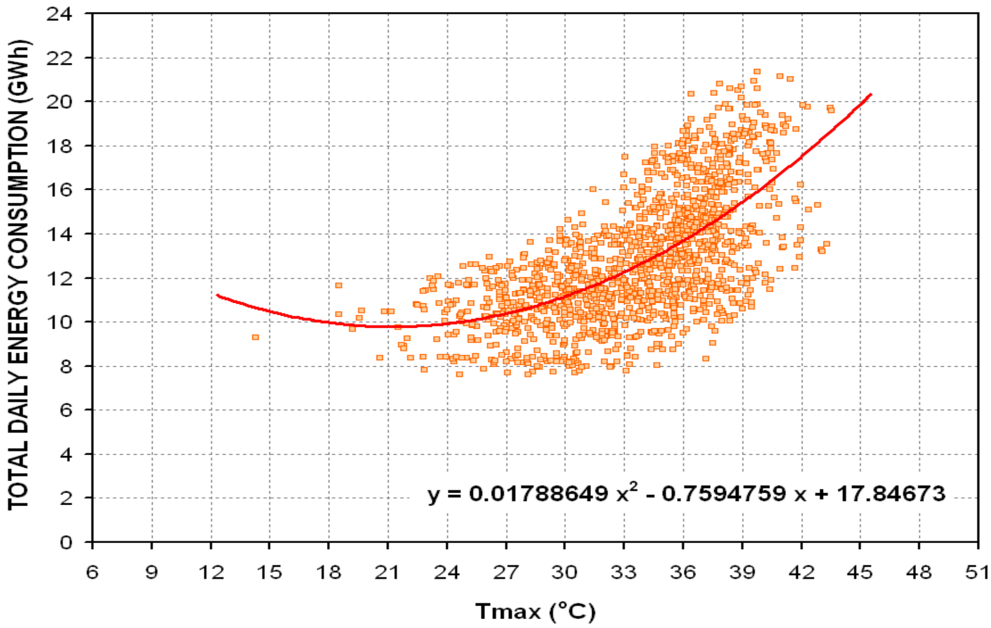


Figure 10-41: Relation of daily energy consumption with daily maximum air temperature for the 'warm' period of the year for the period 1999-2009 in Cyprus

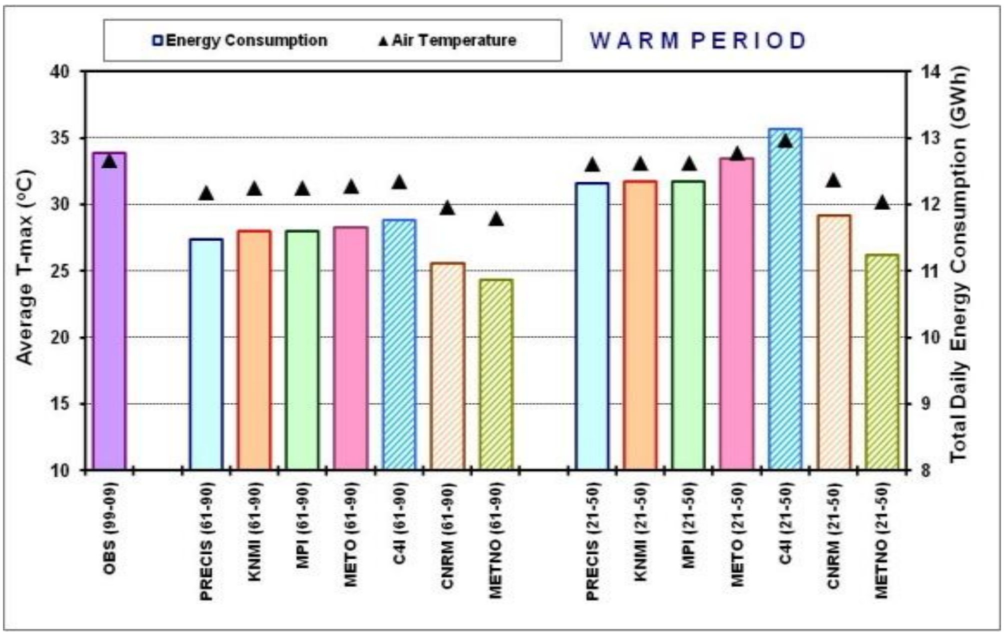


Figure 10-42: Cyprus energy consumption (bars, right axis) and daily maximum air temperature (triangles, left axis) for the 'warm' period of the year for the observations period 1999-2009, the various models for the control period 1961-1990, and the future period 2021-2050

Heading and cooling demand

In order to assess the current and future exposure of the heating and cooling demand to climate changes, the indicator of Degree-Day (DD) is used. Degree Day is a measurement designed to reflect the demand for energy needed to heat or cool a building. It is defined as the difference of the mean daily outdoor temperature from the base temperature. Base temperature is the temperature above or below which a building presents no requirements for heating or cooling, respectively. In other words, base temperature is usually an indoor temperature which is adequate for human comfort. Degree-Days are categorized into Heating Degree Days (HDD – demand for heating) and Cooling Degree Days (CDD – demand for cooling).

For the calculation of the HDD and CDD indices, the following equations were used:

$HDD = \max (T^* - T, 0)$

$CDD = \max (T - T^{**}, 0)$

where T^* and T^{**} are the base temperatures for HDD and CDD respectively, which can be either the same or different and T is the mean daily temperature calculated from the daily data of RCMs models for both the control – reference period (1961 – 1990) and the future (2021 – 2050) period.

Kadioğlu et al. (2001) used different base levels of 15°C and 24°C for the calculations of HDD and CDD respectively in Turkey. In our study we used 15°C for the calculation of HDDs and 25°C for the calculation of CDDs. We identified the changes in energy demand levels by showing differences in the cumulative numbers of CDDs and HDDs between the reference (1961–1990) and the future (2021 – 2050) period.

All calculations were performed using the PRECIS Regional Climate Model (RCM). In addition, six RCMs of the ENSEMBLES project have also been used namely KNMI, METNO, CNRM, METO, C4I and MPI. The results of models were used as an ensemble mean for testing and comparing the respective results of PRECIS.

Following, PRECIS results regarding estimated current and future HDD and CDD in Cyprus are presented. The changes in future and current HDD and CDD indicate the change in energy requirements for heating or cooling and thus the exposure to future climate changes.

Heating Degree Days:

Spring is generally a transient season in which energy demand levels are kept nearly constant and at low levels. Due to warmer climate conditions a decrease is anticipated in energy demand both during spring and winter which can be considered as a “positive aspect” of climate change in Cyprus. Figure 10-43 shows cumulative HDD during spring for control period using PRECIS RCM. It is shown that inland and southeastern areas present an energy demand for heating of about 90 and 50 degree-days respectively. Southern and western areas present an energy demand of around 100 degree-days. The maximum energy demand is presented at high elevation areas of Troodos Mountain varying from 130 to 225 degree-days. As far as future changes are concerned, Figure 10-44 depicts that energy demand during spring is projected to decrease in all Cyprus. The greater reductions are projected for mountain areas of about 75 degree-days. For inland and southeastern areas, although the demand is small, it is projected to drop further in the near future of about 25-30 degree-days. For southern and western areas the decrease is expected to reach 30 degree-days.

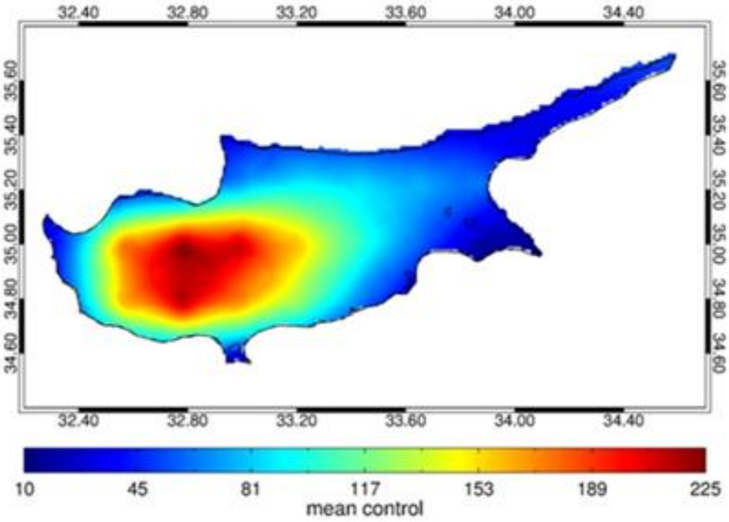


Figure 10-43: Spring cumulative HDD for control period (1960-1990), PRECIS RCM model

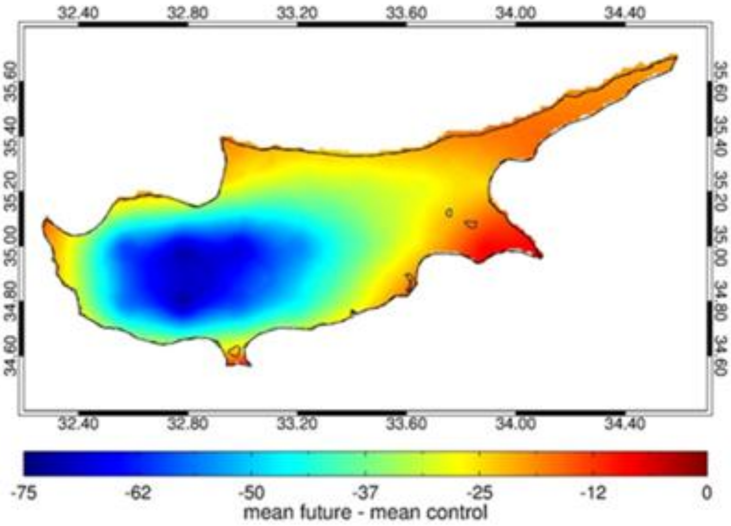


Figure 10-44: Change in spring cumulative HDD in the near future (Future – Control period)

In Cyprus, the greatest energy demand for heating is observed during winter months. As shown in Figure 10-45, control period energy demand for heating reaches 650 degree-days mainly in the wider area of Troodos Mountain and approximately 350 degree-days in western and 450 degree-days in southern-southeastern and inland regions. Significant reductions in energy demand due to warming conditions are projected for the near future for almost all the island. Figure 10-46 depicts that mountain regions (from high to medium elevations) will benefit most from the greatest reductions of about 90 degree-days. Furthermore for inland, south-southeastern and western areas the reduction is approximately 60 degree-days.

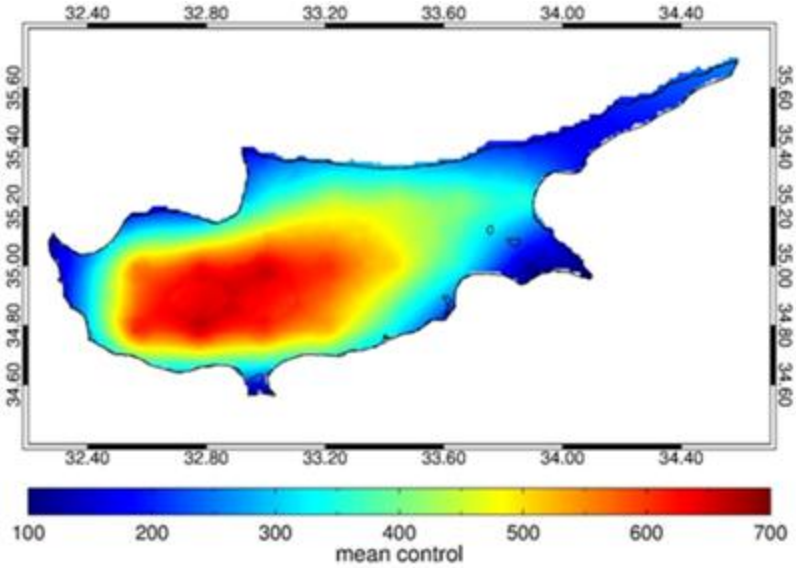


Figure 10-45: Winter cumulative HDD for control period (1960-1990)

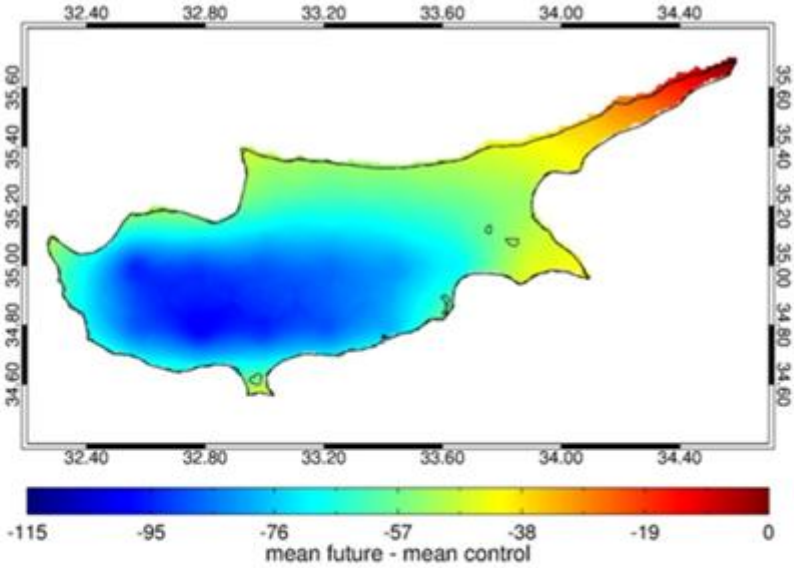


Figure 10-46: Change in winter cumulative HDD in the near future (Future – Control period)

Apart from seasonal distribution of energy demand for heating, it has also been studied the annual distribution of it. As Figure 10-47 shows, the pattern of distribution is similar with the respective patterns of the previous seasonal plots. It is depicted that maximum energy demand for heating of about 950 degree-days derives from high elevation areas (Troodos Mountain). In addition inland, southeastern as well as southern and western areas present lower energy demand of about 550 degree-days. The “beneficial impacts” of warming in the future are shown in Figure 10-48 where a significant reduction of energy demand for heating of about 200 degree-days in the wider area of Troodos Mountain is testified. Also, inland, southeastern and western areas show a reduction of about 110 degree-days.

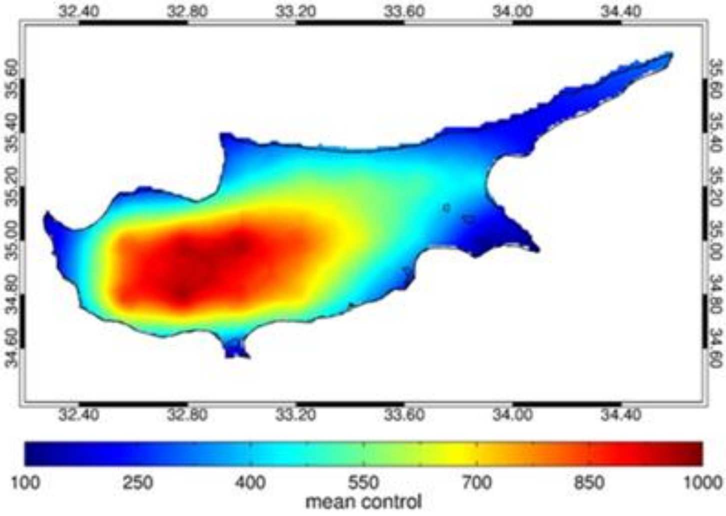


Figure 10-47: Annual cumulative HDD for the control period (1960-1990)

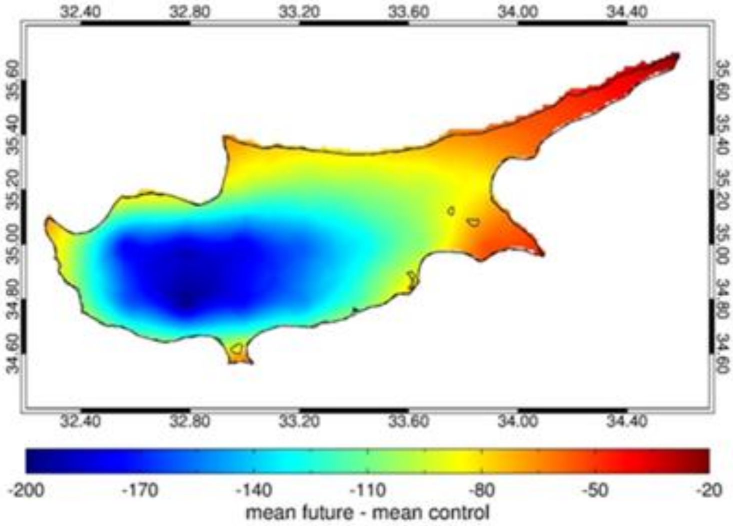


Figure 10-48: Change in annual cumulative HDD in the near future (Future – Control period)

Finally, Figure 10-49 shows the number of days per year requiring heavy heating i.e. days requiring heating of more than 5°C from the base temperature of 15°C. It is also shown that mountain regions of Troodos demand approximately 100 days of heavy heating while inland and southern areas require approximately 55 days. Southeastern and western regions require fewer days for heavy heating of the order of 35. Regarding projections on future changes (Figure 10-50), a decrease in the number of days per year requiring heavy heating is testified. In particular, a decrease of about 18 days is projected for mountain region while for Nicosia and Limassol Districts the decrease is about 12 days. Also, southeastern and western areas show a reduction of about 10 days.

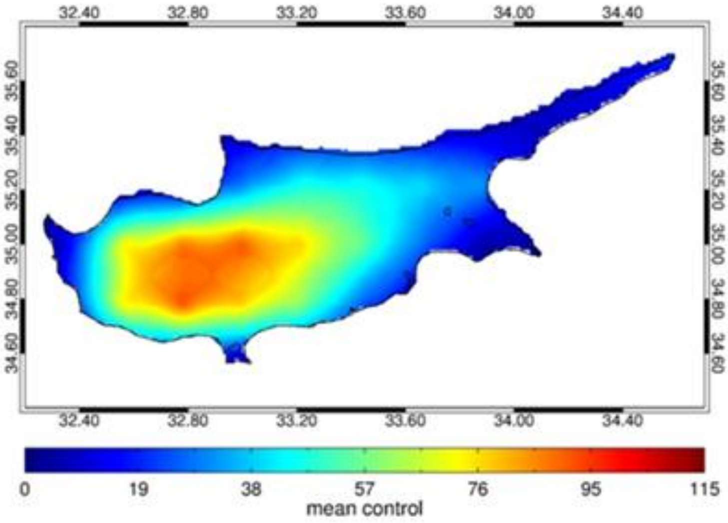


Figure 10-49: Number of days with high HDD (>5) for the control period (1960-1990)

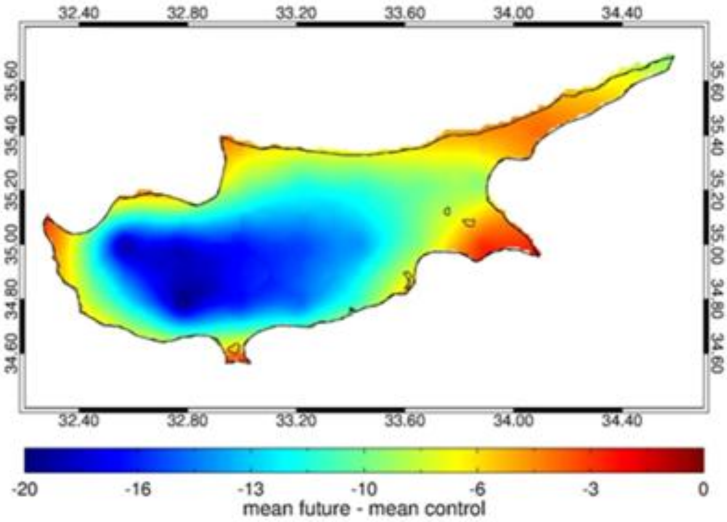


Figure 10-50: Change in the number of days with high HDD (>5) in the near future (Future – Control period)

The overall findings of the analysis regarding both present-day climate and potential near future changes due to climate change with negative or positive impacts on Cyprus energy demand for heating are summarized in Table 10-6 and Table 10-7.

Table 10-6: Values of indices with particular relevance to energy demand for heating

	Western Regions	Mountain Regions	Inland Regions	Southern Regions	Southeastern Regions
Spring cumulative HDD	100	130-225	90	100	50
Winter cumulative HDD	350	650	450	450	450
Annual cumulative HDD	550	950	550	550	550
Nb of days with high HDD (>5)	35	100	55	55	35

Table 10-7: Potential future changes in indices with particular relevance to energy demand for heating

	Western Regions	Mountain Regions	Inland Regions	Southern Regions	Southeastern Regions
Spring cumulative HDD (degree-days)	(–) 30	(–) 75	(–) 25	(–) 30	(–) 25
Winter cumulative HDD (degree-days)	(–) 60	(–) 90	(–) 60	(–) 60	(–) 60
Annual cumulative HDD (degree-days)	(–) 110	(–) 200	(–) 110	(–) 110	(–) 110
Nb of days with high HDD (>5)	(–) 10	(–) 18	(–) 12	(–) 12	(–) 10

Cooling Degree Days:

To begin with, Figure 10-51 depicts current energy demands during summer using PRECIS model. It is testified that greater energy demands for cooling, of around 300 degree-days are presented in southeastern (Larnaca District) and inland (Nicosia District) regions. Lower energy needs are shown in mountain and much lower in western regions where energy demands reaches 100-200 degree-days and 50-100 degree-days respectively. As far as future changes are concerned, Figure 10-52 shows that an extended increase in energy demand of about 160-200 degree-days for mountain regions and about 200 degree-days in inland and southern – southeastern areas is anticipated. Fewer energy needs are projected for western areas of the order of 100 degree-days.

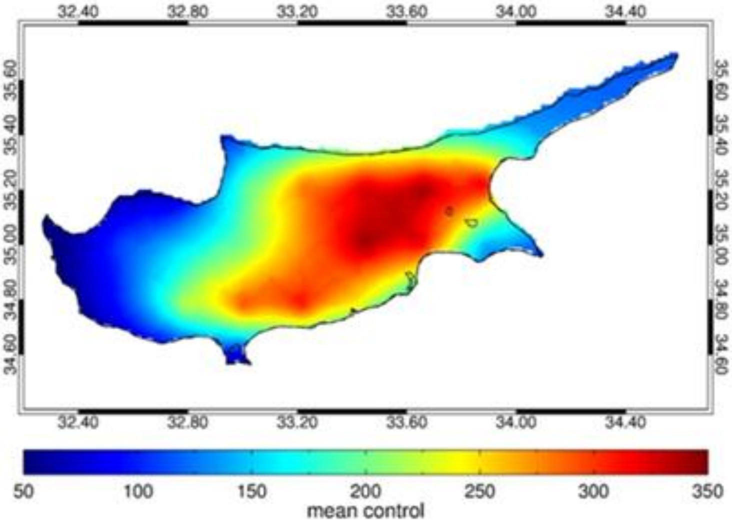


Figure 10-51: Summer cumulative CDD for the control period (1960-1990)

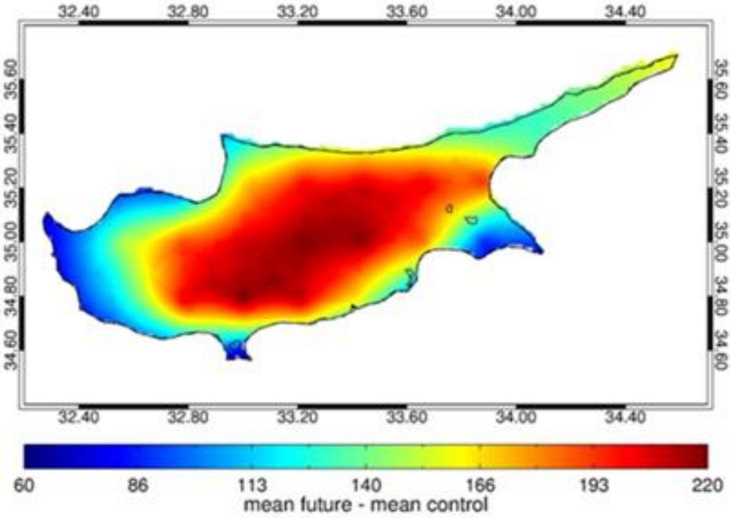


Figure 10-52: Change in summer cumulative CDD in the near future (Future – Control period)

Regarding the possibility of warming influencing energy demand during autumn, the fall cumulative cooling degree-days parameter has been examined. Figure 10-53, presents that in the present-day climate, energy demand for cooling during the autumn is at low levels, 30 degree-days with most demand being confined at southeastern and inland regions. Western regions shows lower energy demands of about 10 degree-days. Concerning future changes, Figure 10-54 shows a rise in energy demand of about 50 degree-days in inland and southeastern regions and about 40 degree-days in southern regions. For mountain and western regions the increase is lower of around 30 and 20 degree-days respectively.

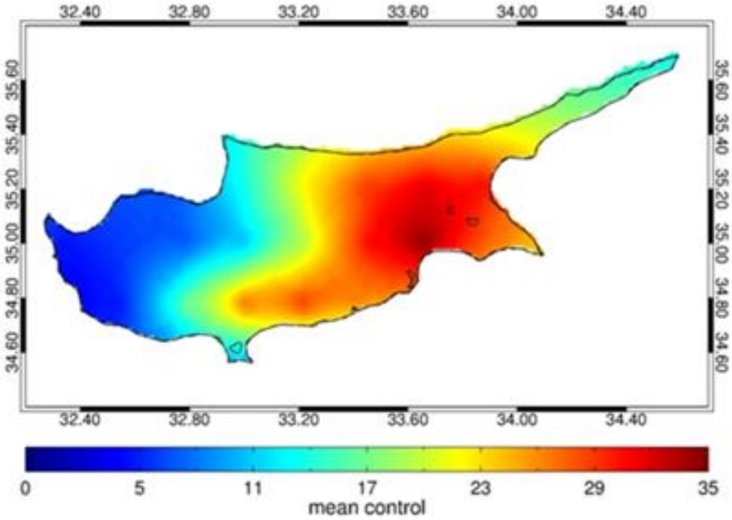


Figure 10-53: Fall cumulative CDD for the control period (1960-1990)

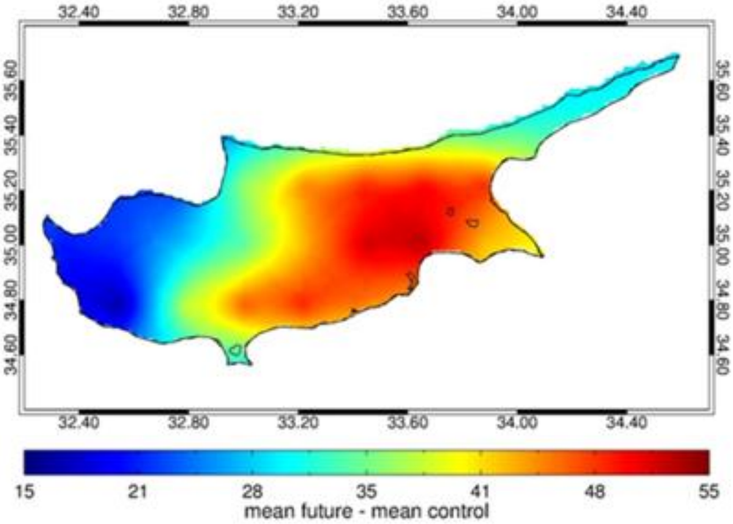


Figure 10-54: Change in fall cumulative CDD in the near future (Future – Control period)

To examine the annual pattern of energy demand for cooling, annual cumulative CDD parameter has also been investigated. Figure 10-55 depicts that in the present-day climate, the yearly maximum energy demands of about 350 degree-days are derived from southeastern and inland regions while mountain and western regions shows lower demands of about 200-260 degree-days and 100 degree-days respectively. Concerning future changes according to PRECIS projections (Figure 10-56), an important increase of about 260 degree-days is anticipated for inland and southern and southeastern regions. In mountain areas the increase varies from 170 to 260 depending on the altitude. Only the western part of the island is expected to experience lower increases of about 100 degree-days.

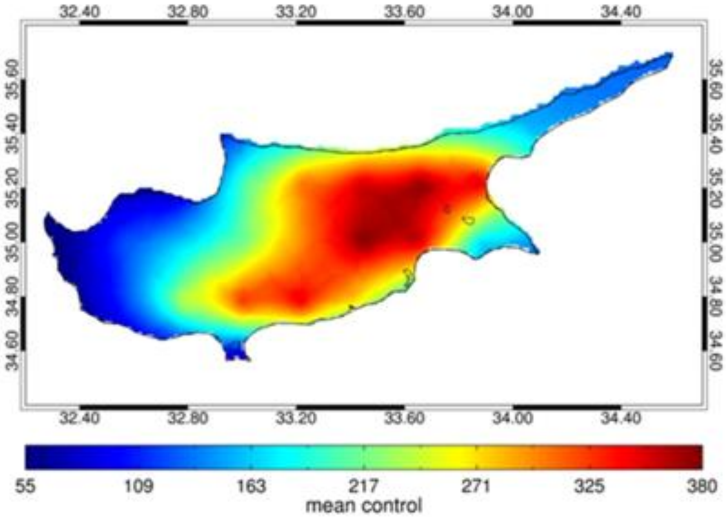


Figure 10-55: Annual cumulative CDD for the control period (1960-1990)

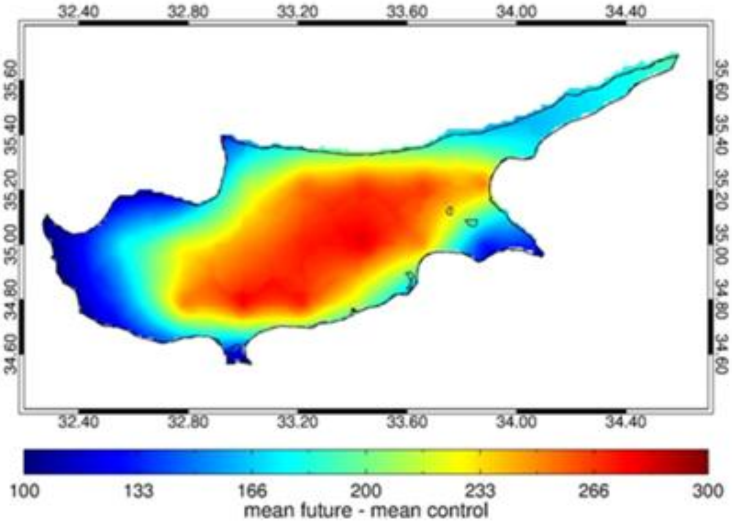


Figure 10-56: Change in annual cumulative CDD in the near future (Future – Control period)

Finally, an important parameter in assessing the changes in energy demand for cooling was examined, namely the number of days per year requiring excessive cooling of more than 5°C from the base temperature of 25°C. Figure 10-57 shows that, nowadays, it is required 25-30 days per year of heavy cooling mainly in southeastern and inland regions as well as southern regions (Limassol). In mountain and western regions the number of days with heavy cooling is around 5-15 days and 0-5 days respectively. Regarding future changes, Figure 10-58 shows that it is anticipated an additional month of heavy cooling in the near future period for inland, southern and southeastern regions. In mountain regions the increase varies from 15 to 30 days depending on the height. For western regions a smaller increase of about 5 days is expected.

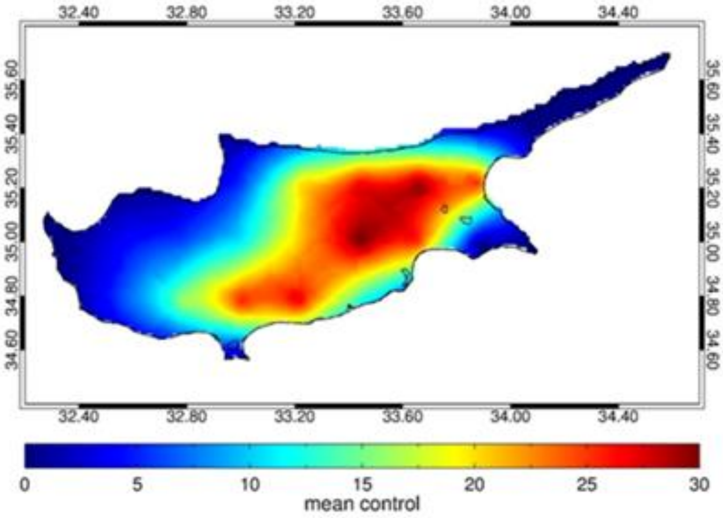


Figure 10-57: Number of days with high CDD (>5°C) for the control period (1960-1990)

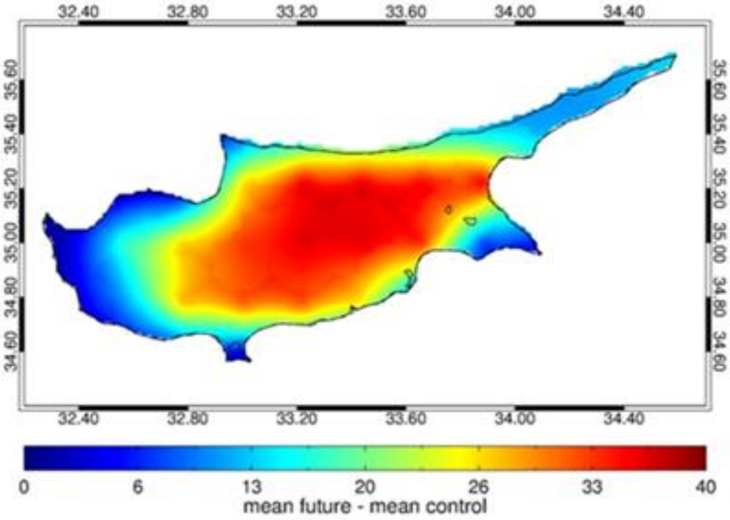


Figure 10-58: Change in the number of days with high CDD (>5 °C) in the near future (Future – Control period)

The overall findings of the analysis regarding both present-day climate and potential near future changes due to climate change with negative or positive impacts on Cyprus energy demand for cooling are summarized in Table 10-8 and Table 10-9.

Table 10-8: Values of indices with particular relevance to energy demand for cooling.

	Western Regions	Mountain Regions	Inland Regions	Southern Regions	Southeastern Regions
Summer cumulative CDD (degree-days)	50-100	100-200	300	150-250	300

	Western Regions	Mountain Regions	Inland Regions	Southern Regions	Southeastern Regions
Fall cumulative CDD	10	10-20	30	20	30
Annual cumulative CDD (degree-days)	100	200-260	350	190-220	350
Nb of days with high CDD (>5^{o}C)	0-5	5-20	25-30	10-20	25-30

Table 10-9: Potential future changes in indices with particular relevance to energy demand for cooling.

	Western Regions	Mountain Regions	Inland Regions	Southern Regions	Southeastern Regions
Summer cumulative CDD (degree-days)	(+) 100	(+) 160-200	(+) 200	(+) 200	(+) 200
Fall cumulative CDD	(+) 20	(+) 30	(+) 50	(+) 40	(+) 50
Annual cumulative CDD (degree-days)	(+) 100	(+) 170-260	(+) 260	(+) 260	(+) 260
Nb of days with high CDD (>5 ^{o}C)	(+) 5	(+) 15-30	(+) 30	(+) 30	(+) 30

Taking into account both the future changes in annual energy demand for cooling (CDD) and in annual energy demand for heating (HDD) in Cyprus, it can be said that most pronounced is the effect of increased demand for cooling in the inland regions (Nicosia) and southern and southeastern coastal regions (Limassol, Larnaca and Famagusta). In particular, the difference between the annual CDD and HDD is 150 days, while for the mountain regions (Troodos) and western regions (Paphos) the difference is minor (Table 10-10).

Table 10-10: Future changes in accumulative annual HDD and CDD in Cyprus

	Western Regions	Mountain Regions	Inland Regions	Southern Regions	Southeastern Regions
Change in accumulative annual HDD (A)	(-)110	(-)200	(-)110	(-)110	(-)110
Change in accumulative annual CDD (B)	(+)100	(+)215	(+)260	(+)260	(+)260
Difference (A)-(B)	**(-)10**	**(+)15**	**(+)150**	**(+)150**	**(+)150**

Given that the areas projected to be mostly affected by increases in temperature and especially Nicosia which is the capital of the island are densely populated, as well as that the free area of Famagusta constitutes a highly touristic area with excess demand for cooling in the summer period, while the mountain areas are more sparsely populated, the exposure of heating/cooling demand to climate changes has been ranked as **very high**.

10.4.3.2. Assessment of adaptive capacity

The adaptive capacity of the sector to changing demand in power and heat is dependent on the following four (4) aspects:

- Installation of new power plants for following future energy demand of the island;
- Energy efficiency measures undertaken or underway;
- Use of solar energy for heating and cooling. In Cyprus, solar thermal systems are widely used for the needs for hot water, while photovoltaic systems are increasingly used at household level reducing therefore the pressure on the energy supply sector; and
- Introduction of natural gas in the energy supply portfolio.

New power stations

Maximum output capacity (2016):	**~1,700 MW**[13]
Peak demand (2016):	**~1,400 MW**[14]
Energy capacity (2020):	**7,360 GWh**[15]

In order to assess the sensitivity of the sector regarding the changing demand for electricity and heat a series of additional indicators should be taken into consideration, as for instance energy dependence of the island on imports.

First of all, the main sensitivity lies in the capacity of supplying the ever increasing demand for electricity, which is partly attributed to economic and development factors as well as to climate change (mainly temperature increase).

The projected increase in electricity demand is presented in Figure 10-59.

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[13] Source: (EAC, 2011; p. 31)
[14] Source: (EAC, 2011; p. 31)
[15] Source: (EEA, 2011; p. 207)

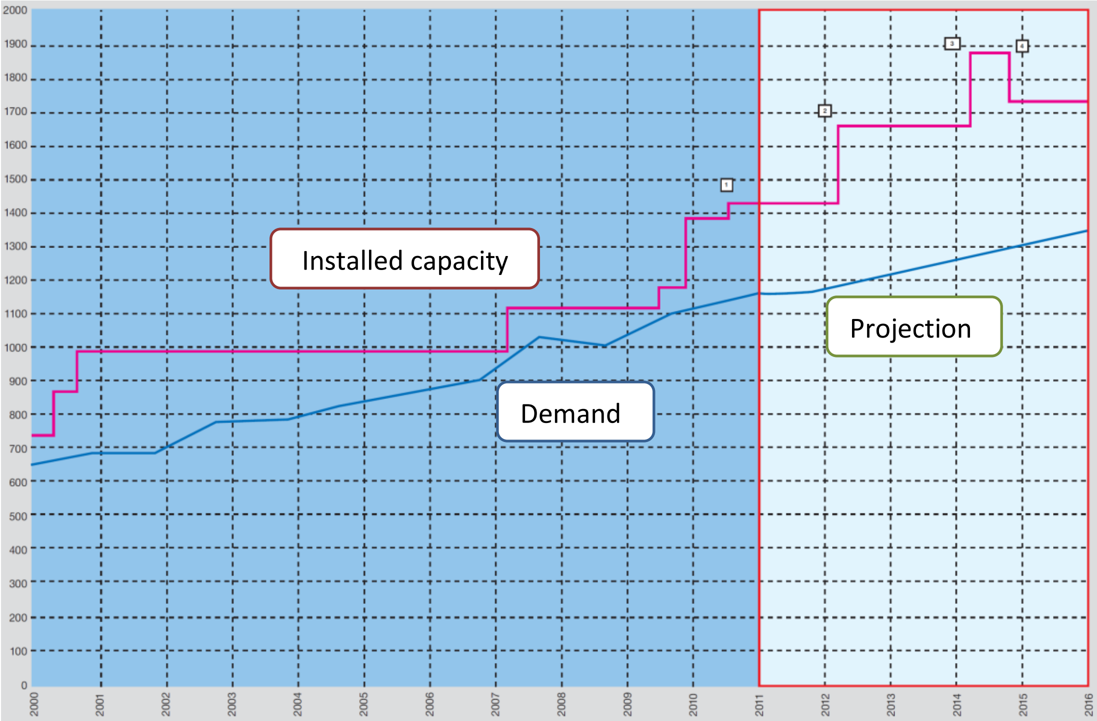

Figure 10-59: Installed capacity and demand: Actual figures and projection

Source: EAC, 2010

As obvious from the above diagram, the electrical requirements are expected to grow over time, fact that requires the installation of new power plants. The EAC's plan for the commissioning of new power plants and the decommissioning of old, existing plants is presented in Figure 10-60.

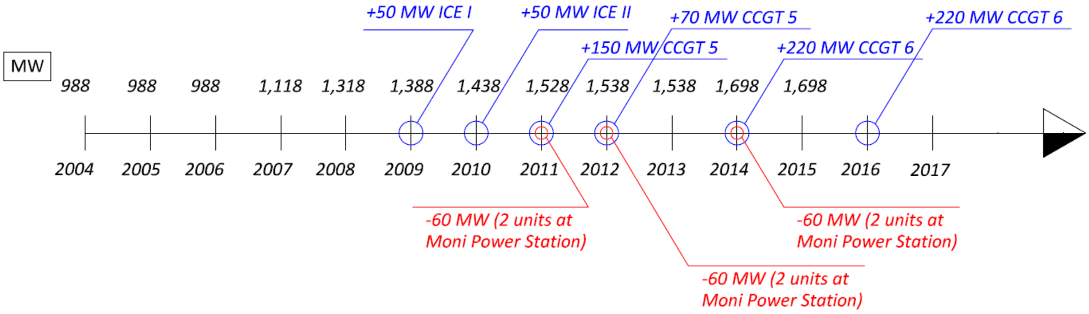

Figure 10-60: Installation of new power plants and decommissioning of existing units until 2017

Source: Own production (NTUA working team)

It must be noticed that, while there exists a sufficient follow-up between supply and demand, meaning that EAC has developed a plan to guarantee the succesfull delivery of power in order to meet the increasing demand (lowering down the sensitivity), there is a sustained challenge which needs to be addressed. The current electricity production regime is dependent on imported oil, fact that implies concern over the energy dependence of the island, which in turn implies questions about how secure is the energy system and capable of delivering electrical energy whatever the external political and economic circumstances.

More specifically, as illustrated in Figure 10-62, the primary energy consumption of Cyprus is dependent highly in petroleum products[16], the cost of which totaled to 3 billion € corresponding to 19.7% of the total cost on imports or 7.3% of the GDP of the Republic of Cyprus. The same does not apply for EU-27 and the globe.

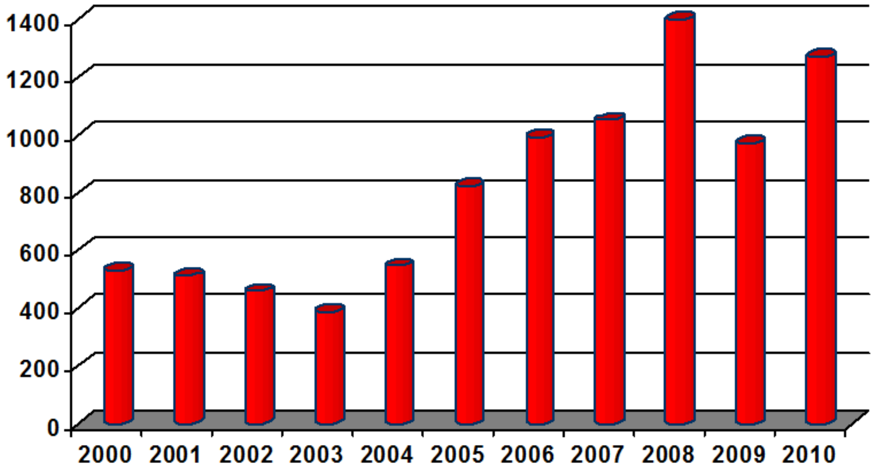

Figure 10-61: Cost of imported fossil fuels in Cyprus for the years 2000-2010

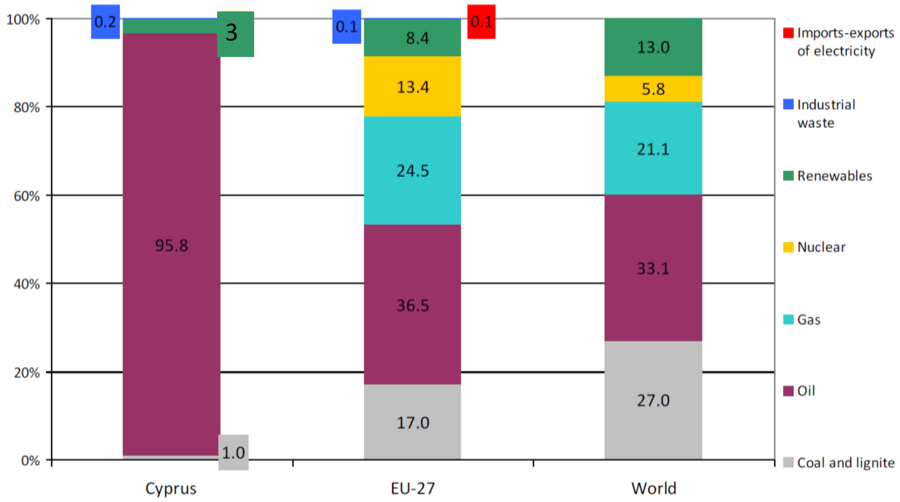

Figure 10-62: Primary energy consumption by fuel for Cyprus, EU-27 and worldwide

Energy efficiency measures

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[16] There is a minor contribution of coal and lignite (1%) to the primary energy consumption. The major consumer of this type of energy resource is industry and in particular cement production.

Cyprus has established a National Energy Efficiency Action Plan, which involves the implementation of a set of measures for improving energy efficiency until 2020. The indicative intermediate target for 2016 was set at 185,000 toe[17], while the contribution by sector is as follows (MCIT, 2011):

- Residential sector: 161,877 toe (87.5%);
- Tertiary sector (public sector, general government and enterprises): 23,681 (12.8%);
- Industrial sector: 1,284 toe (0.69%) and
- Transport sector: 3,909 toe (2.11%).

The Republic of Cyprus in compliance with Article 14 of Directive 2006/32/EC of the European Parliament has submitted its 2nd National Energy efficiency Action Plan in 19/07/2011. In this report all energy efficiency measures that have already been implemented or/and are expected to be implemented by 2020, are recorded and analyzed. A comprehensive summary of these measures is given by sector next.

Primary energy savings

- Penetration of natural gas in power generation (combined cycle generation) from 2015 and onwards
- Reduction of transmission and distribution losses (improvement of the power factor of substations, development of new interconnections with increased capacity such as rubus twin type etc.)
- Grant scheme for promoting the cogeneration of electricity and heat

End use energy savings

(a) Residential sector (9 measures: 4 implemented, 5 not implemented yet)

1. Energy efficiency of new dwellings (building codes and enforcement), *Implemented*
2. Grants Scheme for energy savings in the residential sector (existing dwellings) 2004-2009 (Grants Scheme for energy savings in the residential sector (existing dwellings)) , *Implemented*
3. Distribution of free compact fluorescent lamps (Budget: € 2,713,138) , *Implemented*
4. Grants scheme to encourage the use of RES in the residential sector, 2004-2010 (Budget: € 14,658,440) , *Implemented*
5. Energy efficiency of dwellings undergoing major renovation (building codes and enforcement) , *Not Implemented yet*

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[17] Reflecting 10% energy savings comparing to the energy consumption of the reference year.

6. Maintenance and inspection of boilers and heating installations (building codes and enforcement) , *Not Implemented yet*

7. Maintenance and inspection of air conditioning systems of an effective rated output of more than 12 kW (building codes and enforcement) , *Not Implemented yet*

8. Grants Scheme for energy savings in the residential sector (existing dwellings) 2011-2020 (Budget: € 52,680,000) , *Not Implemented yet*

9. Grants scheme to encourage the use of RES in the residential sector, 2011-2020, *Not Implemented yet*

(b) Tertiary sector:

1. National action plan for Green Public Procurement, 2007-2009 (Budget: € 24,300 for purchasing fluorescent lamps, € 328,880 for purchasing new air conditioners installed where a new need has come up, € 301,167 for purchasing new air conditioners in replacement of existing ones, € 3,988,321 for purchasing office computers, € 265,226 for purchasing new LCD monitors) , *Implemented*

2. Government grants scheme for energy savings/RES for the public and wider public sector, 2004-2009 (Budget: € 37,908) , *Implemented*

3. Energy efficiency of new buildings in the tertiary sector, *Implemented*

4. Grants Scheme for (end-use) energy savings in the tertiary sector (existing enterprises) 2004-2009 (Budget: € 2,141,440) , *Implemented*

5. Grants scheme to encourage the use of RES (end use) in the tertiary sector, 2004-2010 (Budget: € 1,399,503) , *Implemented*

6. Energy efficiency of tertiary buildings undergoing major renovation, *Not Implemented yet*

7. Maintenance and inspection of boilers and heating installations in the tertiary sector, *Not Implemented yet*

8. Maintenance and inspection of air conditioning systems of an effective rated output of more than 12 kW in the Tertiary Sector, *Not Implemented yet*

9. National action plan for Green Public Procurement, 2010-2020, *Not Implemented yet*

10. Grants Scheme for (end-use) energy savings in the tertiary sector (existing enterprises) 2011-2020 (Budget: € 5,791,464) , *Not Implemented yet*

11. Grants scheme to encourage the use of RES (end use) in the tertiary sector, 2011-2020 (Budget: € 2,600,000) , *Not Implemented yet*

12. Grants Scheme for cogeneration of high efficiency heat and power in the Tertiary Sector, 2011-2020 (Budget: € 7,700,000) , *Not Implemented yet*

13. Action Plans of Municipalities and Communities, 2010-2020, *Not Implemented yet*

(c) Industrial sector

1. Grants Scheme for energy savings (in existing industrial enterprises), 2004-2009 (Budget: € 653,054) , *Implemented*
2. Grants scheme to encourage the use of RES (end use) in the industrial sector and agriculture, 2004-2010 (Budget: € 187,597) , *Implemented*
3. Grants Scheme for energy savings (in existing industrial enterprises), 2011-2020 (Budget: € 2,591,813) , *Not Implemented yet*
4. Grants scheme to encourage the use of RES (end use) in the industrial sector and agriculture, 2011-2020 (Budget: € 424,000) , *Not Implemented yet*
5. Grants Scheme for cogeneration of high efficiency heat and power in the Industrial Sector, 2011-2020 (Budget: € 8,500,000) , *Not Implemented yet*

(d) Transport sector

1. Grants Scheme for energy saving in transport (purchase of hybrid vehicles, electric vehicles and low-emissions vehicles), 2004-2009 (Budget: € 2,596,823) , *Implemented*
2. Scrapping of Vehicles, 2008-2010 (Budget: € 5,785,055) , *Implemented*
3. Scrapping of Vehicles, 2011-2020, *Not Implemented yet*
4. Action plan to strengthen public transport, *Not Implemented yet*

(e) Horizontal measures (*all implemented*)

1. Information campaign on energy saving issues (Budget: € 210,000)
2. Online student training programmes
3. Publishing educational books for students
4. Publishing 2 special information publications for young children
5. Publishing and distributing posters and stickers on energy saving
6. Establishing a student competition for students' projects on RES and ES, with 3 monetary awards (Budget: € 1,700 annually)
7. Lectures on RES and ES at schools
8. Publishing and distributing various information publications and guides on RES and ES investment

9. Energy saving report (Information campaign)
10. Energy Saving Award (Information campaign)
11. Organizing training seminars and day events for citizens and organized groups of people
12. Energy Awareness and reducing energy consumption program in buildings in the Public sector and general government

Natural gas introduction

In order to diversify the energy supply mix, a policy measure which shall be soon undertaken is the introduction of natural gas. By 2014 new gas-fired plants are scheduled to operate. The use of natural gas in power generation is estimated to lead savings of up to 271,000toe (MCIT, 2011).

On the 28th of December 2011 Noble Energy announced the discovery of natural gas at the Cyprus Block 12 prospect, offshore the Republic of Cyprus as a result of the 1st licensing round for hydrocarbon exploration in its EEZ. The Cyprus A-1 well encountered approximately 310 feet of net natural gas pay in multiple high-quality Miocene sand intervals. The discovery well was drilled to a depth of 19,225 feet in water depth of about 5,540 feet. Results from drilling, formation logs and initial evaluation work indicate an estimated gross resource range of 5 to 8 trillion cubic feet (Tcf), with a gross mean of 7 Tcf. The Cyprus Block 12 field covers approximately 40 square miles and will require additional appraisal drilling prior to development.

The discovery of indigenous gas reserves is anticipated to lead to a redesign of the gas sector structure in Cyprus and revisions of policies, political decisions and schedules would have to be done.

Natural gas is estimated to be available in Cyprus’ domestic market approximately in 2016.

Since after the discovery of the natural gas field, there have been changes in the policy of the Republic of Cyprus. More particularly, even if it was initially considered to transport the natural gas to the onshore receiver terminal at Vasilikos in liquefied form, it is unclear whether this option comprises an alternative today or not.

The natural gas demand is projected to rise as illustrated in Figure 10-63. It is expected that the introduction of natural gas in the energy mix will provide a diversified, safer energy profile for Cyprus and that will gradually be used in the electricity production, industry and household sector (MANRE, 2010; pp. 41-42), making the energy sector less sensitive to increasing energy demand patterns.

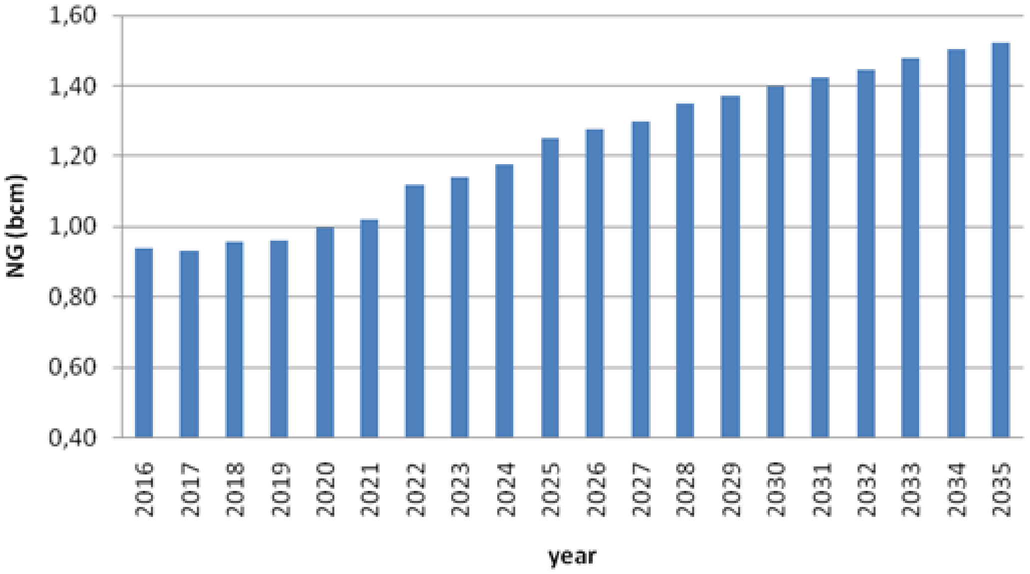

Figure 10-63: Projected natural gas demand between 2016 and 2035

Based on the measures taken so far and those under way, the adaptive capacity of the cooling/heating energy demand was ranked as **High**.

Following, additional recommended adaptation measures that are considered to further enhance adaptive capacity towards this impact (Shoukri & Zachariadis, 2012) are presented indicatively. Nevertheless, their assessment and final selection for implementation will be made through the use of the Multicriteria Analysis (MCA) tool which will be developed and implemented in the framework of Actions 4 and 5 of the CYPADAPT project.

- Increased contribution of renewable sources in the final use of energy
- Increased contribution of bio-fuels in the road transport sector
- Introduction of natural gas to the energy mix/ diversification of energy resources;
- Increased energy efficiency
- Exploitation of indigenous fossil fuel energy potential
- Accelerated adoption of 'near-zero' energy new buildings, in conjunction with biophilic and bioclimatic architecture
- Investments in improving the energy efficiency of existing buildings
- Adjustment of long-term electricity generation plans in order to account for additional capacity needed while prioritizing renewable electricity generation
- Implementation of proper carbon pricing of all energy forms in order to encourage energy conservation

- Proper maintenance of electricity transmission lines to reduce losses
- Raise awareness for energy saving (i.e. energy saving appliances, controlled use of air conditioning)
- Greening of towns to avoid/reduce urban heat island phenomenon, aiming to decrease energy consumption for cooling

10.4.4. Assessment of overall vulnerability

The principal aim of this chapter is to identify the key vulnerabilities of the energy sector to climate changes, as well as to assess the magnitude of these vulnerabilities. However, it must be noted that, as there were no sufficient data to evaluate all indicators further research is required.

In order to quantify the vulnerability potential of the energy sector against a climatic change impact, the values of sensitivity, exposure, adaptive capacity and vulnerability are quantified as follows:

Degree of sensitivity, exposure & adaptive capacity		Degree of vulnerability		Legend
None	0	None	V≤0	
Limited	1	Limited	0<V≤1	🟩
Limited to Moderate	2	Limited to Moderate	1<V≤2	🟨
Moderate	3	Moderate	2<V≤3	🟨
Moderate to High	4	Moderate to High	3<V≤4	🟧
High	5	High	4<V≤5	🟧
High to Very high	6	High to Very high	5<V≤6	🟥
Very high	7	Very high	6<V≤7	🟥
Not evaluated	-	Not evaluated	-	⬜

Since vulnerability is defined by the following formula:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity * Exposure$$

“Impacts” and “Adaptive capacity” should be evaluated on the same scale (1-7). For this to be achieved, the square root of “Sensitivity x Exposure” is used. The results of the vulnerability assessment for the energy sector in Cyprus are summarized in Table 10-11.

Table 10-11: Overall vulnerability assessment of the energy sector in Cyprus to climate changes

Impact	Sensitivity	Exposure	Adaptive Capacity	Vulnerability
Renewable energy yield	Limited to Moderate (2)	Limited (1)	Moderate (3)	None (-1.6)
Efficiency of thermal power plants	Limited (1)	Moderate (3)	Limited to Moderate (2)	None (-0.3)
Energy demand	Very High (7)	Very High (7)	High (5)	Limited to Moderate (2)

As it can be observed from the table above, the energy sector of Cyprus in general is not considered very vulnerable to climate changes. In particular, the first and only vulnerability priority identified for the sector is related to the energy demand for cooling and heating, since it is directly affected by climate changes. However, given that there is potential for increasing energy supply in Cyprus in order to meet the increasing energy demand, the vulnerability towards this impact is characterized as limited to moderate. The impact on the efficiency of thermal power plants is not expected to be significantly affected by climate changes while with regard to the impact of climate changes on RES generation, no vulnerability was identified since the only type of RES which is expected to be significantly affected by climate changes is hydropower, which is not exploited in Cyprus due to the already limited water resources, while the impact of climate changes on the other types of RES is minor.

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11 TOURISM

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Abbreviations and Acronyms

BCI	Beach Climate Index
CCA	Carrying Capacity Assessment
CTO	Cyprus Tourism Organization
CYSTAT	Cyprus Statistical Service
FWI	Fire Weather Index
MAP	Mediterranean Action Plan
MCA	Multi-Criteria Analysis
PRECIS	Providing Regional Climates for Impact Studies
RCM	Regional Climate Model
RR	Precipitation
SCI	Site of Community Interest
SLR	Sea Level Rise
SPA	Special Protection Areas
SST	Sea Surface Temperature
TCI	Tourism Climatic Index
TX	Maximum temperature
UNEP	United Nations Environmental Programme

11.1. Climate change and tourism

Tourism is considered to be a highly climate-sensitive economic sector, since it is strongly related to the climate and the environment in general. (Simpson et al., 2008). Tourism is sensitive to a range of climate variables such as temperature, hours of sunshine, precipitation, humidity, and storm intensity and frequency (Matzarakis and de Frietas, 2001; Matzarakis et al., 2004), along with the consequences that these may imply, such as fires, floods, landslides, coastal erosion and disease outbreaks (Wilbanks et al., 2007).

The impact, vulnerability and adaptation assessment for tourism regarding the climate changes that have occurred the recent years in Cyprus (Deliverable 1.2), showed that the first vulnerability priority of the sector to climate changes is related to the warmer summers which are responsible for the increase in the level of uncomfortability of tourists visiting Cyprus during summer. However, the adaptive capacity for lengthening the tourist summer season is considered to reduce the vulnerability of tourism towards this impact. The reduced water availability for meeting the need to provide for additional tourist facilities (e.g. golf courses) constitutes the second priority of the sector, considering that the available water resources are limited especially during summer when the majority of tourists visits Cyprus and that a significant part of the tourism industry is based on water use. The vulnerability towards this impact is reduced due to the adaptive capacity of Cyprus for increasing water supply mainly with the use of desalination plants. The third vulnerability priority is related to heat waves and coastal erosion. Heat waves are a common phenomenon in Cyprus during summer when the majority of tourists visits Cyprus. However, the impact on tourism is not so intense considering that the most sensitive population groups to heat waves, i.e. the elderly people, prefer to take their holidays during the cooler seasons of the year. The adaptive capacity of the sector towards this impact is restricted mainly to providing a cool environment indoors for relieving heat discomfort. The erosion of Cyprus’ coasts has a significant impact on tourism since the majority of tourism infrastructure is located at the coasts. Nevertheless, the coastal protection works which have taken place have alleviated the problem in a great extent. Finally, storms, waves and floods constitute the last vulnerability priority for the tourism of Cyprus regarding climate changes. However, due to the fact that sea floods, which constitute the major threat for tourism infrastructure, are not so common in Cyprus, the vulnerability of this impact was considered low.

In the sections that follow, an attempt is being made to assess the impacts of future climate changes on the tourism sector of Cyprus based on the climate projections output produced by the PRECIS (Providing Regional Climates for Impact Studies) regional climate model as well as on other socio-economic projections for the period 2021-2050. The reason why PRECIS was selected to be used in the present study is that, unlike in other regional climate models, in PRECIS Cyprus lies at the center of the domain of the study. The future period 2021-2050 has been chosen, instead of the end of the twenty-first century as frequently used in other climate impact studies, in order to assist stakeholders and policy makers to develop near future plans.

11.2. Baseline situation

Tourism is a very important sector of Cyprus economy, attracting millions of tourists every year and providing economic growth and employment for the country. On average, the overnight stays in Cyprus during the period 2000-2010 consisted of 93% foreign tourists and 7% of Cyprus residents (internal tourism) (CYSTAT, 2011). Regarding the source countries of foreign tourists, arrivals of tourists from the United Kingdom during the period 2000-2010 constituted the main source of foreign tourism with 54% of total tourist arrivals, followed by the Nordic countries, Germany, Russia and Greece (CTO, 2011a).

It is estimated that approximately 90% of the tourists visits Cyprus for leisure purposes (e.g. sun and sea, sports, culture etc.) while the rest 10% for business purposes (e.g. conferences, meetings etc.) and for visiting relatives and friends.

During the last decades, Cyprus has developed its tourist accommodation infrastructure to a great extent in order to meet the needs of the increasing incoming tourism. According to the Cyprus Tourism Organization, 95% of beds are established in the coastal cities of Famagusta, Paphos, Larnaca and Limassol, 2.6% in the capital of Nicosia which is located inland and 2.5% in the villages of the mountain Troodos (Hill Resorts) (CTO, 2010b).

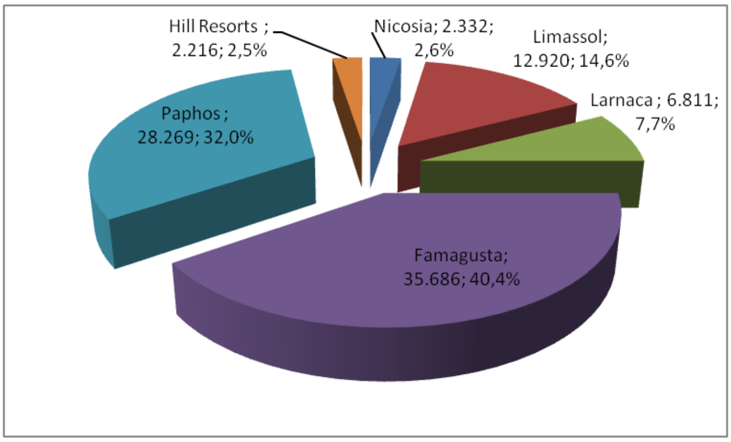

Figure 11-1: Concentration of accommodation beds in the main tourist areas of Cyprus, 2010 (CYPADAPT)

Source: CTO, 2010b

Apart from the tourist accommodation infrastructure, there is a number of other types of tourist infrastructure that is being developed especially during the last decade, in order to diversify the tourist product from the 'Sun and Sea' model, such as sports tourism infrastructure (golf, diving, skiing and other sports), nautical tourism infrastructure (e.g. marinas) and business tourism infrastructure (e.g. conference halls).

In 2010, 89% of the tourist arrivals recorded in Cyprus resided in the coastal cities of Cyprus, 5.9% in Nicosia and only 0.2% stayed at the Hill Resorts (Figure 11-2) (CTO, 2010b).

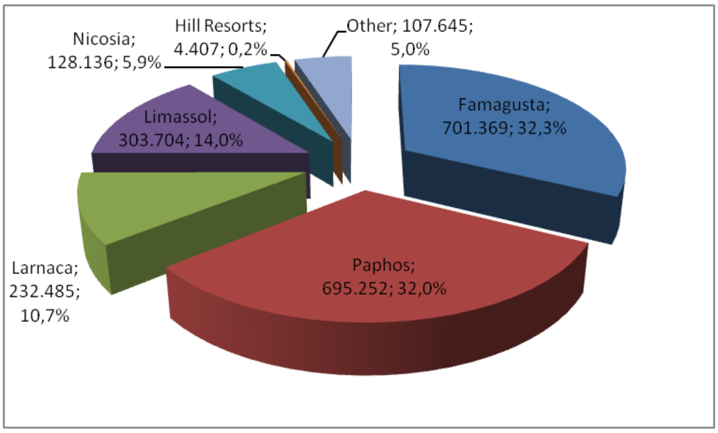

Figure 11-2: Tourist preferences on the location of stay, 2010 (CYPADAPT)

Source: CTO, 2010b

The distribution of tourist arrivals over the four quarters of 2010 was as follows: January-March 9.4%, April-June 31.0%, July-September 41.4% and October-December 18.2% (CTO, 2010b).

Tourist arrivals during the year for the period 2001-2010 may be categorized in two seasons. The season from May to October where the monthly share of tourist arrivals is above 11%, with the highest shares of the year recorded in July and August (13-14%), and the season from November to April where the share is below 9%, with the months from December to February reaching the lowest shares throughout the year (2-3%) (aggregated data from Tourist arrivals 2001-2010, CTO).

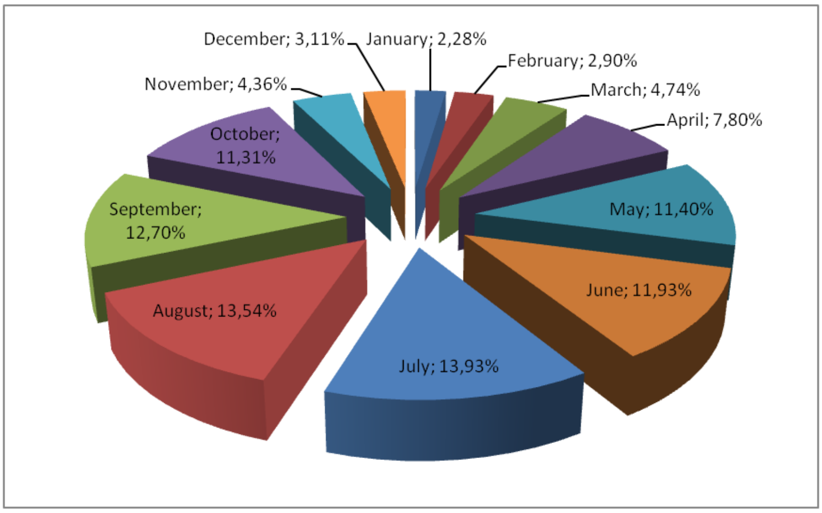

Figure 11-3: Average distribution of tourist arrivals during the year, 2001-2010 (CYPADAPT)

Source: Aggregated data from CTO “Tourist arrivals”

Since the record year 2001 tourism receipts have been in decline, registering an average annual decrease of 2.6% for the period 2000-2010. The significant decline in tourism receipts over the past decade has resulted in the reduction of the dependence of Cyprus economy on tourism. The decline in the last decade has significantly reduced the contribution of tourism to the economy resulting in 2009 the tourism accounts to constitute about 10% of GDP from 23% in 2000 and about 21% of exports of goods and services compared to 43% in 2000 (CTO, 2011a; CYSTAT, 2012).

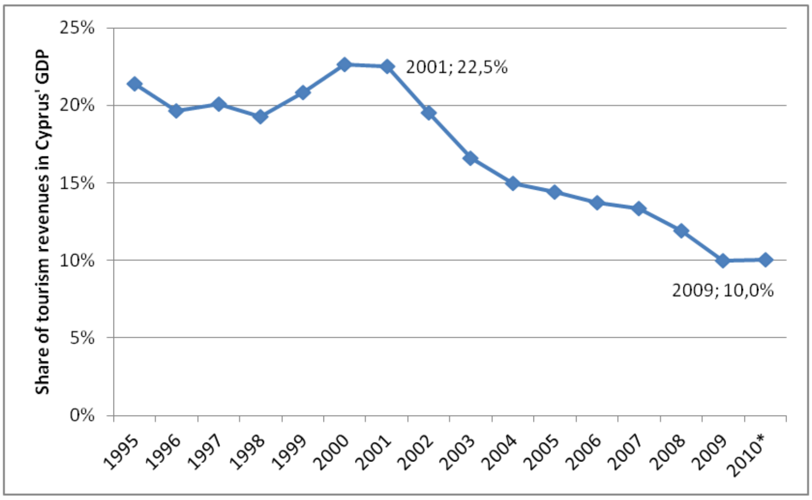

Figure 11-4: Share (%) of tourism revenues in Cyprus Gross Domestic Product (1995-2010) (CYPADAPT)

Source: CYSTAT, 2012

11.3. Future impact assessment

In this section, the climate change impacts on the tourism sector as these have been identified in Deliverable 1.2 “Climate change impact, vulnerability and adaptation assessment for the case of Cyprus” will be reassessed in light of the climate projections for the future (2021-2050).

The climate change impacts on the tourism sector can be divided into two categories; (i) the direct impacts and (ii) the indirect impacts. The first category refers to the impacts on tourism caused directly by climate changes while the second category refers to the impacts caused by climate-induced environmental changes. Following, the changes in climate and their respective impacts on the tourism sector for the case of Cyprus are presented in Table 11-1.

Table 11-1 : Relationship between climate changes and impacts on the tourism sector

Potential climate changes	Impacts
Increase in air temperature and decrease in precipitation	– **Warmer summers** : Lengthening of the summer tourist season to autumn and spring, decrease in tourism during the summer season, increase in cooling costs and irrigation needs – **Warmer winters**: Reduced snow cover in ski resorts, shorter winter sports seasons, increased snow-making costs, reduced landscape aesthetics – **Changes in terrestrial biodiversity**: Loss of natural attractions and species, reduced landscape aesthetics and losses in nature-based tourism – Increase in infectious diseases
Increase in the frequency and intensity of extreme weather events	– **Heat waves:** Risk for heat stress, higher operating expenses in energy backup systems for increased cooling requirements – **Droughts:** Water shortages, competition over water between tourism and other sectors, additional emergency preparedness requirements in the water sector, limitation to further tourism development (e.g. golf cources), higher operating expenses in water backup systems (desalination plants) – **Storms, waves and floods:** Risk for tourism infrastructure damage, reduced safety of tourists, soil erosion, reduced landscape aesthetics
Potential climate induced changes	
Sea surface temperature rise	– **Extension of the swimming season** – **Changes in marine biodiversity:** Loss of natural attractions and species, marine resource and aesthetics degradation in dive and snorkel destinations, losses in nature-based tourism

Potential climate changes	Impacts
Sea level rise	– **Coastal erosion:** Loss of beach area, reduced landscape aesthetics, higher costs to protect and maintain seafront resorts

In the following sections of this chapter, the future impacts of climate change on the tourism sector are further analyzed where relative data and information are available. The impacts are presented according to their initial categorization in the current impact assessment (Deliverable 1.2), namely:

- Warmer summers
- Warmer winters
- Extension of the swimming season
- Heat waves
- Water availability
- Storms, waves and floods
- Increase in infectious diseases
- Biodiversity attractions
- Coastal erosion

11.3.1. Warmer summers

Higher summer temperatures, increased humidity and heat waves are expected to lead to a gradual decrease in summer tourism in the Mediterranean and to a shift towards northern destinations due to the increase of tourist discomfort to unpleasant climate conditions. At the same time, an increase in spring and autumn tourist season is expected due to the prevalence of more favourable climate conditions during this period thus lengthening and flattening tourism season. This could partially offset the losses in tourism during the summer months.

Figure 11-5 depicts the mean annual temperature for the period 1990-2010 in five representative areas of Cyprus where tourist arrivals are concentrated. Three areas concentrate mainly summer tourism (Larnaca, Limassol, Pafos), one professional tourism (Nicosia) and one winter tourism (Hill resorts). As it can be seen in this figure, temperature has recorded substantial increasing trends during this period in all five areas.

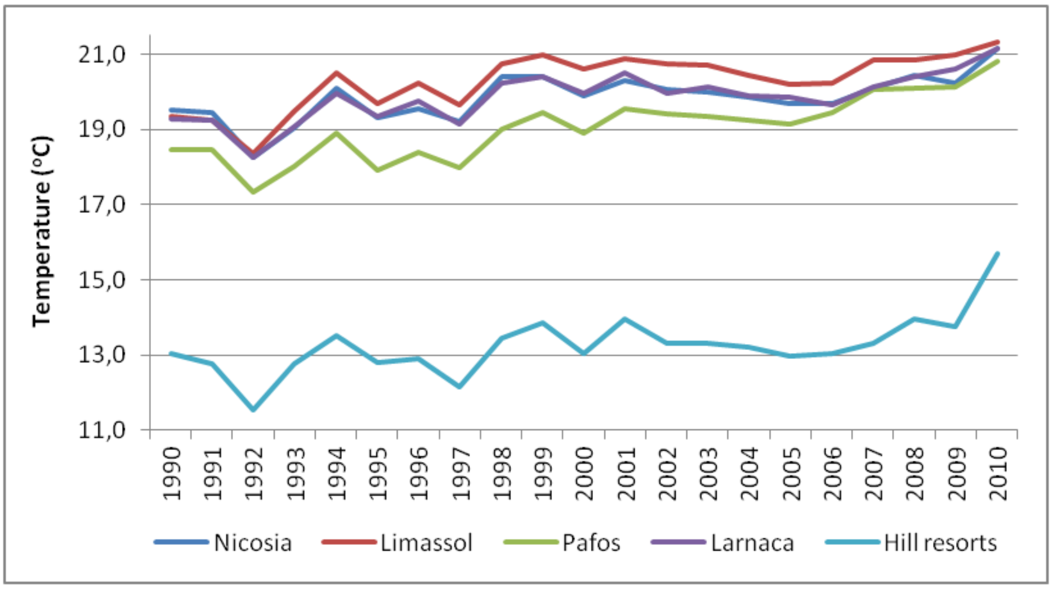

Figure 11-5: Mean annual temperature in selected cities of Cyprus (1990-2010), (CYPADAPT)

Source: Meteorological Service of Cyprus

Cyprus is also experiencing high levels of humidity and frequent heat waves which may decrease favourable conditions and increase tourist discomfort.

Following, the available data regarding the trends of tourist arrivals and overnight stays over the last decade in Cyprus which could potentially signify the impact of warmer summers on Cyprus' tourism, are presented.

Regarding the alterations in tourism seasonality, the data available on seasonal distribution of tourist arrivals to Cyprus for the current period (2001-2010), show an increase in the autumn tourist season followed by an increase in the summer season while a small decrease is noted in the winter and spring season with April presenting a significantly higher decrease (Figure 11-6). The increase in the autumn tourist season could be justified by the prevalence of more favourable climatic conditions for beach tourism in Cyprus during this period.

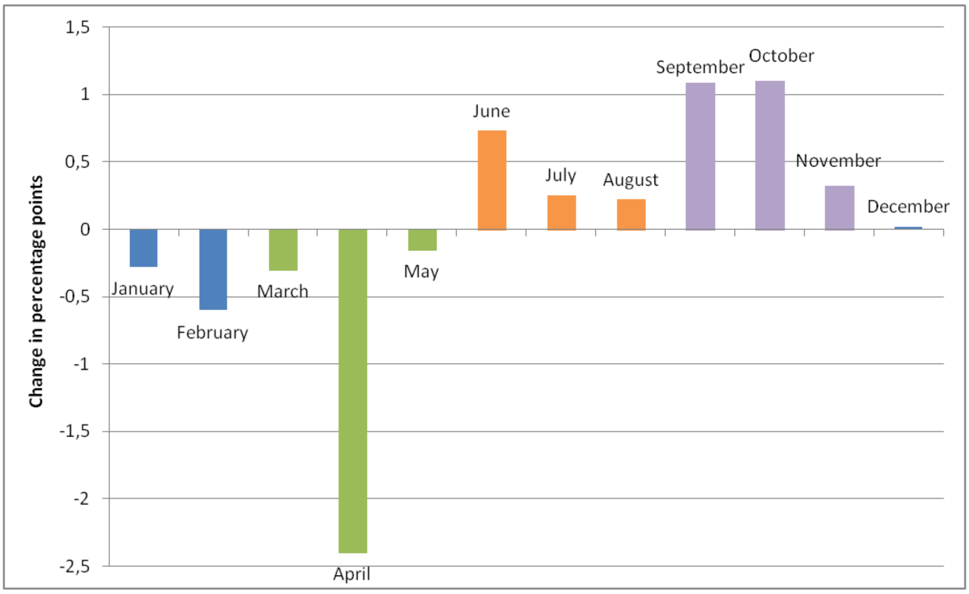

Figure 11-6: Change in the seasonality of tourist arrivals for the period 2001-2010 in percentage points (CYPADAPT)

Source: Cyprus tourism in figures 2001-2010, CTO

However, a decreasing trend is observed in the overall annual tourist arrivals in Cyprus since 2001 (CTO, 2010a), with an average reduction of 2.1%[1] (Figure 11-7), while in the same period both the global and European tourism was growing. It must be mentioned though that this has been attributed so far to other factors, such as the increase of competiveness from neighboring countries, the ageing infrastructure, the fading of local traditions and authenticity etc. (CTO, 2011a).

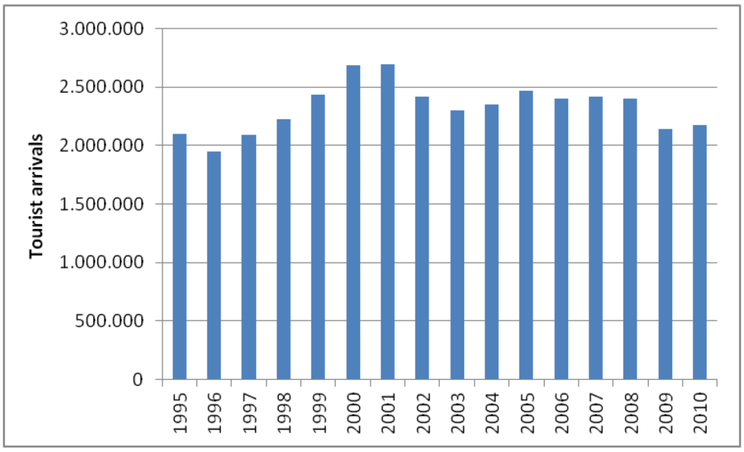

Figure 11-7: Tourist arrivals in Cyprus 1995-2010 (CYPADAPT)

Source: CTO, 2009a; CTO, 2010a

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[1] It must be mentioned that the global economic crisis had a particularly significant effect on the levels of incoming tourism in Cyprus. However, if the effect of 2009 is isolated, the average annual reduction of incoming tourists to Cyprus for the period 2000 to 2008 is limited to 1.4%.

The number of overnight stays during the same period recorded a proportional reduction as well. Overnight stays presented a reduction in Limassol, Larnaca, Paphos and Famagusta while Nicosia recorded a slight increase in overnight stays during the period 2000-2010 (CYSTAT, 2011). The opposite trend observed in the case of Nicosia, could be attributed to the fact that Nicosia as the capital of Cyprus has a more steady tourism (mainly business tourism) which cannot be easily affected by climate conditions. Furthermore, Nicosia is not a coastal city and thus do not attract the 'sun and sea' tourism segment which is more climate-sensitive.

However, it must be noted that according to the World Travel and Tourism Council, the contribution of tourism to the GDP of Cyprus will increase during the period 2012-2022 with an annual growth rate of 4.2% (WTTC, 2012).

It is also worth noting that, another climate change impact on tourism due to higher temperatures is the increased energy consumption for cooling and the subsequent higher costs for hotel owners, which will inevitably lead to higher accommodation rates.

Next, the future changes in temperature that are considered to be associated with the impact of warmer summers on tourism are presented in brief.

Summer presents the largest projected warming in the Mediterranean region according to the A1B scenario (Christensen et al. 2007; Hadjinicolaou et al. 2011; Giannakopoulos et al. 2010) and with potentially strong impacts. The changes of the mean maximum summer temperature between the control period 1960-1990 and the future period 2021-2050, according to the PRECIS projection, indicate a quite significant increase, ranging from 1.6°C to 2.6°C on average. In addition, the mean number of hot days (temperature >30^{o}C) per year are projected to increase by 17 days to 24 days on average. The mean number of days per year with daily maximum temperature higher than 35°C (heatwave days) is expected to increase from 2 days to 34 days on average. In addition, the mean number of tropical nights (temperature>20°C) is expected to increase by 25-38 days per year on average all over Cyprus.

The abovementioned changes in temperature as these were projected by the PRECIS model for the future period 2021-2050 are anticipated to intensify the impact of warmer summers on Cyprus' tourism.

11.3.2. Warmer winters

One of the potential impacts of climate change is related to the reduction of the snow-covered area and snow residence time, i.e. the time snow remains before melting due to the increase in temperature. This may shorten the winter sports season, an important tourism attraction during winter. Last but not least, increased temperatures, decreased precipitation and in general more favorable climate conditions during winter are expected to increase sightseeing tourism as well as nature-based tourism.

There are no reliable and sufficient data available for the case of Cyprus regarding the reduction of snow-covered area and the snow residence time as far as the past, present and future period is concerned. A climatic parameter which could however indicate the reduction in snow is temperature. As it can be seen in Figure 11-5, the mean annual temperature in Hill resorts which are located at the Troodos mountain and constitute a tourism attraction during winter, has recorded a substantial increasing trend during the period 1990-2010.

As shown in Figure 11-6, the decreasing trend in tourist arrivals in Cyprus during January and February could be partially attributed to the fact there are less ideal conditions for this kind of vacation. It must be noted though that, skiing tourism constitutes a minor share of the overall tourism attractions in Cyprus, as snow is not a frequent phenomenon in Cyprus. Although there is a ski resort in the Troodos mountain, tourist arrivals are mainly local tourism. In addition the length of visit does not exceed one day in most of the cases.

In Cyprus, climate change projections for the period 2021-2050 according to the PRECIS model indicate that the average change in the mean winter maximum temperature will range from +0.8°C to +1.3°C compared to the period 1960-1990 while the mean winter minimum temperature will range from +0.8°C to +0.9°C. An increase in temperature will affect the mountain area of Troodos which already experiences mild winter temperatures near zero, by further reducing ski season.

In addition, winter total precipitation is expected to present minor changes ranging from -5mm to - 15mm.

As the share of winter ski tourism in Cyprus is estimated to be very small (mainly internal tourism), it is not considered necessary to conduct further research on the subject.

11.3.3. Extension of the swimming season

Mediterranean Sea Surface Temperature (SST) is expected to gradually increase due to climate change, although less than the global mean temperature rise (Nicholls et al., 2007).

Satellite and in situ-derived data indicate a strong eastward increasing sea surface warming trend in the Mediterranean basin from the early 1990s onwards. The satellite-derived mean annual warming rate over the period 1985–2008 is about 0.037°C year^{-1} for the whole basin and about 0.042°C year–1 for the eastern sub-basin where the island of Cyprus is located (Skliris et al., 2011). In addition, analyses of annual mean satellite SST data indicate that over the last 16 years (1996-2011) a general warming has occurred over the Levantine Basin where Cyprus belongs, at an average rate of approximately 0.065°C per year (Samuel-Rhoads et al., 2012).

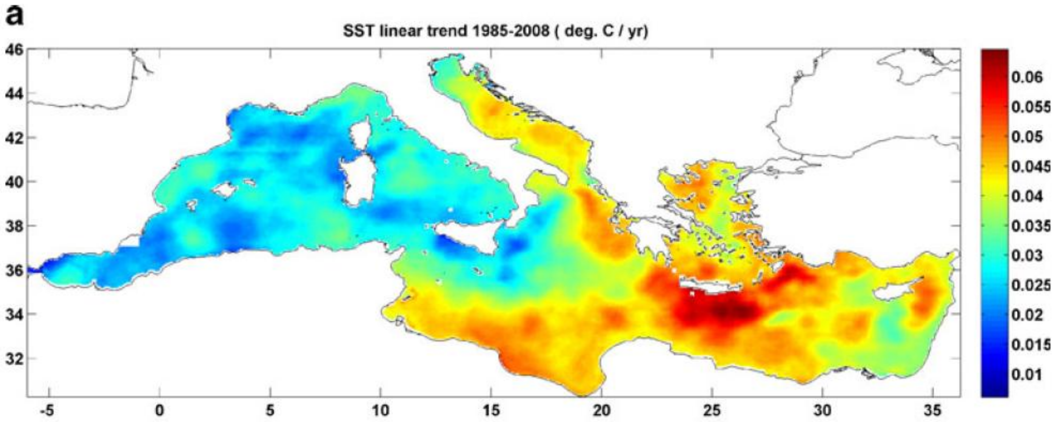
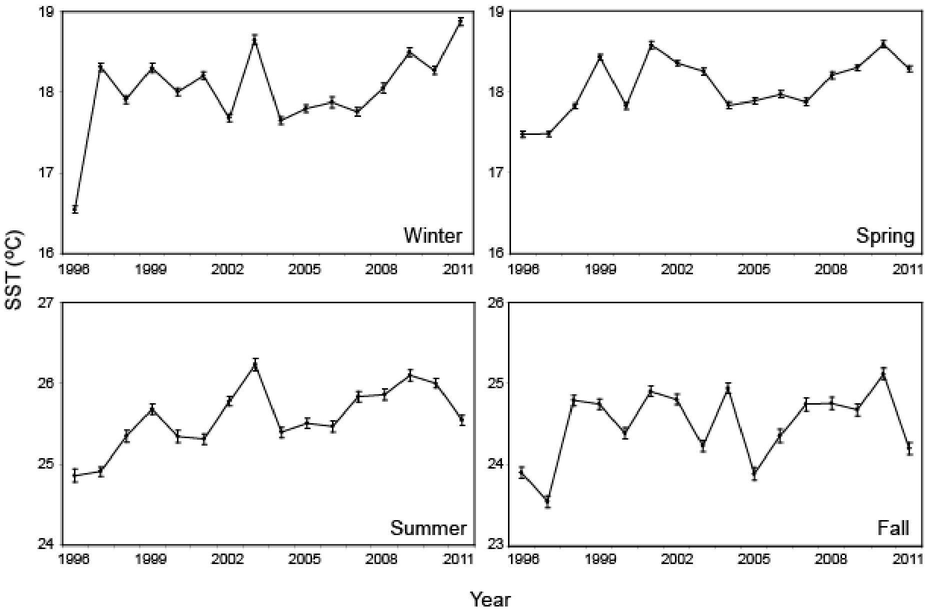


Figure 11-8: Horizontal distribution of satellite-derived SST annual linear trends (°C/year) over 1985–2008

Source: Skliris et al., 2011

Higher SST may lead to an extension of the swimming season, during which other water activities are also practiced. Given that for comfortable water activities SST should be around 20-21°C, current SST during winter and spring, in the Levantine basin where Cyprus is located, is too cold for swimming, while during autumn SST is still suitable for swimming, thus extending the swimming season to 6 months. In Figure 11-9, the mean seasonal SST of the Levantine Basin during the period 1996-2011 is presented.



Seasonal mean values are shown in solid line with points. The annual standard error (s.e.m.) is shown in solid vertical bars.

Figure 11-9: Mean satellite remote sensing sea surface temperatures (SSTs) data from 1996 until 2011

Source: Samuel-Rhoads et al., 2012

Tourists in Cyprus are taking advantage of the ideal conditions for swimming prevailing in the beaches of Cyprus during autumn, as it can be seen also from Figure 11-6, where it is shown that the tourist arrivals during autumn in the last ten years have significantly increased.

Although there are no projections for the SST trend in the Mediterranean basin in the future, it is believed that the increase in air temperature in Cyprus of 1-2^{o}C which is projected by PRECIS will enhance the increasing trend in SST, with a slower rate though. Consequently, the climate change impact on the extension of the swimming season will be further consolidated.

11.3.4. Heat waves

Like other destinations in the Mediterranean region, Cyprus has been affected by extended heat waves. Heat waves are very likely to affect tourist decisions regarding the travel destination or the length of stay due to tourist discomfort, especially for those population groups that are sensitive to such events (e.g. elderly).

In addition, heat waves may affect the tourism sector through increased energy costs for cooling or due to failures in the energy supply network that may cause business interruptions.

As it is shown by the PRECIS climate model, in the future (2021-2050) the mean number of days per year in Cyprus with daily maximum temperature higher than 35°C (heat wave days) is expected to increase from 2 days to 34 days on average. The latter is anticipated to intensify the impact of heat waves on Cyprus' tourism. However,

No data are available for the case of Cyprus regarding losses for the tourism sector due to heat waves. It is proposed, that a survey should be conducted on the issue addressing the tourists of Cyprus.

11.3.5. Water availability

Tourism is directly or indirectly dependent on water, whether it is winter tourism, agrotourism, wildlife tourism, golf tourism or 'sun and sea' tourism. Cyprus is characterized as a drought prone area as the country experiences frequent and prolonged drought periods. The water reserves are often limited during the summer periods when the tourism season is at its peak, thus driving up already high local water demand and competition over water between sectors.

Decreased rainfall and extended drought periods have led the Government of Cyprus to construct a number of desalination plants to secure safe and continuous water supply. In particular, the tourist areas of Nicosia, Larnaca, Ayia Napa, Limassol and recently Pafos are provided with desalinated water while other areas (mainly rural and/or mountain areas) depend solely on freshwater resources (surface water and groundwater), thus being more sensitive to dry weather. It must also be noted that, the production of great amounts of desalinated water significantly increased energy consumption which had as a consequence the price of water to increase and part of the increased cost to pass to the tourism sector. However, it is expected that the exploitation of Cyprus' gas reserves will lower the cost of energy supply as Cyprus depended mainly on fuel imports for energy production. Subsequently the cost for the production of desalinated water is expected to decrease.

In addition, water scarcity could also affect the sector by substantially limiting its growth and sustainability, as for example in the case of golf tourism. The irrigation of golf courses is regulated through decisions which enforce restrictions on the water resources to be used. The decision limits the use of fresh water resources for irrigation and encourages the use of recycled water. In addition, in order to meet the demand for water supply in most cases it is essential to provide for private desalination plants.

-The future water availability for the case of Cyprus was estimated by using data regarding the distribution of precipitation (as this was projected by the PRECIS climate model) in relation to evapotranspiration, dam inflow, aquifer recharge and losses to the sea. The analysis showed that the available freshwater resources will decrease by 23% on average in the period 2021-2050 compared to the period 1970-2000. On the other hand, the increase in the desalination capacity (up to 92Mm^3) is expected to fully satisfy future drinking water demand of both the permanent population and tourism. In particular, the average total domestic water demand from the permanent population of Cyprus during the period 2021-2050 is expected to reach 74 Mm^3, implying an increase of about 16% compared to 2011 (63.8 Mm^3). As for the water demand of the tourism sector, it is estimated that water consumption will amount to 12.3Mm^3 (27% increase) on average during the period 2021-2050 compared to 2011 [2]. However, it must be noted that estimations do not take into account the increase in water demand for the irrigation of new golf courses, neither water demand management (water saving measures).

11.3.6. Storms, waves and floods

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[2] For more information on the estimation of future water supply and demand in Cyprus, one may refer to Sections 2.2.2 and 2.2.3 of the Chapter "Water resources" included in the present report

Storms, waves and floods pose risk for the tourism infrastructure as well as for the tourists present in such an event, reduce landscape aesthetics and create business interruption costs. Tourism is more exposed to extreme events than other sectors due to the attractiveness of high-risk areas, as for example coastal tourism is at risk from sea floods, storm surges and waves, etc. In addition, tourists are expected to be at greater risk than residents because they are unfamiliar with the region, the potential hazards and the self-protective behaviour required (Burby and Wagner, 1996).

In Cyprus, no significant floods from the sea or storm surges threatening human lives or causing damage to tourism infrastructure have been recorded. However, it must be mentioned that in 2012, an unprecedented case with high waves in the coasts of Cyprus reaching up to 6 meters height was recorded[3]. As this constitutes an 'one-off' case, no concerns have risen for the safety of Cyprus' coasts and tourism.

As far as the future impact is concerned, the climate projection model used does not provide estimates for storms, waves and floods. Nevertheless, there is an indicator referring to the annual maximum total precipitation over one day indicating heavy rainfall which could also be associated with flood risk. However, the PRECIS model shows that there will be no significant changes to this indicator in the future period (2021-2050), with only a minor increase of 2-5 mm per year, on average. It must be noted though that this indicator alone is not sufficient for estimating flood risk since other factors play an important role as well.

As the frequency and intensity of storms, waves and floods in the future cannot be estimated, the impact cannot be assessed.

11.3.7. Increase in infectious diseases

The increase in vector-borne and water-borne diseases caused by high temperatures, increased extreme weather events and especially flooding could affect the tourism sector by deterring future tourists from visiting the country or by shortening the length of stay of tourists that are already at the island due to sickening or for preventive purposes. Although tourist behaviour is especially sensitive to the presence of infectious diseases, no such event has taken place in Cyprus the last decades.

Following, the future climate changes in Cyprus that are considered to be associated with the impact of infectious diseases on tourism are presented in brief.

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[3] For relative information one may visit the following web address :
http://www.newsit.gr/default.php?pname=Article&art_id=122851&catid=7

According to the PRECIS output, a quite significant increase is anticipated in the average maximum summer temperature in Cyprus in the future period 2021-2050 compared to the control period 1960-1990, ranging from 1.6°C to 2.6°C. In addition, the mean number of hot days (T>30°C) per year are projected to increase by 17 to 24 days on average while the number of tropical nights (T>20°C) is expected to increase by 20 to 45 days per year. The mean number of days per year with daily maximum temperature higher than 35°C (heat wave days) is expected to increase from 2 days to 34 days on average. As it can be seen, there will be a considerable increase in high temperatures in Cyprus in the future. However, the magnitude of the impact of such an increase on the infectious diseases is not known.

In addition, the annual maximum total precipitation over one day (heavy rainfall index) which could also be associated with flood risk is not expected to substantially change in the future, as PRECIS shows only a minor increase of 2-5 mm per year.

As the magnitude of the effect of high temperatures and extreme weather events on infectious diseases is not clearly known yet, the impact of infectious diseases on the tourism sector cannot be assessed.

11.3.8. Biodiversity attractions

Climate change could affect natural ecosystems by worsening their state as a result of changes in temperature and precipitation. The landscape as well as the environmental assets and amenities are essential for the development of the nature-based tourism. Loss of natural attractions and species and reduced landscape aesthetics could result in significant reduction of the nature-based tourism. Furthermore, the increase of sea surface temperature may have adverse impacts for the marine biodiversity, leading to loss of natural attractions and species, thus resulting in losses in nature-based tourism.

Next, the future climate changes that are considered to be associated with the impact of biodiversity loss on tourism are presented in brief.

According to PRECIS projections for the future period 2021-2050, the average annual temperature in Cyprus is expected to increase by 1 - 2°C with respect to the control period 1960-1990, while the average annual precipitation is expected to present minor decrease or no changes at all. In addition, the maximum length of dry spells (precipitation<0.5mm) is expected to increase up to 13 days/year. However, the magnitude of the impact of the abovementioned climate changes on biodiversity loss and consequently on tourism is not known.

It is proposed that (i) a more extended research on the impacts of climate changes on the biodiversity of Cyprus should be conducted and (ii) a survey on the impact of biodiversity loss on the tourist sector should be carried out.

11.3.9. Coastal erosion

Coastal flooding and inundation due to a sea level rise combined with potential extreme storm events may cause erosion in the coasts of Cyprus, loss of beach areas, higher costs to protect and maintain waterfronts and damage to public beaches. Seaside resorts in Cyprus will also be significantly affected due to their proximity to the shoreline since many of them are violating the public maritime domain setback for commercial construction.

The phenomenon of erosion is already apparent in many of the coasts of Cyprus. However, it is mainly attributed to harmful practices, such as sand and gravel mining, construction of breakwaters for the protection of part of a coast without taking into account the consequences in other parts of the coast etc. and to a lesser extent to climatic factors.

The impacts from a Sea Level Rise (SLR) in Cyprus are expected to further deteriorate the existing problem of the erosion of Cyprus' coasts. However, it must be noted that the SLR is not expected to be significant for the case of Cyprus.

Since no trends regarding SLR in Cyprus' coasts have been identified so far, no correlation can be made to the phenomenon of coastal erosion.

11.4. Future vulnerability assessment

In this section, the future vulnerability of the tourism sector to climate change impacts is assessed in terms of its sensitivity, exposure and adaptive capacity based on the available quantitative and qualitative data for Cyprus and the climate projections for the period 2021-2050. In particular, sensitivity is defined as the degree to which tourism will be affected by climate changes, exposure is the degree to which tourism will be exposed to climate changes and their impacts whereas the adaptive capacity is defined by the autonomous ability of tourism to adapt to changing environmental conditions as well as by the effectiveness of the relative existing and planned adaptation measures.

For the assessment of future vulnerability, the same indicators used in the current vulnerability assessment (CYPADAPT, 2012) were used, wherever the necessary data were available. These indicators are summarized in Table 11-2.

Table 11-2: Indicators used for the vulnerability assessment of climate change impacts on the tourism sector of Cyprus

Vulnerability Variable	Selected Indicators
Warmer summers	
Sensitivity	– Share of arrivals visiting for leisure purposes – Percent of tourists that preferred the coastal cities for their stay – Climate factors affecting beach tourism (Beach Tourism Climate Index)
Exposure	– Beach Tourism Climate Index
Adaptive capacity	– Diversification of the tourism product to less-climate dependent and seasonal activities – Expansion of the summer tourist season to less warm months – Use of air-conditioning systems and other relevant appliances
Warmer winters	
Sensitivity	– Share of arrivals during the winter months – Tourists visiting the ski resort of Troodos – The existence of other attractions apart ski during winter – Climate factors affecting winter tourism (Tourism Climate Index)
Exposure	– Area of reduced snow-cover (no data) – Reduced snow residence time (no data) – Losses in income (no data) – Number of ski tourism related businesses – Tourism Climate Index

Adaptive capacity	– Snow making at the ski resorts – Diversification of the tourism product to less-climate dependent and seasonal activities
Heat waves	
Sensitivity	– Percent of elderly people / tourists visiting Cyprus
Exposure	– Summer months that elderly people visit Cyprus – Number of heat wave days – Share of tourists visiting the mostly affected areas by heat waves in the future
Adaptive capacity	– Use of air-conditioning systems and other relevant appliances
Storms, waves and floods	
Sensitivity	– Consequences of such events on tourist areas – Share of tourism infrastructure in the coastal areas – Share of tourism infrastructure in the urban centers – Proximity of coastal tourism infrastructure to the coast*
Exposure	– Heavy rainfall index – Frequency and mean height of waves* – Frequency and intensity of storms – Wind speed – Sea Level Rise
Adaptive capacity	– Construction of coastal defense works
Water availability	
Sensitivity	– Share of water demand from the tourism sector to the domestic water demand and to the total water demand – Daily water consumption per tourist – Percent of tourist accommodations having swimming pools – Future tourism water demand and share to the total demand – Number of golf courses – Water price – Decisions limiting the use of fresh water resources for irrigation

Exposure	– Precipitation – Droughts – Reduction in future water availability
Adaptive capacity	– Desalination plants – Application of water saving techniques – Water reuse – Private production of water (private desalination plants)
Coastal erosion	
Sensitivity	– Concentration of tourism infrastructure and resources to the coastal zone – Dependence of Cyprus’ tourism on coastal tourism – Extent of tourist zones of the total coastal length of the Republic of Cyprus
Exposure	– Sea level rise – % of coast already subject to erosion – Storm surges – Wind speed – Coasts exposed to large waves – Heavy rainfall index
Adaptive capacity	– Coastal defense works (breakwaters etc) – Beach nourishment works
Biodiversity attractions	
Sensitivity	– Percent of nature-based tourism – NATURA areas in Cyprus – Share of tourists visiting the Hill resorts
Exposure	– Degree of biodiversity loss in nature tourism attractions * – Increase in SST * – Fire Weather Index – precipitation – maximum length of dry spells
Adaptive capacity	– Carrying Capacity Assessment – Apply of environmentally sound practices (waste and wastewater management etc)

*There were no data available regarding this indicator

The relationship between sensitivity, exposure and adaptive capacity is based on the following qualitative equation:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity * Exposure$$

Sensitivity, exposure and adaptive capacity are evaluated on a 7-degree qualitative scale ranging from “none” to “very high”.

In the sections that follow, the vulnerability is assessed for each of the impact categories presented in Section 11.3:

1. Warmer summers
2. Warmer winters
3. Heat waves
4. Water availability
5. Storms, waves and floods
6. Biodiversity attractions
7. Coastal erosion

It must be noted that, there are no sufficient scientific evidence and data to evaluate or correlate all impacts and indicators to future climate changes. Consequently, further research is required in order to provide concrete information for a more detailed and descriptive assessment of the future vulnerability of the sector. Nevertheless, an attempt was made to provide a preliminary assessment of the future vulnerability. In case additional data are provided by the competent authorities of Cyprus, the future vulnerability of the sector could be re-assessed.

11.4.1. Warmer summers

11.4.1.1. Assessment of sensitivity and exposure

Sensitivity

As an indicator of the dependence of Cyprus on summer (or leisure) tourism, the share of arrivals visiting Cyprus for leisure purposes is selected while tourists travelling for business purposes or to see friends and relatives are considered less sensitive to changes in climate (Fagence and Kevan, 1997). According to data from the Statistical Service of Cyprus, the reasons for visiting Cyprus in 2008 were mainly recreational (81.6%) while there was also a small percentage of tourists (6.9%) who visited Cyprus for professional reasons, i.e.

conferences and meetings. In addition, in order to relate recreational tourism with beach tourism, the share of tourists residing in coastal cities is selected as an indicator. As mentioned in Section 11.2, 89% of the tourists visiting Cyprus prefer the coastal cities for their stay. The assessment of both indicators shows that Cyprus tourism is strongly dependant on beach tourism. Following, the assessment will not be limited to summer tourism but to beach tourism in order to investigate the effect of warmer climate on beach tourism throughout the year.

To assess the sensitivity of beach tourism to warmer climate, first the results of a survey conducted by M. Rutty and D. Scott (2010) which shows that beach visitor preferences are particularly sensitive to temperature will be presented. The survey which was conducted among students attending university in five countries of northern Europe (Austria, Germany, Netherlands, Sweden, Switzerland) provided valuable insight for the identification of temperature thresholds at which behavioural response is initiated, regarding tourism destinations in the Mediterranean. The survey resulted in the designation of the “ideal” and “unacceptable” temperature ranges for beach tourism. In particular, as “unacceptable” was defined the threshold to which tourists respond to the climatic stimulus—i.e. the point at which temperatures (climatic stimuli) are “too hot” or “too cool” (threshold) that tourism demand declines (behavioural response). The majority of respondents defined ideal temperatures as between 27^{o}C and 32 ^{o}C, with less than 22^{o}C identified as unacceptably cool and greater than 37^{o}C identified as unacceptably hot. The survey showed that there is great sensitivity of beach visitor preferences to temperature.

In addition, another relative sensitivity indicator is the Tourism Climatic Index (TCI) (Mieczkowski,1985) which is widely used to measure the suitability of climate for tourism. The tourism climatic index as a concept has evolved from more general knowledge about the influence of climatic conditions on the physical wellbeing of humans. In the 1960s and 1970s systematic research in this field yielded many insights, ranging from preferred temperatures, and the role of relative humidity to the appreciation of wind effects. It should be noted that the appreciation of climatic conditions is also dependent on a host of non-climatic factors, such as the level of activity, clothing, and genetic setup.

Based on the work by Mieczkowski (1985), Morgan et al. (2000) developed a user-based climate index to assess the climate suitability of coastal destinations specific for beach recreation. Similar to Mieczkowski’s TCI, Morgan et al.’s Beach Climate Index (BCI) is made up of climatic parameters (sub-indices) that, after weighting, add up to a maximum score of 100 (ideal conditions). The weights are based on the importance that the beach users attached to each of the components. The weights in this case represent the degree of sensitivity of tourist preferences to each of the climatic parameter (sub-index). The resulting equation is as follows:

$$\mathbf{BCI = 0.18TS + 0.29P + 0.26W + 0.27S}$$

where BCI is the beach climate index, TS, P, W, and S are the components of thermal sensation, precipitation, wind, and sunshine, respectively. Each of the four components is itself represented by an index, with values ranging from 0 to 100. These values are the beach users' evaluation of the underlying weather conditions. The four sub-indices and their relative contribution to the BCI are outlined in Table 4-5. In the equation proposed by Morgan, the highest weight (sensitivity) is given to the precipitation index to reflect the negative impact that this element has on outdoor activities. Wind speed and the amount of sunshine are given the second-highest weights, followed by thermal sensation. Table 11-3, Table 11-4, Table 11-5 and Table 11-6 summarize the BCI weighting scheme. After summing the weighted individual components, the result is multiplied by two, so that the maximum TCI score is 100.

Table 11-3: Sub-indices within the beach climate index

Sub- Index	Daily Variables	Climate Influence on BCI	Weighting in BCI
Thermal Sensation (Ts)	Maximum daily temperature, minimum daily relative humidity, proportion of daylight hours in which there is sunshine & wind speed	Represents beach users' preferred thermal sensation	18%
Precipitation (P)	Total precipitation	Reflects the negative impact that this element has on outdoor activities	29%
Sunshine (S)	Total hours of sunshine	Rated as positive for tourism- but can be negative because of the risk of sunburn and added discomfort on hot days	26%
Wind (W)	Average wind speed	Occurrence of high wind on beaches can cause annoyance in terms of disruption of personal belongings (so that they have to be secured or weighted down) and indirect effects of blowing sand	27%

Table 11-4: BCI Weighting Scheme for Thermal Sensation

Rating	Effective Temperature (°C)
100	32.5-34.4

Rating	Effective Temperature (°C)
77	34.5–35.4
39	29.0–32.4
24	35.5–36.4
21	26.0–28.9
2	21.0–25.9

Table 11-5: BCI Weighting Scheme for Precipitation and Sunshine

Rating	Precipitation (mm)	Sunshine (hrs)
100	<15	10h or more
90	15-30	9h-9h59min
80	30-45	8h-8h59min
70	45-60	7h-7h59min
60	60-75	6h-6h59min
50	75-90	5h-5h59min
40	90-105	4h-4h59min
30	105-120	3h-3h59min
20	120-135	2h-2h59min
10	135-150	1h-1h59min
0.0	>150	<1h

Table 11-6: BCI Weighting Scheme for Wind Speed

Rating	Wind Speed (m/s)
100	> 4
50	4–6
0	> 6

From the above numbers, it can be said that sensitivity of beach tourism in Cyprus to climate changes is considered **high to very high**.

Exposure

In order to assess the exposure of beach tourism to warmer summers in Cyprus, the TCI during winter and autumn is calculated for the two time periods; the control period (1961-1990) and the future period (2021-2050). All sub-indices were calculated with daily values from RACMO2 regional climate model (RCM) developed at KNMI in the Netherlands (Lenderink et al. 2003, 2007), developed within the framework of the ENSEMBLES project. Also, two other RCMs of the ENSEMBLES project have also been used namely METNO and C4I. The results of models were used as an ensemble mean for testing and comparing the respective results of KNMI. The other models were not used since they did not include in their simulations all required parameters for the calculation of BCI.

The final Beach Climate Index (BCI) can attain values ranging from 0 to 100. Morgan et al. (2000) divides this range as suggested by Mieczkowski (1985), with values below 40 seen as unfavorable, the range between 40 and 60 as acceptable, values from 60 to 70 as good, between 70 and 80 as very good, and scores above 80 as excellent for beach tourism.

Table 11-7: Classification of BCI score

Numeric value of index	Description of comfort level for beach activity
> 80	Excellent
70-80	Very Good
60-70	Good
40-60	Acceptable
< 40	Unfavorable

To begin with, since the BCI was formed to assess the climate suitability of coastal destinations specific for beach recreation, the analysis of BCI will be confined to the coastal zone of Cyprus from west (Paphos District) to southeast (Larnaca and Famagusta District).

Figure 11-10a (KNMI) and Figure 11-10b (Ensemble model mean) illustrate the average summer BCI for the present-day climate. More precisely, it is shown that western coastal zone presents a BCI of about 76 classified as “very good” while in southern and southeastern zone BCI is approximately 80 classified as “excellent”. As far as future changes are concerned, both KNMI and the ensemble mean projections (Figure 11-10c, d) show no or negligible changes in the near future for the domain of study.

Regarding spring BCI, Figure 11-11a (KNMI) illustrates that in western coastal zone BCI is about 68 while in southern and southeastern BCI reaches 75 and is classified as “good” and “very good”, respectively. As for the ensemble model mean, Figure 11-11b shows that BCI reaches 67 in western coastline and approximately 72 in southern and southeastern areas.

Therefore, BCI is classified as “good” in western areas and “very good” in southern and southeastern areas. As far as future changes are concerned, KNMI (Figure 11-11c) as well as ensemble mean (Figure 11-11d) projections show no changes or negligible increases respectively.

BCI during autumn, in the present-day climate, is presented in Figure 11-12a and Figure 11-12b. It is shown that in the western coastal zone BCI is about 68 (classified as “good”) while in southern and southeastern coastal zone BCI is 73 (classified as “very good”) (Figure 11-12a). On the other hand, the ensemble model mean plot (Fig. 4-10b) shows that in western coastline BCI is about 67 (classified as “good”) while in southern and southeastern coastal zone is approximately 72 (classified as “very good”). As far as future changes are concerned, no significant changes are projected by both KNMI (Figure 11-12c) and the ensemble model mean (Figure 11-12d).

Concerning winter BCI, both KNMI and ensemble model mean plots (Figure 11-13a and Figure 11-13b – control period) show that BCI is about 54 in western coastal zone (classified as “acceptable”) while in southern and southeastern coastal zone, BCI varies from 60 to 63 (classified as “good”). As far as future changes are concerned, KNMI projections (Figure 11-13c) show an increase of about 2 in western, southern and southeastern coastal areas. In addition, ensemble model mean projections (Figure 11-13d) testify similar increases.

The average annual BCI is presented in Figure 4-12. Specifically, Figure 11-14a (KNMI) shows that in the present-day climate, in western coastal zone BCI reaches 67 while in southern and southeastern coast zone, BCI is about 73. According to the classification, western areas are classified as “good” while southern and southeastern areas are classified as “very good”. In addition, Figure 11-14b (ensemble model mean) depicts that in western coastal areas BCI is about 67, while in southern and southeastern areas BCI ranges between 70 and 72. As far as future changes are concerned, KNMI (Figure 11-14c) and the ensemble model mean projections (Figure 11-14d) do not show any change in the near future.

Similar with TCI’s analysis, apart from seasonal and annual variability of the BCI, the number of days with BCI>70 (classification is “very good”) and BCI>80 (classification is “excellent”), have also been examined. Figure 11-15a (KNMI) shows that in the present-day climate, western coastal areas present 170 days with BCI>70 while southern and southeastern coastal zone present 260 days with BCI>70. In addition, Figure 11-15b (ensemble model mean) shows that in western coastal areas the number of days with BCI>70 is 180 and in southern and southeastern coastal zone ranges between230 and 250 days. As far as near future changes are concerned, KNMI projections (Figure 11-15c) show that an increase of about 4 days is expected in western coastal areas, 2 days in the southern and 3 days in the southeastern coastal areas. Regarding ensemble model mean projections, Figure 11-15d shows that for western coastal areas an increase of about 6 days is expected, for southern regions the increase is 5 days and for southeastern coastal areas the increase is 9 days.

Finally, Figure 11-16 depicts the number of days with BCI>80. More precisely, Figure 11-16a (KNMI) indicates that in western coastal areas the number of days with excellent conditions for beach activity is 100 while in the southern and southeastern coastal areas the number of days is 160. In addition, according to ensemble model mean calculations (Figure 11-16b), western areas show 115 days with BCI>80 whilst southern and southeastern coastal regions show approximately 150 days. As far as future changes are concerned, KNMI projections (Figure 11-16c) testify an increase of 3 days in western and southeastern areas and 2 days in the southern coastal regions. On the contrary, higher changes are projected by ensemble model mean as Figure 11-16d shows. In western and southeastern coastal areas an increase of about 6 days and 8 days respectively is anticipated. Also, in southern regions the increase is about 3 days.

The overall findings of the analysis regarding both present-day climate and potential near future changes due to climate change on Cyprus' Beach Climate Index – BCI are summarized in Table 11-8 and Table 11-9.

Table 11-8: Current values of indices with particular relevance to beach tourism

	Western Coastal Regions		Southern Coastal Regions		Southeastern Coastal Regions	
	KNMI	ENSEMBLE MODEL MEAN	KNMI	ENSEMBLE MODEL MEAN	KNMI	ENSEMBLE MODEL MEAN
Average Summer BCI	76	76	80	80	80	80
Average Spring BCI	68	67	75	72	75	72
Average Fall BCI	68	67	73	72	73	72
Average Winter BCI	53	53	62	61	63	63
Average Annual BCI	67	67	73	71	73	72
Nb of days BCI>70	170	180	260	230	260	250
Nb of days BCI>80	100	115	160	150	160	150

Table 11-9: Potential future changes in indices with particular relevance to beach tourism

	Western Coastal Regions		Southern Coastal Regions		Southeastern Coastal Regions	
	KNMI	ENSEMBLE MODEL MEAN	KNMI	ENSEMBLE MODEL MEAN	KNMI	ENSEMBLE MODEL MEAN
Average Summer BCI	0	(+) 0.7	0	(+) 0.4	0	(+) 0.5
Average Spring BCI	0	(+) 2	0	(+) 1.5	0	(+) 1.5
Average Fall BCI	(–) 0.3	(+) 0.3	(–) 1.0	(+) 0.3	(–) 0.7	(+) 0.5
Average Winter BCI	(+) 2.2	(+) 2.2	(+) 2	(+) 1.5	(+) 2	(+) 1
Average Annual BCI	0	(+) 1.3	0	(+) 0.7	0	(+) 1
Nb of days BCI>70	(+) 4	(+) 6	(+) 2	(+) 5	(+) 3	(+) 9
Nb of days BCI>80	(+) 3	(+) 6	(+) 2	(+) 3	(+) 3	(+) 8

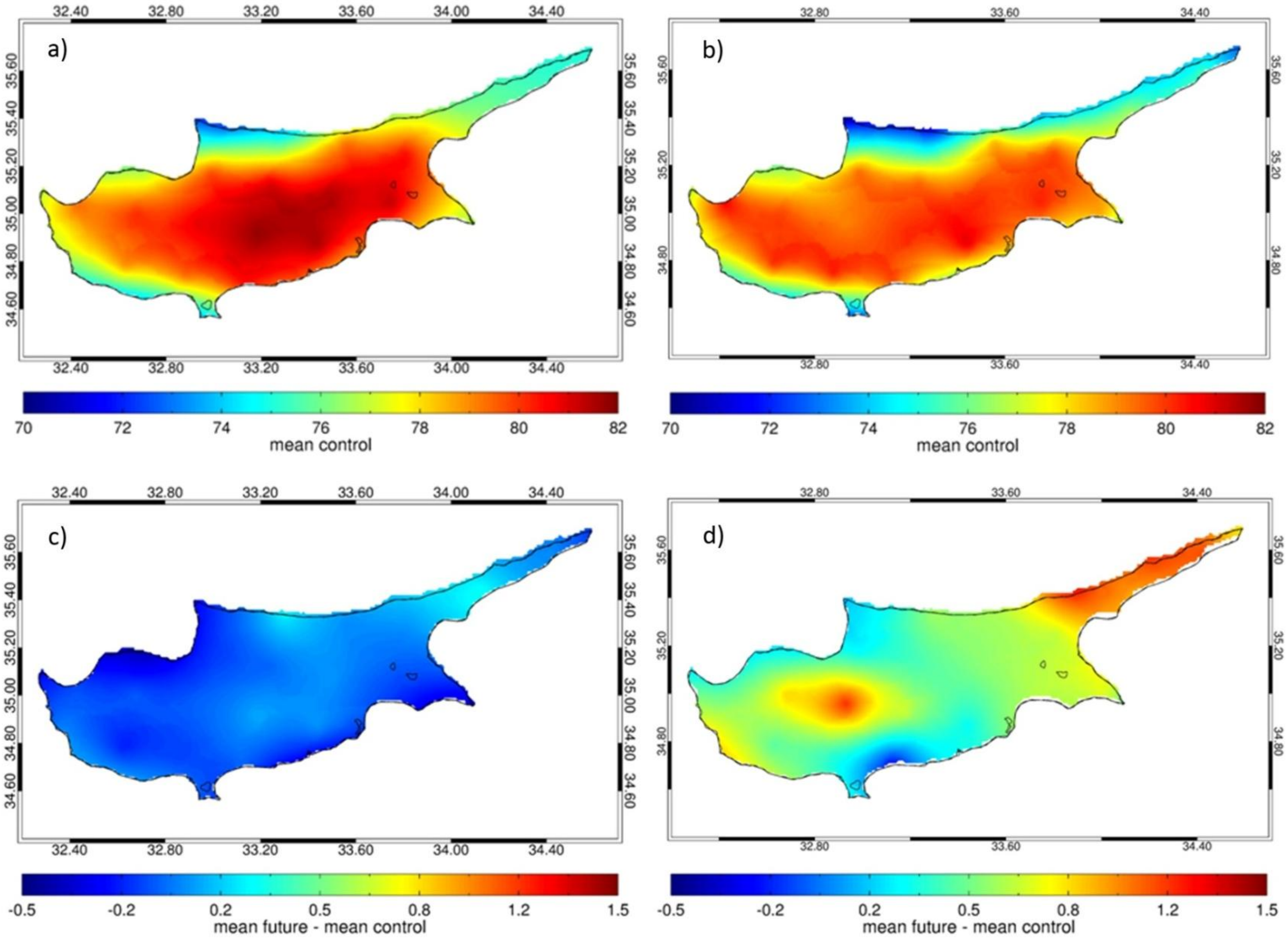

Figure 11-10: Average Summer BCI for the control period (1961-1990) using (a) the KNMI RCM output (b) the ensemble mean of the 2 RCMs. (c) differences in average summer BCI between the control (1961-1990) and the future period (2021-2050) using the KNMI output (d) differences in average summer BCI between the control (1961-1990) and the future period (2021-2050) using the ensemble mean of the 2 RCMs

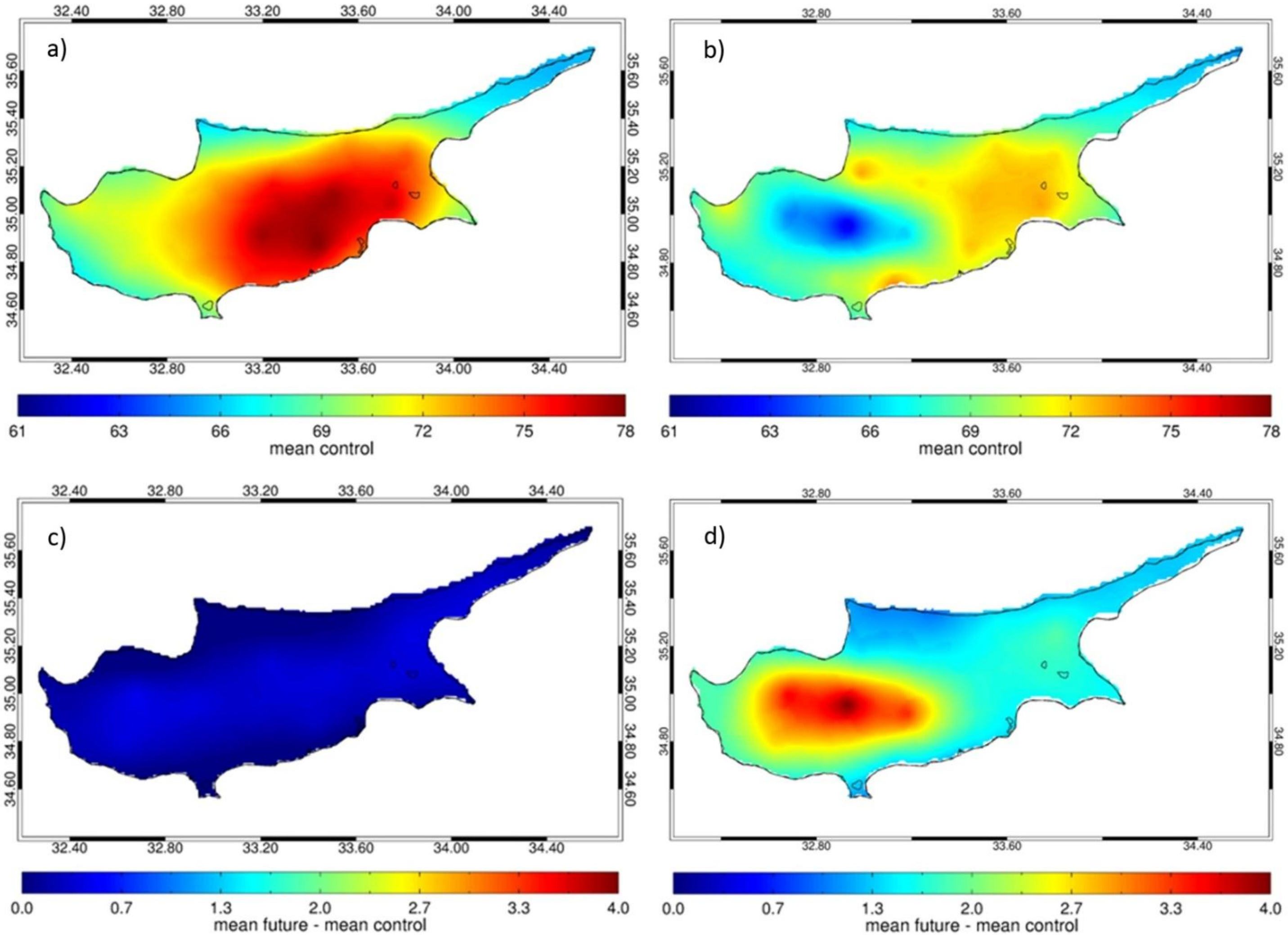

Figure 11-11: Average Spring BCI for the control period (1961-1990) using (a) the KNMI RCM output (b) the ensemble mean of the 2 RCMs. (c) differences in average spring BCI between the control (1961-1990) and the future period (2021-2050) using the KNMI output (d) differences in average spring BCI between the control (1961-1990) and the future period (2021-2050) using the ensemble mean of the 2 RCMs

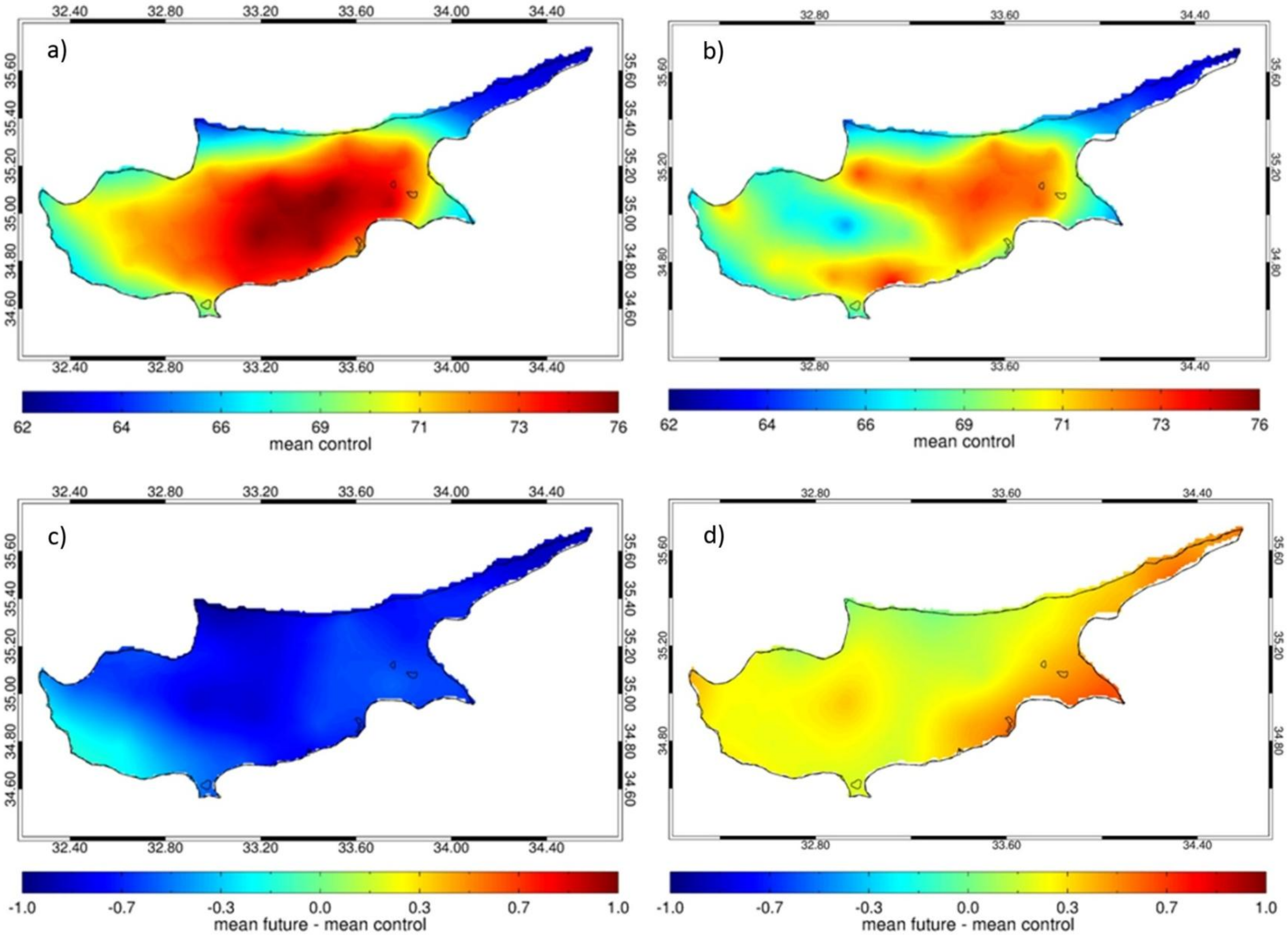

Figure 11-12: Average Autumn BCI for the control period (1961-1990) using (a) the KNMI RCM output (b) the ensemble mean of the 2 RCMs. (c) differences in average autumn BCI between the control (1961-1990) and the future period (2021-2050) using the KNMI output (d) differences in average autumn BCI between the control (1961-1990) and the future period (2021-2050) using the ensemble mean of the 2 RCMs

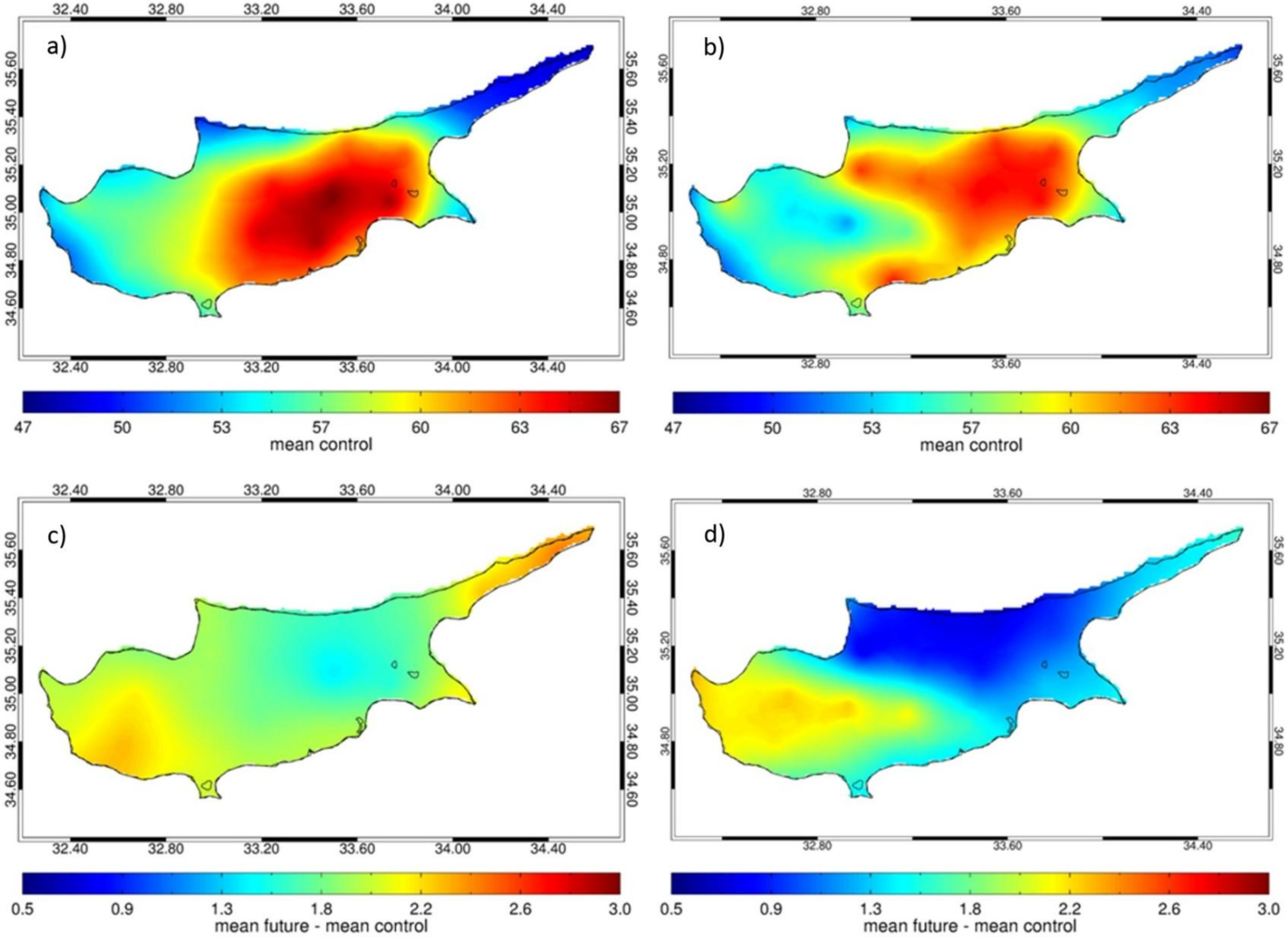

Figure 11-13: Average Winter BCI for the control period (1961-1990) using (a) the KNMI RCM output (b) the ensemble mean of the 2 RCMs. (c) differences in average winter BCI between the control (1961-1990) and the future period (2021-2050) using the KNMI output (d) differences in average winter BCI between the control (1961-1990) and the future period (2021-2050) using the ensemble mean of the 2 RCMs

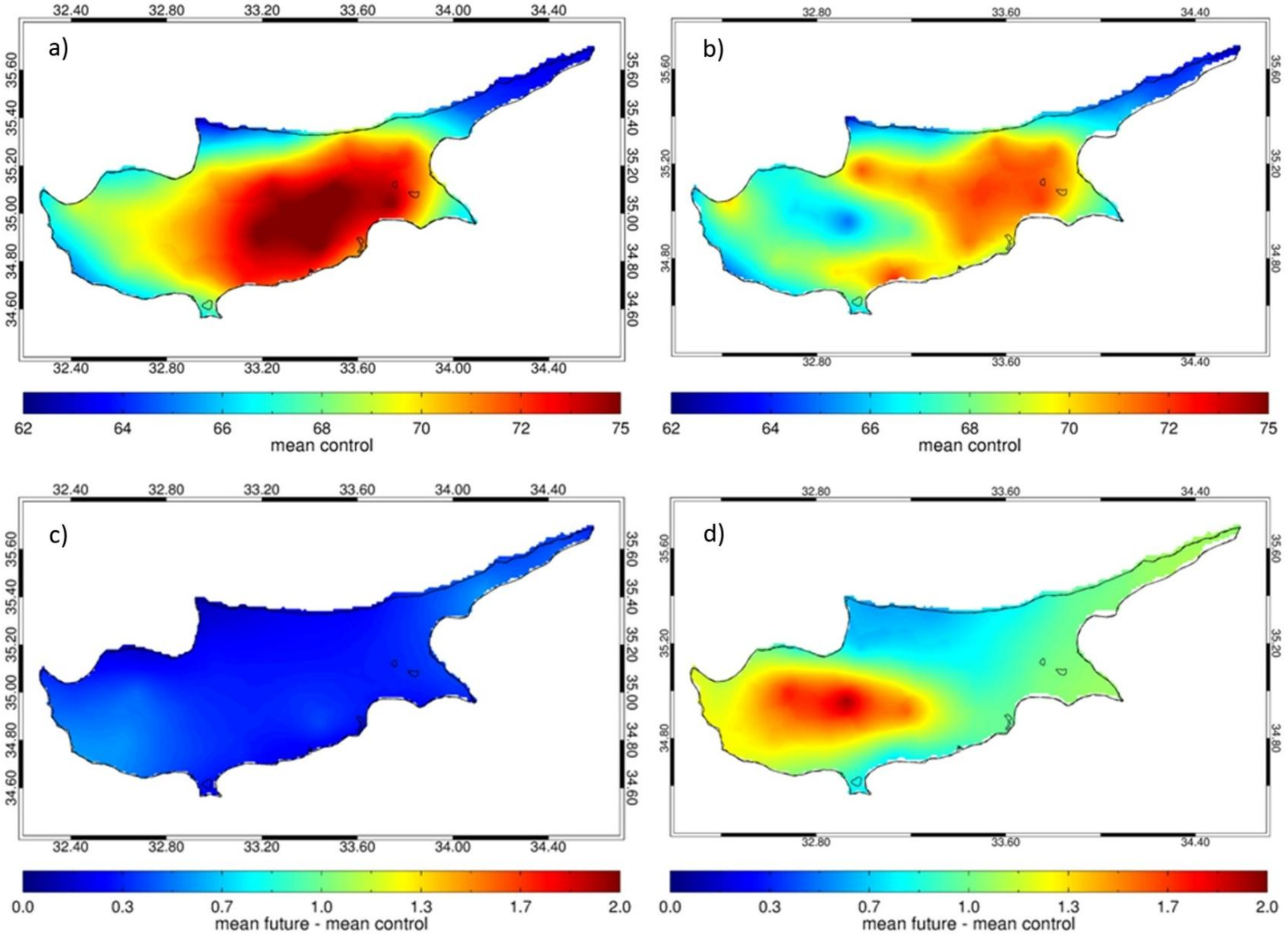

Figure 11-14: Average Annual BCI for the control period (1961-1990) using (a) the KNMI RCM output (b) the ensemble mean of the 2 RCMs. (c) differences in average annual BCI between the control (1961-1990) and the future period (2021-2050) using the KNMI output (d) differences in average annual BCI between the control (1961-1990) and the future period (2021-2050) using the ensemble mean of the 2 RCMs

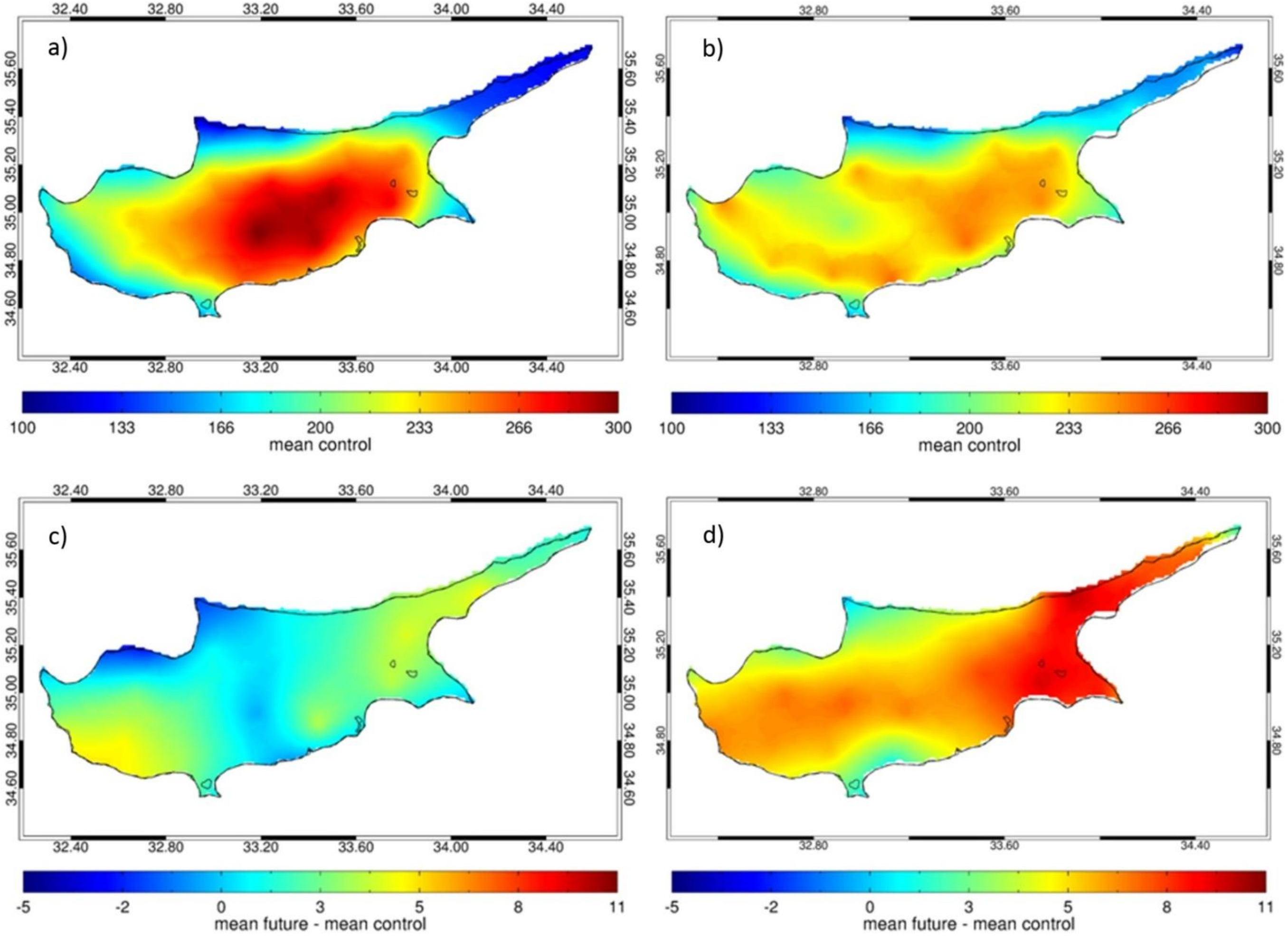

Figure 11-15: Number of days with BCI>70 for the control period (1961-1990) using (a) the KNMI RCM output (b) the ensemble mean of the 2 RCMs. (c) differences in the number of days with BCI>70 between the control (1961-1990) and the future period (2021-2050) using the KNMI output (d) differences in the number of days with BCI>70 between the control (1961-1990) and the future period (2021-2050) using the ensemble mean of the 2 RCMs

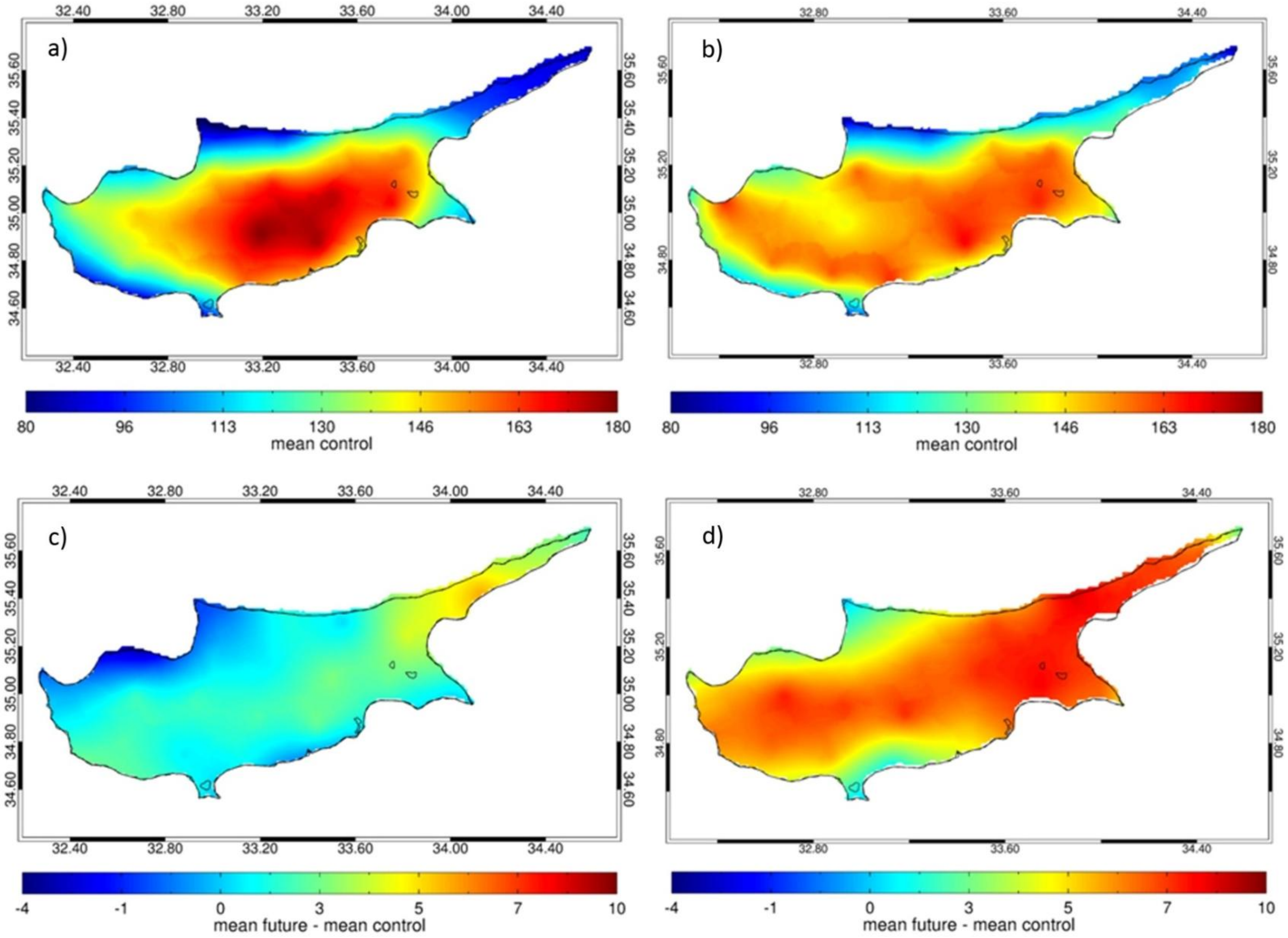

Figure 11-16: Number of days with BCI>80 for the control period (1961-1990) using (a) the KNMI RCM output (b) the ensemble mean of the 2 RCMs. (c) differences in the number of days with BCI>80 between the control (1961-1990) and the future period (2021-2050) using the KNMI output (d) differences in the number of days with BCI>80 between the control (1961-1990) and the future period (2021-2050) using the ensemble mean of the 2 RCMs

Considering the above, it can be concluded that the exposure of Cyprus beach tourism to warmer climate (throughout the year) will not have a negative impact. In specific, it is anticipated that there will be no significant changes regarding its exposure throught the year in the future while any changes will be positive. Thus, the exposure towards this impact is considered as **none**.

11.4.1.2. Assessment of adaptive capacity

In the Mediterranean region, the likely reduction of tourism during the hotter summer months may be compensated for by promoting changes in the temporal pattern of seaside tourism, for example by promoting tourism during the cooler months of the year (Amelung and Viner, 2006) and by diversifying the tourism product to less-climate dependent and seasonal activities (Scott et al., 2008). Another “common practice” that could provide relief to tourists from the discomfort caused by heat waves while they are inside closed tourist areas, is the use of air conditioning systems or other relevant appliances.

It must be mentioned that the Cyprus Tourism Organization (CTO) has undertaken several initiatives towards the diversification of Cyprus’ tourist product. As it can be seen from the Tourism Strategy Plans of the CTO, additional tourist products apart from the ‘Sun and Sea’ product are being promoted, such as conference tourism, sport tourism, cycling, golf, weddings and honeymoon trips, etc. The relative infrastructure is being developed and the new products are being widely advertised. Nevertheless, beach tourism remains the most attractive tourist product that Cyprus offers.

The summer tourist season in Cyprus has already been expanded from the hot months of July and August to May-October, thus partially compensating for possible reduced tourist arrivals during the hot months. On the other hand, the fact that the total tourist arrivals have decreased during the last ten years may be partially attributed[4] to insufficient adaptive capacity of tourism to hot summers. In addition, it must be noted that the main vacation period of the economically active population is the summer period.

The adaptive capacity of Cyprus’ tourism sector to warmer summers in the future is considered to be **moderate**.

To further enhance adaptive capacity towards this impact, it is recommended to take action to combat the emerged competitiveness of other destinations in Europe (exc. Mediterranean), which will be favoured by climate change (Shoukri and Zachariadis, 2012).

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[4] A number of other reasons such as the increase in the price of airline fares is estimated that contributed to decreasing tourist arrivals in Cyprus

11.4.2. Warmer winters

11.4.2.1. *Assessment of sensitivity and exposure*

Sensitivity

For the assessment of the sensitivity of winter tourism to warmer winters, first two factors were used as indicators, namely: (i) the dependence of tourism on winter months and (ii) the existence of other attractions during winter. Tourism in Cyprus during the winter months concentrates only 8.3% (see Figure 11-3) of the total arrivals throughout the year in Cyprus. Regarding the second indicator, a large percent of winter tourist arrivals is linked to professional tourism (which is not sensitive to climate) and a smaller percent is linked to nature-based tourism. The nature-based tourists, are mainly residents of Cyprus which constitute approximately 10% of the total tourist arrivals. The evaluation of the above two indicators shows that the sensitivity of Cyprus' tourism to warmer winter is limited.

However, it must be noted that warmer winters are expected to act beneficially towards winter tourism, as the climate during that period will be more ideal for sightseeing. Following, the assessment will not be limited to winter tourism but to sightseeing tourism in order to investigate the effect of warmer climate on sightseeing tourism throughout the year.

To assess the sensitivity of sightseeing tourism to warmer climate and especially to climate parameters, the Tourism Climate Index developed by Mieczkowski (1985) was used. Mieczkowski applied the general findings about human comfort to the specific activities related to recreation and tourism. He devised a tourism climatic index consisting of five sub-indices, describing daytime thermal comfort, daily thermal comfort, precipitation, hours of sunshine, and wind speed. Beach holidays require climatic conditions different from ski holidays; in his article, light activities, such as touring, are used as a reference. A standardized rating system, ranging from 5 (optional) to 0 (extremely unfavorable), was devised to provide a common basis of measurement for each of the sub-indices. Mieczkowski (1985) proposed the following equation for calculating the TCI for outdoor recreational activities:

$$\mathbf{TCI = 8CID + 2CIA + 4R + 4S + 2W}$$

Where:

CID = daytime comfort index

CIA = daily comfort index

R = precipitation index

S = sunshine index

W = wind speed index

The thermal comfort sub-indices are based on effective temperature, which is a measure of temperature that takes the effect of relative humidity into account. The wind sub-index combines information about wind speed and temperature. The other sub-indices are based on single variables and reflect either the empirical findings of physiological research or qualitative assessments of tourist preferences, for example in relation to precipitation.

The weights used in the equation represent the degree of sensitivity of each sub-index and are ultimately subjective, although they do have a basis in scientific knowledge. In the equation proposed by Mieczkowski (1985), the highest weight is given to the daytime comfort index to reflect the fact that tourists are generally most active during the day. The amount of sunshine and the amount of precipitation are given the second-highest weights, followed by daily thermal comfort and wind speed. The five sub-indices and their relative contribution to the TCI are outlined in Table 11-10.

Table 11-10: Sub-indices within the tourism climate index

Sub- Index	Daily Variables	Climate Influence on TCI	Weighting in TCI
Daytime Comfort Index (CID)	Maximum daily temperature & minimum daily relative humidity	Represents thermal comfort when maximum activity occurs	40%
Daily Comfort Index (CIA)	Mean daily temperature and relative humidity	Represents thermal comfort over the full 24h period (including sleeping hours)	10%
Precipitation (P)	Total precipitation	Reflects the negative impact that this element has on outdoor activities	20%
Sunshine (S)	Total hours of sunshine	Rated as positive for tourism-but can be negative because of the risk of sunburn and added discomfort on hot days	20%
Wind (W)	Average wind speed	Variable effect depending on temperature (evaporative cooling effect in hot climates rated positively, while “wind chill” in cold climates rated negatively)	10%

Table 11-11 and Table 11-12 summarize the TCI weighting scheme. After summing the weighted individual components, the result is multiplied by two, so that the maximum TCI score is 100.

Table 11-11: TCI Weighting Scheme for Effective Temperature, Precipitation and Sunshine

Rating	Effective Temperature (°C)	Precipitation (mm)	Sunshine (hrs)
5.0	20-27	0.0-14.9	10h or more
4.5	19-20 27-28	15.0-29.9	9h-9h59min
4.0	18-19 28-29	30.0-44.9	8h-8h59min
3.5	17-18 29-30	45.0-59.9	7h-7h59min
3.0	15-17 30-31	60.0-74.9	6h-6h59min
2.5	10-15 31-32	75.0-89.9	5h-5h59min
2.0	5-10 32-33	90.0-104.9	4h-4h59min
1.5	0-5 33-34	105.0-119.9	3h-3h59min
1.0	(-5)-0 34-35	120.0-134.9	2h-2h59min
0.5	35-36	135.0-149.9	1h-1h59min
0.0	(-10)-(-5)	150.0 or more	<1h

Table 11-12: TCI Weighting Scheme for Wind Speed

km/h	Beaufort scale	Normal System	Trade Wind System	Hot Climate System
<2.88	1	5.0	2.0	2.0
2.88-5.75	2	4.5	2.5	1.5
5.76-9.03	2	4.0	3.0	1.0
9.04-12.23	2	3.5	4.0	0.5
12.24-19.79	3	3.0	5.0	0
19.80-24.29	4	2.5	4.0	0
24.30-28.79	4	2.0	3.0	0
28.80-38.52	5	1.0	2.0	0
>38.52	6	0	0	0

Considering both the first two indicators and the TCI, the winter tourism in Cyprus is characterized by **moderate** sensitivity to warmer climate.

Exposure

In order to assess the exposure of winter tourism to warmer winters in Cyprus, the TCI during winter and autumn is calculated for the two time periods; the control period (1961-1990) and the future period (2021-2050). The winter and autumn TCI is rated based on the optimal temperature for sightseeing tourism (i.e. 20-27°C) which is considered to better reflect winter tourism in Cyprus. All sub-indices were calculated with daily values from RACMO2 regional climate model (RCM) output developed at KNMI in the Netherlands (Lenderink et al. 2003, 2007), developed within the framework of the ENSEMBLES project. Also, two other RCMs of the ENSEMBLES project have also been used namely METNO and C4I. The results of these two models were used as an ensemble mean for testing and comparing the respective results of KNMI. The other models were not used since they did not include in their simulations all required parameters for the calculation of TCI.

Mieczkowski (1985) proposed a classification of TCI scores, with values in excess of 60 corresponding to “good” conditions, scores exceeding 70 representing “very good” climatic conditions, levels of over 80 corresponding to “excellent” conditions, and scores of 90 or more standing for “ideal” circumstances. The detailed classification scheme of TCI is outlined in Table 11-13.

Table 11-13: Classification of TCI score

Numeric value of index	Description of comfort level for tourism activity
90-100	Ideal
80-89	Excellent
70-79	Very Good
60-69	Good
50-59	Acceptable
40-49	Marginal
30-39	Unfavorable
20-29	Very Unfavorable
10-19	Extremely Unfavorable
<9	Impossible

To study the potential for winter tourism in Cyprus and how this may change in the future, average winter TCI has also been examined. As shown in Figure 11-17a (PRECIS) the lower TCI of about 53, is presented in Troodos mountain while inland and southeastern regions present higher values of about 59 and 62 respectively. Also, in southern and western regions TCI reaches 56. Regarding classification (Table 11-13), the mountain, southern as well as western and inland regions are classified as "acceptable" while the southeastern regions are classified as "good". Regarding Ensemble model mean plots, Figure 11-17b illustrates lower values for the TCI in comparison with the respective of the PRECIS. In mountain regions, the TCI varies from 45 to 53 depending on the elevation while in western areas TCI reaches 53. On the contrary, inland, southern and southeastern regions present the higher TCI of around 58. The classification with regard to comfort level for tourism activity is "marginal" for mountain and "acceptable" for the remaining areas. As regards future changes, both PRECIS (Figure 11-17c) and Ensemble model mean (Figure 11-17d) present a slight increase for the TCI of about 3 in mountain and western areas and 4 in southeastern and inland regions. The classification with regard to comfort level for tourism activity is "acceptable" for both cases.

Concerning the TCI during autumn, Figure 11-18a (PRECIS) illustrates that in the present-day climate, the average fall TCI varies between 74-76 in mountain, south-southeastern as well as inland and western areas. Similar to spring, autumn is classified as "very good" for tourism activities. As regards Ensemble model mean plot, Figure 11-18b depicts lower values for the TCI comparing with PRECIS. The TCI in mountain regions varies from 65 to 73 depending on the elevation. In addition, southeastern and inland regions present a TCI of about 72. In southern and western coastline the TCI reaches 74. The classification with regard to comfort level for tourism activity is "good" at the high altitudes and "very good" at the remaining area. As far as future changes are concerned, PRECIS projections show a small decrease in the TCI of about 3 in the western and mountain regions while southeastern and inland areas show a higher decrease of about 4.5. In all cases, classification of the TCI remains in the same levels of the control period. As for the Ensemble model mean projections (Figure 11-18d), Troodos Mountain shows the lower decrease of about 2.5 while the remaining area shows a decrease of about 3.5. Those reductions of the TCI, classify Cyprus as "good" with regard to comfort level for tourism activity.

To testify climate change impacts on the summer tourism industry in Cyprus, average summer TCI was examined. Figure 11-20a (KNMI) and Figure 11-20b (ensemble model mean) show that southeastern (Larnaca) and inland (Nicosia) areas present, in the present climate, the lower values for the TCI of about 55-60 in other words "acceptable" conditions for the tourists according to Table 11-13. The mountainous areas of Troodos as well as western and southern regions present larger values for TCI of about 70-75 classified as "very good" for tourism activities. As far as future changes are concerned, KNMI (Figure 11-20c) projects a small reduction of around 6 in the western and mountainous areas as well as in the southern (Limassol) and southeastern areas. A slightly smaller reduction of about 4.5 is projected for inland areas of Cyprus. Regarding ensemble model mean, greater reductions of about 8 are projected for mountainous, southern and western regions. Decreases of around 4-6 are projected for southeastern and inland areas (Figure 11-20d).

To investigate the annual pattern of TCI and the changes which may occur in the near future, the average annual TCI has been analyzed. Figure 11-21a (KNMI – control period) illustrates that in mountainous and inland regions TCI reaches 68 while in the southern-southeastern and western coastal areas TCI reaches 71. This means that annually, mountain and inland regions are classified as “good” while the coastline, where the majority of tourism activities takes place, is classified as “very good”. Regarding the ensemble model mean, Figure 11-21b shows that in Troodos mountain, TCI varies from 60 to 66 depending on the altitude. In inland and coastline areas (from west to east) TCI reaches 66 and 68, respectively. In the case of the ensemble model mean, all areas of Cyprus are classified as “good” with regard to comfort level for tourism activity. As for the near future changes, KNMI and the ensemble model mean (Figure 11-21c, d) project a slight decrease in the TCI of for all of Cyprus. For both cases, the classification level for the future period remains the same compared to the control period.

Apart from seasonal and annual variability of TCI, two further important parameters i.e. the number of days with TCI>70 (classification is “very good”) and TCI>80 (classification is “excellent”), have also been examined. Regarding the number of days with TCI>70, Figure 11-22a (KNMI – control period) shows that in mountainous regions there are 170 – 200 days with TCI higher than 70. In western regions there are 210 days while in southeastern regions the number of days reaches 200. Inland areas of Nicosia District, show 170 days with TCI>70. Regarding the ensemble model mean, Figure 11-22b depicts that in many areas of Cyprus the number of days with TCI>70 ranges between 150 and 165. The highest number of days, approximately 195, is found both in western and southern coastal areas. As far as future changes are concerned, KNMI projections show a decrease of about 20 days for mountainous, southern and western regions while in inland and southeastern regions the decrease is 12 days per year. Moreover, Figure 11-22d shows that ensemble model mean does not project any changes for inland or southeastern regions while in southern and western coastal areas, it projects a decrease of about 10 days and in Troodos Mountain a decrease of about 15-20 days.

Finally, Figure 11-23a (KNMI, control period) shows that there are approximately 100-115 days with TCI higher than 80 in mountainous, inland as well as southern and southeastern regions. Also, western areas present the highest number of days of about 125. On the other hand, the ensemble model mean shows that there are about 85 days with TCI>80 in inland and southeastern areas while in mountain areas the number reaches 90 days. The western coastal areas show the highest number of days with TCI>80, approximately 120 days. Regarding future changes, a reduction of about 20 days per year for mountainous, southern and western areas is projected while in inland and southeastern regions the reduction reaches 15 days. (Figure 11-23c, KNMI). On the other hand, ensemble model mean projects a reduction of about 5 days in inland and southeastern areas and 6 in southern areas while in mountain and western areas the reduction may reach 12 and 10 days, respectively (Figure 11-23d).

The overall findings of the analysis regarding both present-day climate and potential near future changes due to climate change with negative or positive impacts on Cyprus tourism industry are summarized in Table 11-14 and Table 11-15.

Table 11-14: Values of indices with particular relevance to tourism

	Western Regions		Mountain Regions		Inland Regions		Southern Regions		Southeastern Regions	
	KNMI	ENSEMBLE MODEL MEAN	KNMI	ENSEMBLE MODEL MEAN	KNMI	ENSEMBLE MODEL MEAN	KNMI	ENSEMBLE MODEL MEAN	KNMI	ENSEMBLE MODEL MEAN
Average Summer TCI	75	75	70	70	55-60	55-60	70	70	55-60	55-60
Average Spring TCI	75	71	75	65	80	75	75	71	80	75
Average Fall TCI	76	74	75	65-73	74	72	75	74	75	72
Average Winter TCI	56	53	53	45-53	59	58	56	58	62	58
Average Annual TCI	71	67	68-70	60-66	68	66	71	67	71	67
Nb of days TCI>70	210	195	170-200	160	170	160	200	165	200	165
Nb of days TCI>80	125	120	100-115	90	100-115	85	110	100	110-115	85

Table 11-15: Potential future changes in indices with particular relevance to tourism

	Western Regions		Mountain Regions		Inland Regions		Southern Regions		Southeastern Regions	
	KNMI	ENSEMBLE MODEL MEAN	KNMI	ENSEMBLE MODEL MEAN	KNMI	ENSEMBLE MODEL MEAN	KNMI	ENSEMBLE MODEL MEAN	KNMI	ENSEMBLE MODEL MEAN
Average Summer TCI	(–) 6	(–) 8	(–) 6	(–) 8	(–) 4.5	(–) 4-6	(–) 6	(–) 8	(–) 6	(–) 4-6
Average Spring TCI	(+) 2	(+) 3	0	(+) 4	0	0	0	(+) 3	0	0
Average Fall TCI	(–) 3	(–) 3.5	(–) 3	(–) 2.5	(–) 4.5	(–) 3.5	(–) 4	(–) 3.5	(–) 4.5	(–) 3.5
Average Winter TCI	(+) 3	(+) 3	(+) 3	(+) 3	(+) 4	(+) 4	(+) 3	(+) 3	(+) 4	(+) 4
Average Annual TCI	(–) 1	(–) 1	(–) 1	0	(–) 1	(–) 1	(–) 1	(–) 1	(–) 1	0
Nb of days TCI>70	(–) 20	(–) 10	(–) 20	(–) 15	(–) 12	0	(–) 20	(–) 10	(–) 12	0
Nb of days TCI>80	(–) 20	(–) 10	(–) 20	(–) 12	(–) 15	(–) 5	(–) 20	(–) 6	(–) 15	(–) 5

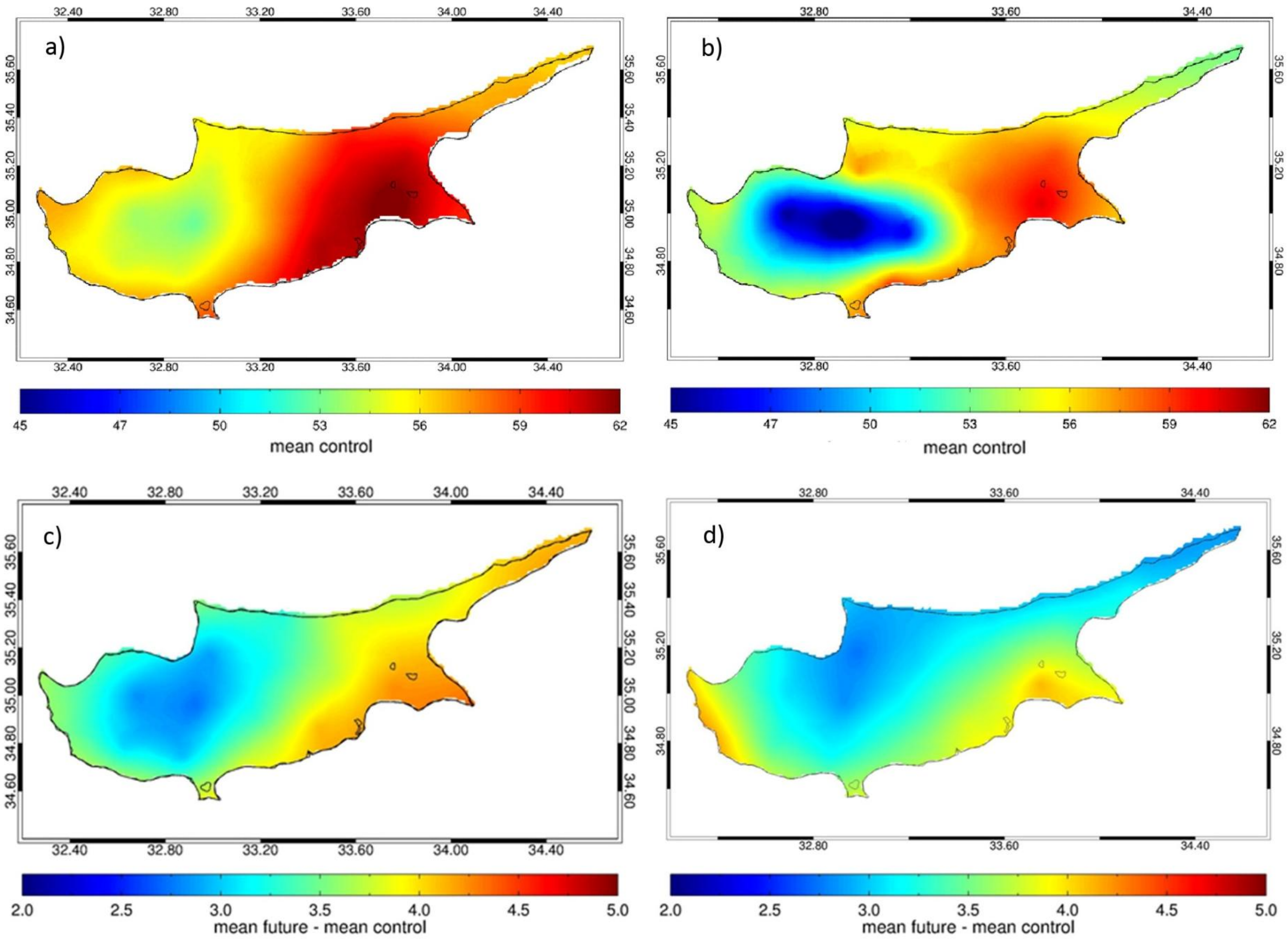

Figure 11-17: Average Winter TCI for control period using PRECIS RCM model (a) and ENSEMBLE RCM models (b). Average Winter TCI in the near future (Future – Control period) using PRECIS RCM model (c) and ENSEMBLE RCM models (d)

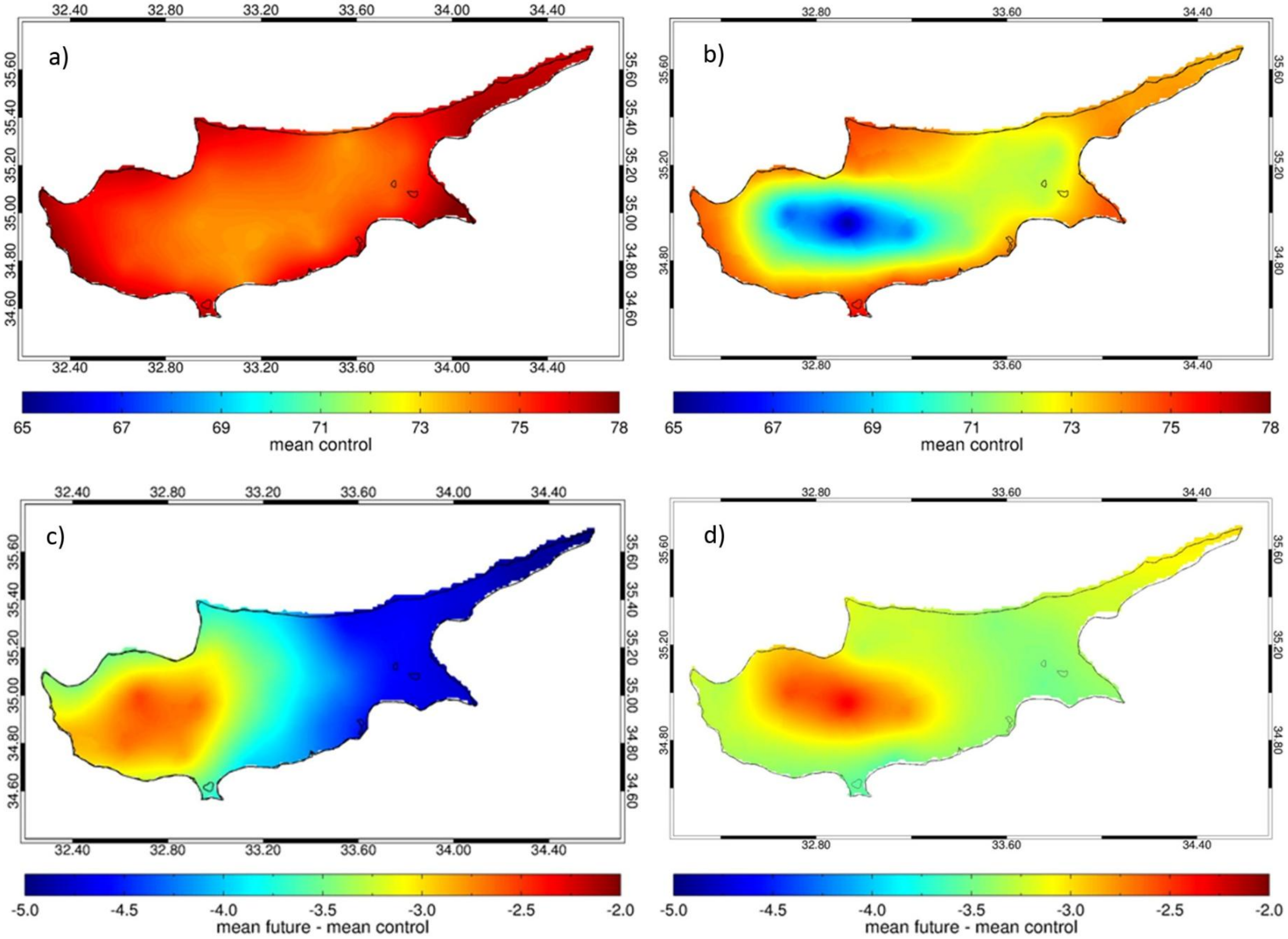

Figure 11-18: Average Autumn TCI for control period using PRECIS RCM model (a) and ENSEMBLE RCM models (b). Average Autumn TCI in the near future (Future – Control period) using PRECIS RCM model (c) and ENSEMBLE RCM models (d).

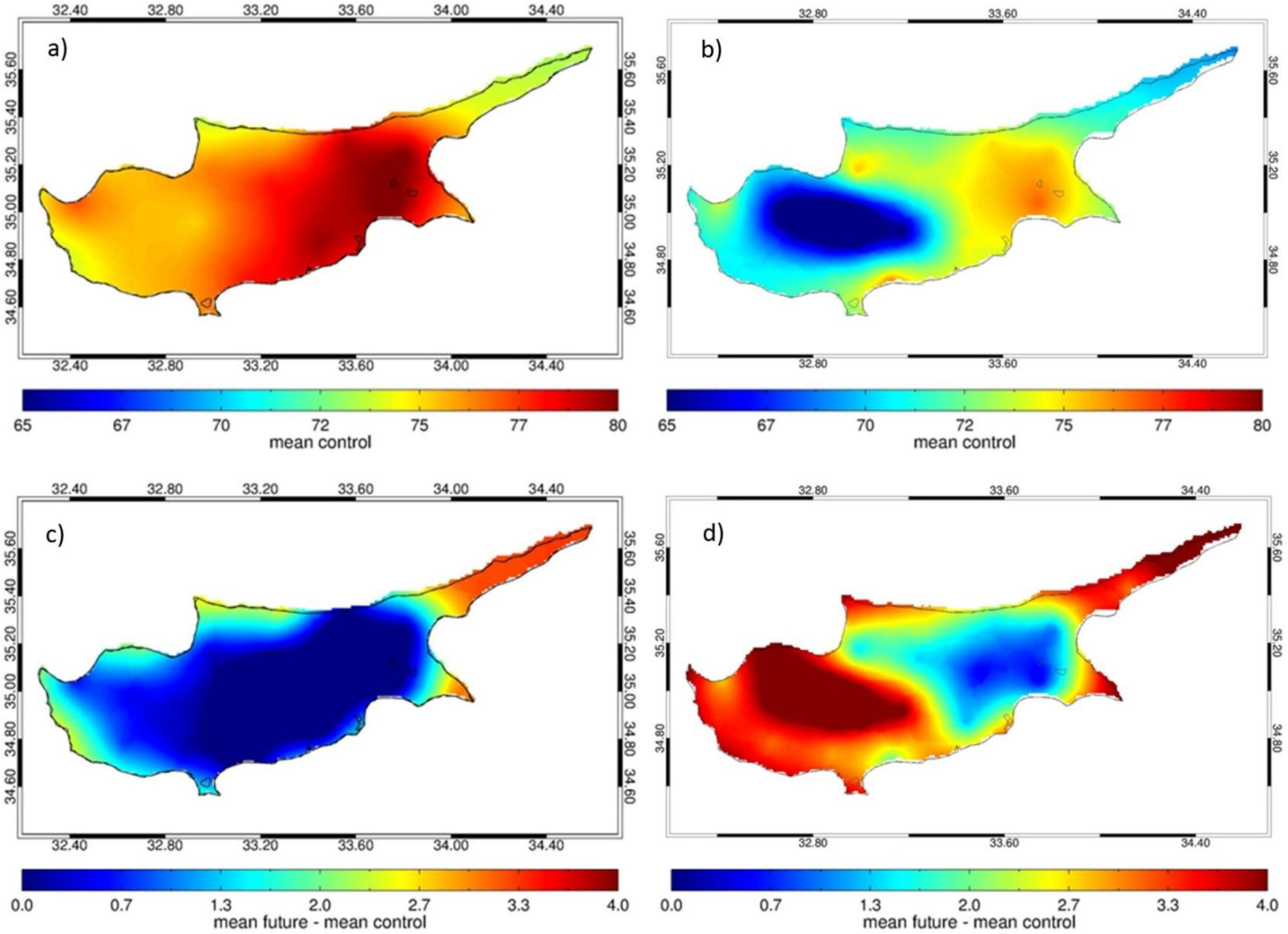

Figure 11-19: Average Spring TCI for the control period (1961-1990) using (a) the KNMI RCM output (b) the ensemble mean of the 2 RCMs. (c) differences in average spring TCI between the control (1961-1990) and the future period (2021-2050) using the KNMI output (d) differences in average spring TCI between the control (1961-1990) and the future period (2021-2050) using the ensemble mean of the 2 RCMs

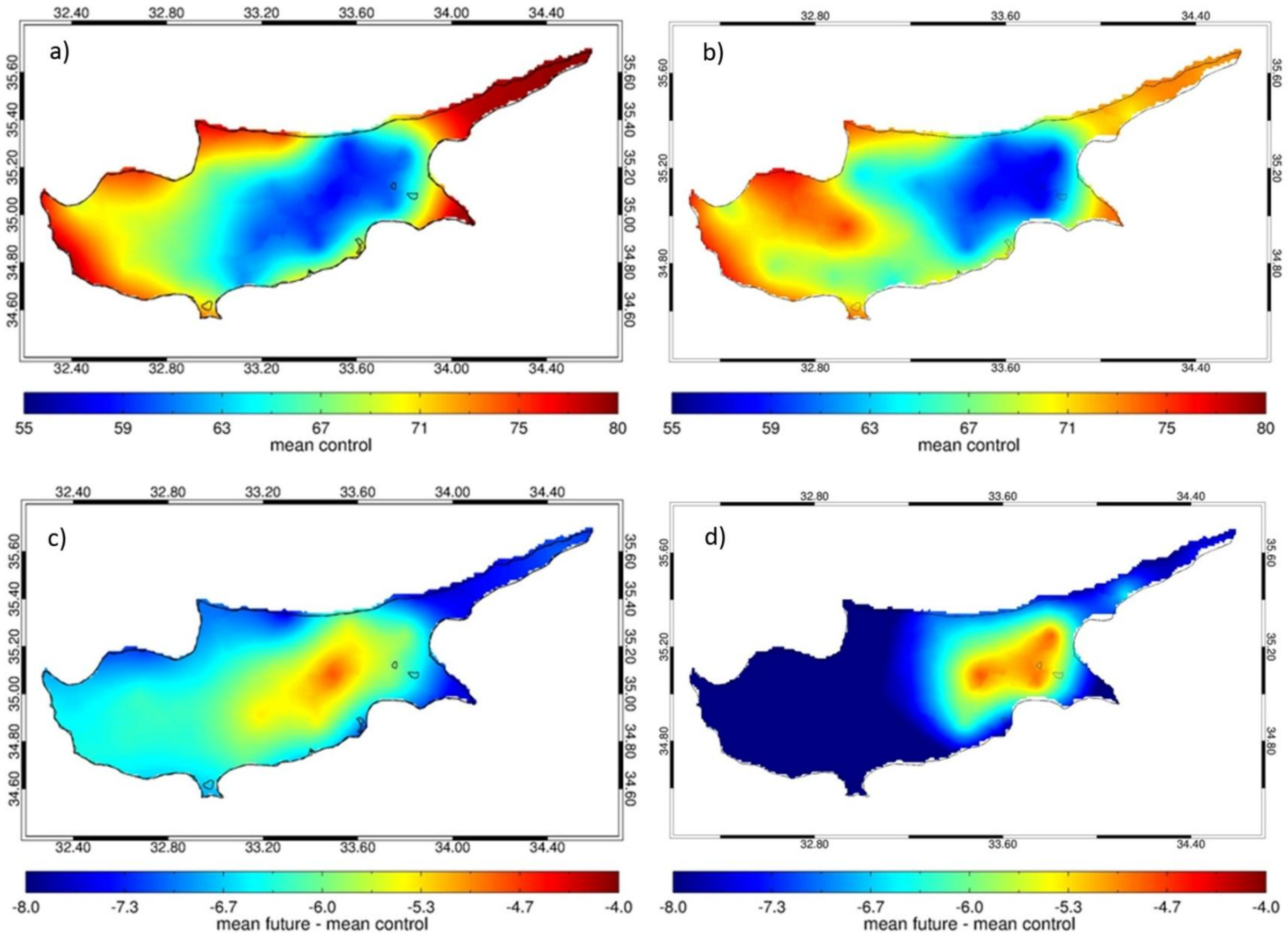

Figure 11-20: Average Summer TCI for the control period (1961-1990) using (a) the KNMI RCM output (b) the ensemble mean of the 2 RCMs. (c) differences in average summer TCI between the control (1961-1990) and the future period (2021-2050) using the KNMI output (d) differences in average summer TCI between the control (1961-1990) and the future period (2021-2050) using the ensemble mean of the 2 RCMs

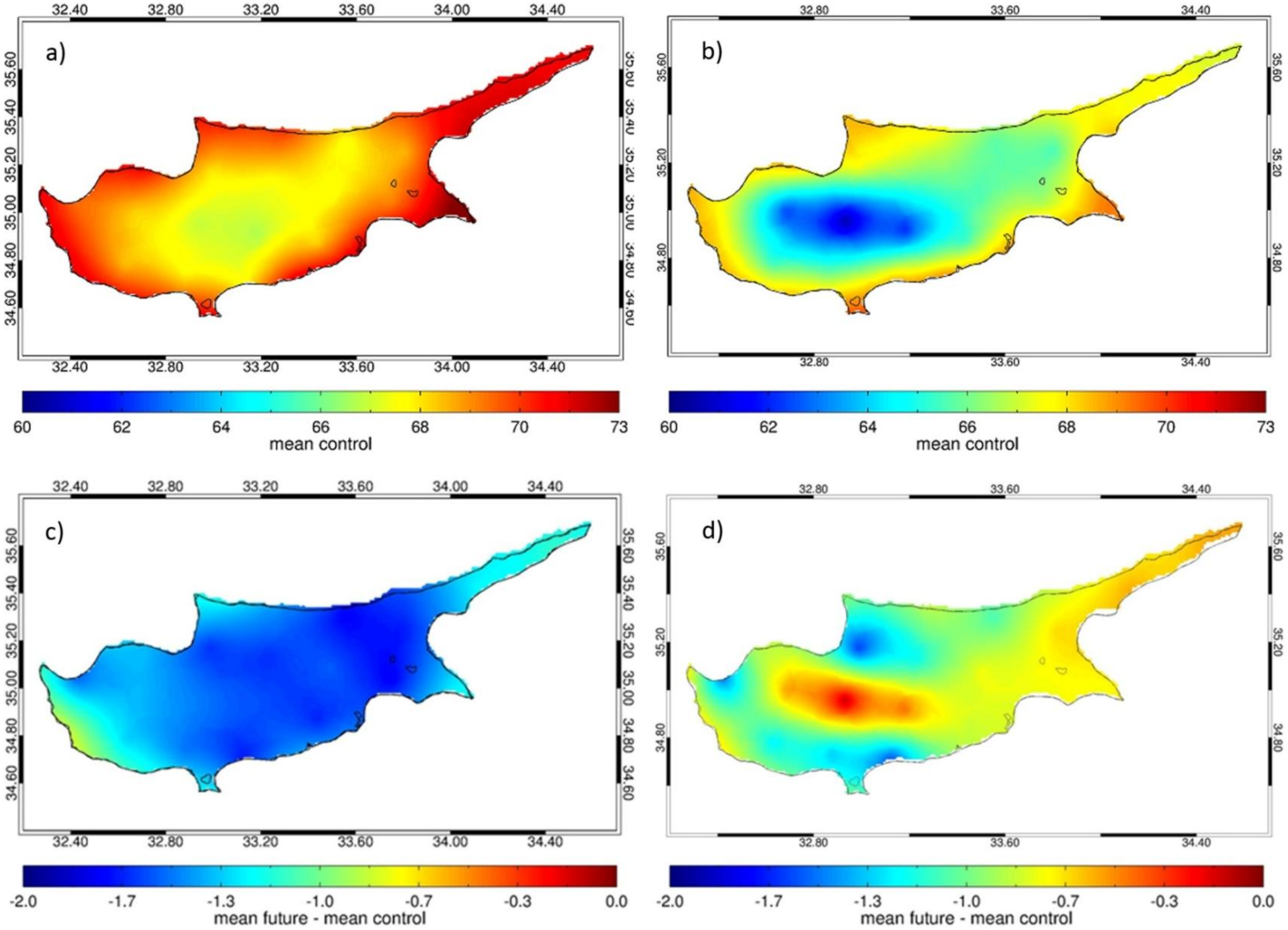

Figure 11-21: Average Annual TCI for the control period (1961-1990) using (a) the KNMI RCM output (b) the ensemble mean of the 2 RCMs. (c) differences in average annual TCI between the control (1961-1990) and the future period (2021-2050) using the KNMI output (d) differences in average annual TCI between the control (1961-1990) and the future period (2021-2050) using the ensemble mean of the 2 RCMs

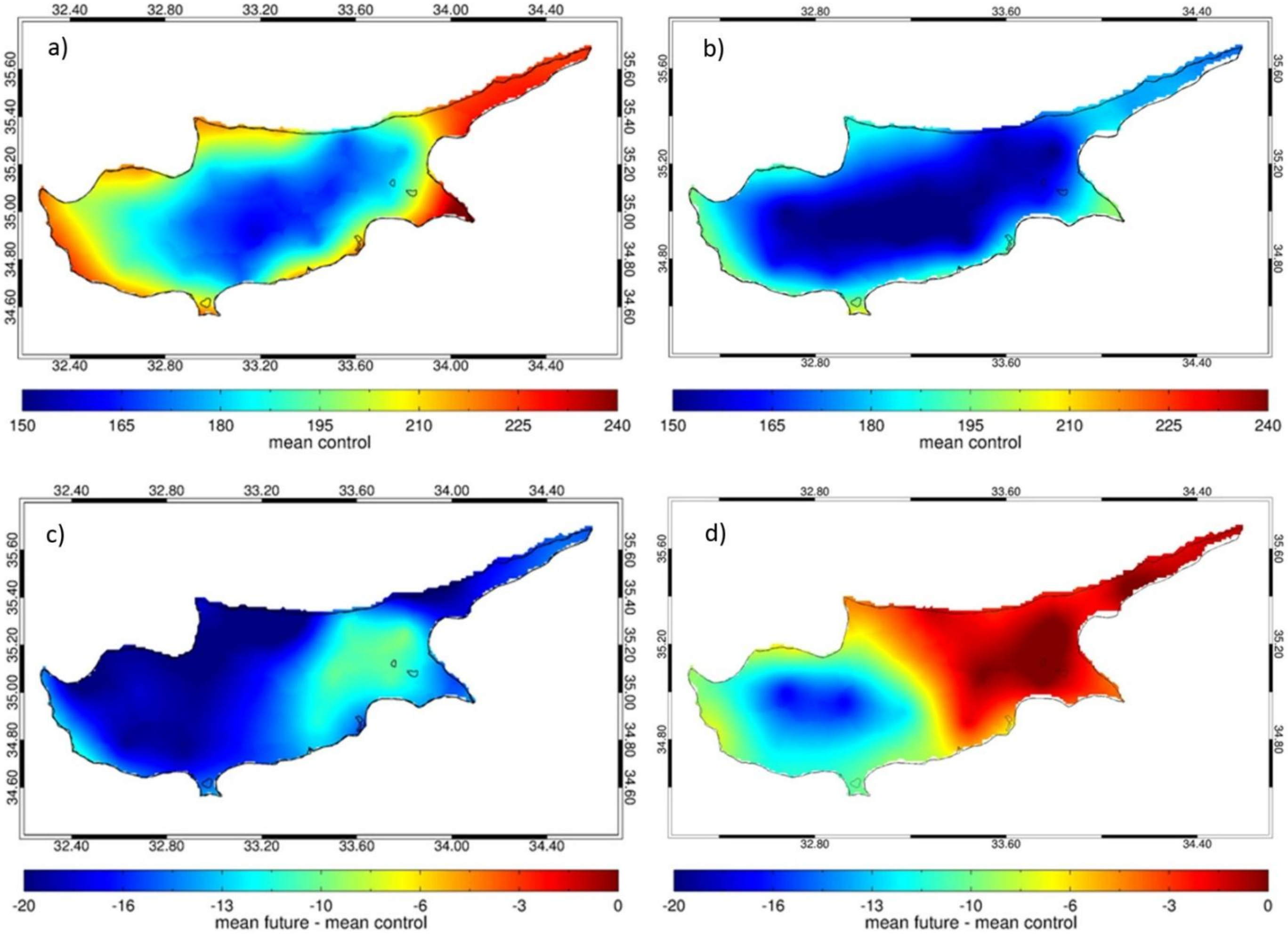

Figure 11-22: Number of days with TCI>70 for the control period (1961-1990) using (a) the KNMI RCM output (b) the ensemble mean of the 2 RCMs. (c) differences in the number of days with TCI>70 between the control (1961-1990) and the future period (2021-2050) using the KNMI output (d) differences in the number of days with TCI>70 between the control (1961-1990) and the future period (2021-2050) using the ensemble mean of the 2 RCMs

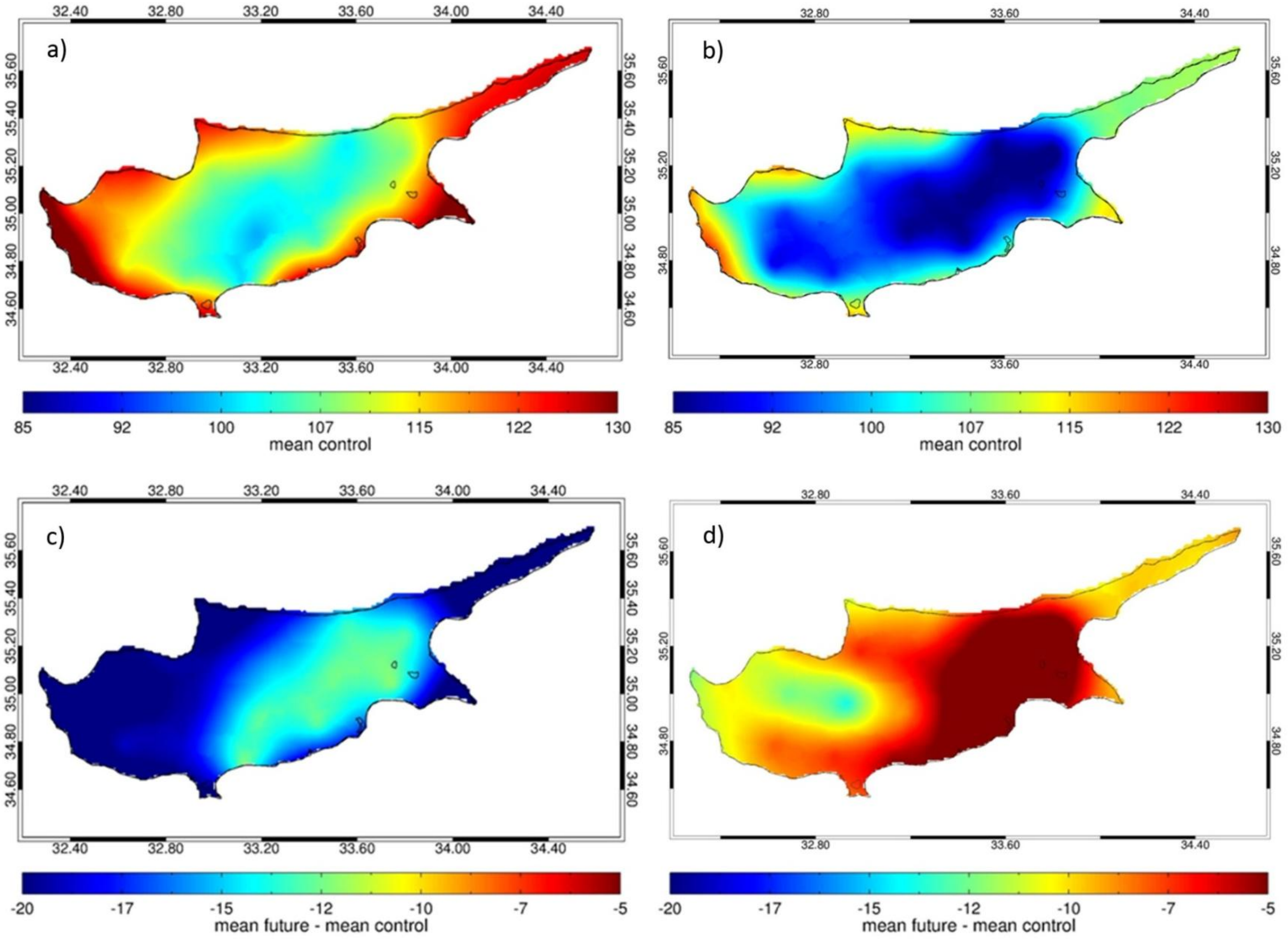

Figure 11-23: Number of days with TCI>80 for the control period (1961-1990) using (a) the KNMI RCM output (b) the ensemble mean of the 2 RCMs. (c) differences in the number of days with TCI>80 between the control (1961-1990) and the future period (2021-2050) using the KNMI output (d) differences in the number of days with TCI>80 between the control (1961-1990) and the future period (2021-2050) using the ensemble mean of the 2 RCMs

To sum up, winter and spring sightseeing tourism are expected to be benefited by warmer climate in all areas while summer and autumn tourism are expected to be exposed to a negative impact due to warmer climate as the conditions will be less than ideal for outdoor activities. Considering that the overall annual exposure is considered to be exposed to a slight negative impact, the overall exposure of Cyprus sightseeing tourism to warmer climate is characterized as **limited**.

11.4.2.2. Assessment of adaptive capacity

Regarding winter ski tourism, compensating for reduced snowfall by artificial snowmaking is already common practice for coping with year-to-year snow pack variability. However, this adaptation strategy is likely to be economic only in the short term, or in the case of very high elevation resorts in mountain regions and, may be ecologically undesirable. New leisure industries, such as grass skiing or hiking could compensate for any income decrease experienced by the ski industry due to snow deterioration (Fukushima et al., 2002).

For the case of Cyprus, although the winter ski tourism is limited, relative adaptation measures have been undertaken. More specific, a snow making machinery is already installed in the Troodos Ski Club from 2003, thus increasing the adaptive capacity of ski tourism in Cyprus.

In addition, the fact that winter or sightseeing tourism is already diversified by a number of other tourism segments such as conference tourism (majority of winter tourism), sports tourism, cycling tourism, golf tourism[5] etc., and the fact that warmer winters will act beneficially towards winter tourism, the adaptive capacity of Cyprus' winter tourism to warmer winters is considered to be **moderate**.

11.4.3. Heat waves

11.4.3.1. Assessment of sensitivity and exposure

Sensitivity

As heat waves occur during the summer seasons, where the temperatures and relative humidity are high and the tourism season is high as well, an increasing risk for heat stress exists. Tourists may be particularly affected by heat waves, as according to the climate of the country of their origin, they may not be used to such kind of phenomena and may not

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[5] It is noted that 14 golf courses have already by licensed

know how to protect themselves from such events. Even if this is not the case, heat waves will make tourists visiting Cyprus in the hot summer months to feel uncomfortable, which may result in shortening the duration of their stay or deciding not to visit this country again.

All age groups are considered sensitive to heat waves while the most sensitive age group is the elderly. This group corresponds to approximately 33% (average 1999-2011) of the total tourism in Cyprus (CYSTAT, 2011).

Therefore, it is considered that Cyprus' tourism has **high** sensitivity to heat waves.

Exposure

Heat waves in Cyprus are a frequent phenomenon during summer. However, it must be noted that the elderly people (such as pensioners) who are more sensitive to heat waves prefer to travel in Cyprus during the autumn and spring when there are no heat waves.

As for the future changes in the number of heat wave days (temperature>35^{o}C) in the years 2021-2050 compared to the control period, as these were calculated by PRECIS (Figure 11-24), most of the areas in Cyprus are expected to experience an increase. A spatial temperature difference between coastal and continental regions expected is evident. In particular, PRECIS shows that the increase of days per year with daily maximum temperature higher than 35°C does not exceed 20 days in coastal areas, with the exception of Famagusta, Larnaca and the coastal area between Larnaca and Limassol, where the increase in heat wave days is more significant. It is also noted that the heat wave index increase, ranges from 30 to 35 days in the southeastern part of Troodos and in continental lowlands, especially near Nicosia. In conclusion, PRECIS shows that heat waves are expected to affect in the near future the cities of Nicosia, Larnaca and Famagusta where a large part of tourism overnights is spent (approximately 50% according to Figure 11-2).

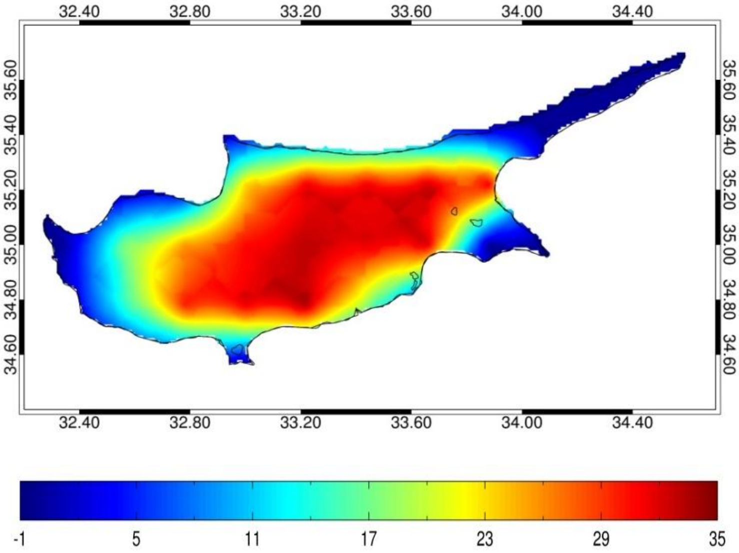

Figure 11-24: Changes in the number of heat wave days (T>35^{o}C) between the future (2021-2050) and the control period (1961-1990)

Considering the above, the future exposure of Cyprus' tourism to heat waves is considered to be **high**.

11.4.3.2. Assessment of adaptive capacity

The adaptation measures of the tourism sector against heat waves are actually restricted to relieving tourist discomfort due to heat while they are inside closed tourist areas with the use of air conditioning systems or other such appliances. According to the CARBONTOUR (2010) database of the tourist accommodation in Cyprus, 89% of the tourist accommodations have air conditioning systems. However, while tourists are in open space areas, the only measure that the tourism sector can take to protect tourists is to provide advises for staying in shady places etc. Therefore, the adaptive capacity of Cyprus' tourism to heat waves is considered to be **moderate**.

To further enhance adaptive capacity towards this impact, it is recommended to improve provision of climatic information to the tourism sector through cooperation with national meteorological services as well as to further invest in infrastructure/technologies to upgrade facilities to face heat waves (Shoukri and Zachariadis, 2012).

11.4.4. Water availability

11.4.4.1. Assessment of sensitivity and exposure

Sensitivity

According to the Water Policy of Cyprus (WDD, 2011), the water demand from the tourism sector is estimated to be 15% of the domestic water supply or 4% of the total water demand. An assessment study of the Cyprus' water resources and water demand in 2000 indicated that daily water use per tourist in Cyprus is more than double in comparison with the water consumption of local residents. As for the future water demand of the tourism sector, it is estimated that water consumption will amount to 12.3Mm^3 on average during the period 2021-2050 compared to 2011[6] (27% increase), while its share to the total demand from all sectors will remain the same (4%).However, it must be noted that

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[6] For more information on the estimation of future water supply and demand in Cyprus, one may refer to Sections 2.2.2 and 2.2.3 of the Chapter "Water resources" included in the present report

estimations do not take into account the increase in water demand for the irrigation of new golf courses, neither water demand management measures (water saving measures).

It must also be noted that, the tourism sector is already paying higher amounts for the water that consumes, as the water price has increased due to the increase in the cost for its production (construction and operation of desalination plants). However, it is expected that the exploitation of Cyprus' gas reserves will lower the cost of energy supply as Cyprus depended mainly on fuel imports for energy production. Subsequently the cost for the production of desalinated water is expected to decrease.

Considering the above, the sensitivity of tourism to the availability of drinking water is characterized as **high**.

Consumption varies of course depending on the type of lodging and facilities offered such as swimming pools and golf courses. The CARBONTOUR (2010) database of the tourist accommodation in Cyprus shows that 64% of the tourist accommodations have swimming pools. In addition, the upgrading of the tourism product of Cyprus is based inter alia to the development of golf courses which require substantial amounts of water for their irrigation. It is mentioned that 14 golf courses have already been licensed in Cyprus. Their operation is expected to significantly increase water demand from the tourist sector. The irrigation of golf courses is regulated through decisions which enforce restrictions on the water resources to be used. The decisions limit the use of fresh water resources for irrigation and encourage the use of recycled water. In addition, in order to meet the demand for water supply in most cases it is essential to provide for private desalination plants, which will further increase private cost for the provision of water.

Considering the above, the sensitivity of tourism to the availability of water for irrigation and other uses is characterized as **high to very high**.

Exposure

In Cyprus, low amounts of precipitation during the whole year lead to limited freshwater availability and especially during the summer period, when there is no precipitation for the most parts of the island (Figure 11-25) and freshwater reserves are running low. During that period, the exposure of tourism to reduced water availability is more pronounced as water demand from the tourism sector increases steeply due to the fact that tourism season reaches its peak at summer.

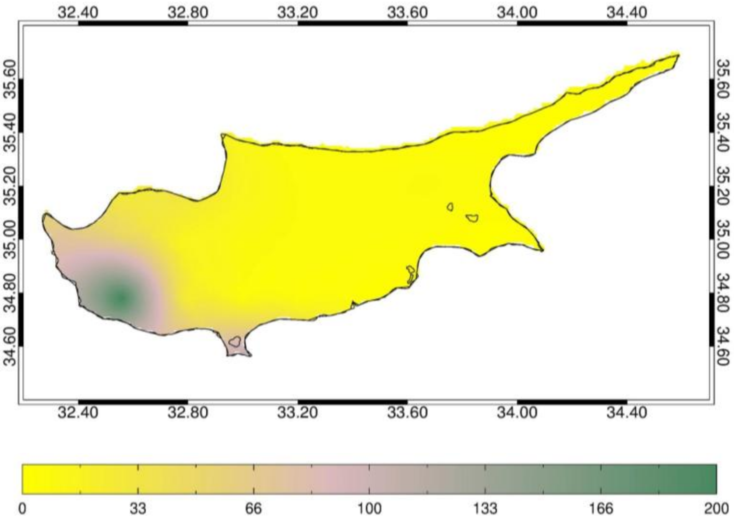

Figure 11-25: Summer total precipitation for the years 1961-1990 (control period)

Droughts which is a common phenomenon in Cyprus especially in summer, are expected to increase in the future (2021-2050) up to 20 days with the exception of the western coastal and higher elevation regions of Cyprus, as well as the area of Ayia Napa (Figure 11-26).

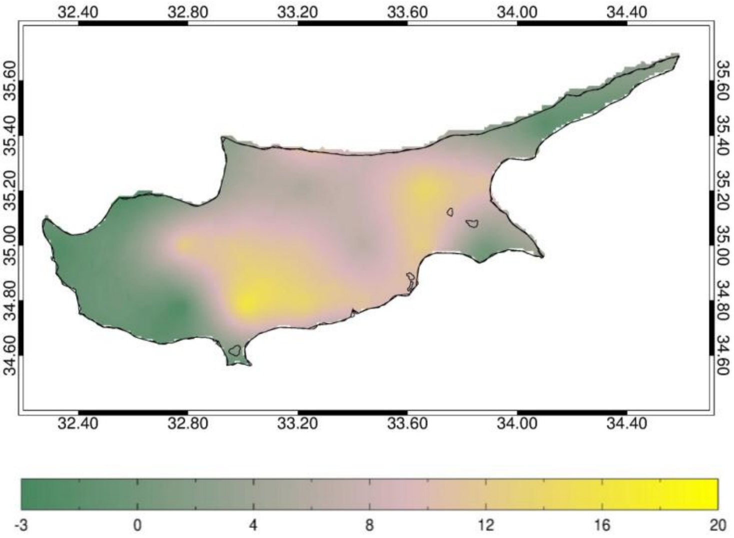

Figure 11-26: Changes in maximum length of dry spell (RR<0.5mm) between the future (2021-2050) and the control period (1961-1990)

The future annual total water availability for the case of Cyprus was estimated by using data regarding the distribution of precipitation (as this was projected by the PRECIS climate model) in relation to evapotranspiration, dam inflow, aquifer recharge and losses to the sea. The results of the analysis showed that the available freshwater resources are expected to decrease by 23% on average in the period 2021-2050 compared to the period 1970-2000.

Considering the above, it can be concluded that the future exposure of Cyprus' tourism to droughts is considered to be **high**, for both drinking water and irrigation water.

11.4.4.2. *Assessment of adaptive capacity*

Decreased rainfall and extended drought periods have led the Government of Cyprus to construct a number of desalination plants to secure safe and continuous drinking water supply. In particular, the tourist areas of Nicosia, Larnaca, Ayia Napa, Limassol and, recently, Pafos are provided with desalinated water while other areas (mainly rural and/or mountain areas) depend solely on freshwater resources (surface water and groundwater).

As far as the future is concerned, desalination capacity (up to 92Mm^3) is expected to fully satisfy future drinking water demand of both the permanent population and tourism which are provided with desalinated water. However, a critical issue focuses on the supply with drinking water of the greater area of Chrysochou at the northwestern part of the island. The area which already presents significant amounts of water consumption, is developing rapidly both with touristic infrastructure and with holiday residences. In addition, a potential direct road connection with Nicosia must be taken into account, as it will lead to further water stress caused by developmental pressures (WDD, 2011).

In addition, as droughts in the recent past have led to water curtailments in drinking water supply, many hotels invested in water saving appliances and practices as well as in water backup systems in order to reinforce their coping ability with such events.

Considering the above, the adaptive capacity of the tourism sector to reduced drinking water availability is characterized as **moderate**.

However, the adaptive capacity for coping with the reduced availability of water for irrigation and other uses is less, limited to the use of additional non-freshwater resources such as the use of recycled water for the irrigation of green spaces (gardens, golf courses) or the use of seawater in swimming pools. In addition, in order to meet the demand for water supply in most cases it is essential to provide for private desalination plants, which further increase private cost for the provision of water.

For these reasons, Cyprus' tourism adaptive capacity to reduced water availability for irrigation and other uses is considered as **limited**.

11.4.5. Storms, waves and floods

11.4.5.1. *Assessment of sensitivity and exposure*

Sensitivity

The coastal tourism infrastructure is especially sensitive to damages from sea floods, waves and storm surges, as such events may significantly reduce the attractiveness of tourist areas and create business interruption costs. Apart from infrastructure, the tourists present in such an event are at risk. As mentioned earlier, tourists are expected to be at greater risk than residents because they are unfamiliar with the region, the potential hazards and the self-protective behaviour required (Burby and Wagner, 1996).

The percent of tourism infrastructure in Cyprus that is located at the coastal areas of the island is 95%. Therefore, it is considered that Cyprus' tourism has **high to very high** sensitivity to storms, waves and floods.

Exposure

For the assessment of the exposure of Cyprus' tourism to storms, waves and floods in the future, a number of climatic factors, such as wind and wave characteristics (Sterr et al., 2003), storminess, heavy rainfall as well as other factors induced by climate change such as sea level rise can be used as indicators.

While changes in storminess may contribute to changes in extreme coastal high water levels, the limited geographical coverage of studies to date and the uncertainties associated with overall storminess changes mean that a general assessment of the effects of storminess changes on storm surge is not possible at this time (IPCC, 2012). Results from embedded high-resolution models and global models show a likely increase of peak wind intensities and notably, increased near-storm precipitation in future tropical cyclones. Most recent published modelling studies investigating tropical storm frequency, simulate a decrease in the overall number of storms, though there is less confidence in these projections and in the projected decrease of relatively weak storms in most basins, with an increase in the numbers of the most intense tropical cyclones. Model projections show fewer mid-latitude storms averaged over each hemisphere, associated with the poleward shift of the storm tracks that is particularly notable in the southern hemisphere, with lower central pressures for these poleward-shifted storms. The increased wind speeds result in more extreme wave heights in those regions (Meehl et al., 2007). However, according to the projections of the PRECIS climate model, the mean wind speed greater than 5 m/s in Cyprus during the future period 2021-2050 is not expected to present substantial changes, on the contrary, it presents minor decreases in general. With regard to the current exposure to high wind speeds of the coastal tourist areas, PRECIS shows that in western (Pafos, Chrysochou) and southeastern (Larnaca, Ayia Napa) areas the number of days with mean wind speed > 5 m/s is approximately 80 while southern (Limassol) regions present about 40-50 days with mean wind speed > 5 m/s. Figure 11-27 depicts PRECIS projections of the changes in the number of days with mean wind speed greater than 5 m/s. As it is shown, in western, and southeastern coastal areas a decrease of about 12 days is anticipated. Also southern areas present a slight decrease of about 5 days. Consequently, it is expected that the future exposure of coastal tourist areas to storm surges is limited. In general, the tourist areas mostly exposed to large waves are those located on the west coast of the island (Demetropoulos, 2002).

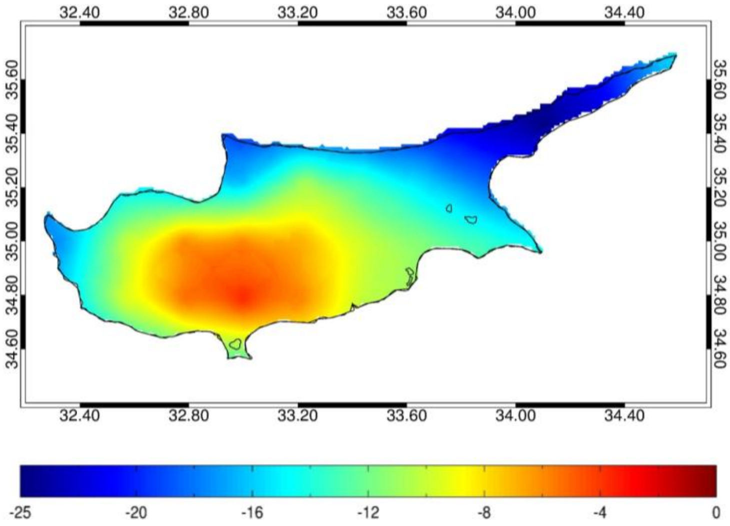

Figure 11-27: Changes in the number of days with mean wind speed > 5m/s between the future (2021-2050) and the control period (1961-1990)

As for the exposure of coastal tourism to floods, the climate projection model used for the case of Cyprus does not provide such estimates directly. There is an indicator referring to the annual maximum total precipitation over one day indicating heavy rainfall, which could indirectly be associated with flood risk. However, the PRECIS model showed that there will be no significant changes to this indicator in the future period (2021-2050). In particular, PRECIS projections (Figure 11-28) show that a slight increase of about 2-5 mm is anticipated in western, inland and mountain regions. Additionally, southern and southeastern areas present an increase of about 1 mm in annual max total rainfall over 1 day. It must be noted though that this indicator alone is not sufficient for estimating flood risk since other factors play an important role as well.

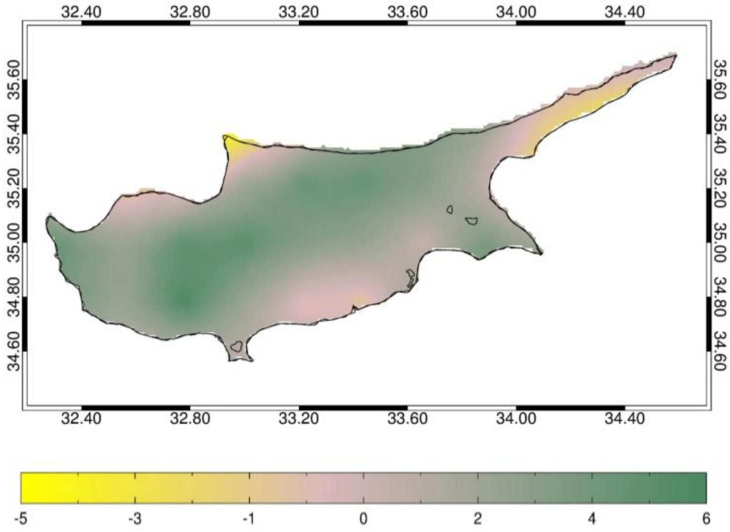

Figure 11-28: Changes in annual maximum total precipitation over 1 day between the future (2021-2050) and the control period (1961-1990)

Finally, the Sea Level Rise which is also considered to play an important role in the increase of floods, for the case of Cyprus, is expected to be moderate (EC, 2009). Furthermore it must be added that, based on archaeological data, Cyprus appears to be experiencing long-term uplift of between 0 and 1 mm per year. This uplift is expected to counteract sea-level rise and given a global rise in sea level of 0.5m by 2100, relative sea-level rise in Cyprus will be in the range 0.4-0.5m (Nicholls and Hoozemans, 1996). The sea level changes in Cyprus as observed during the period between 1993 and 2000 show an increase of 5-10 mm/year (Figure 11-29).

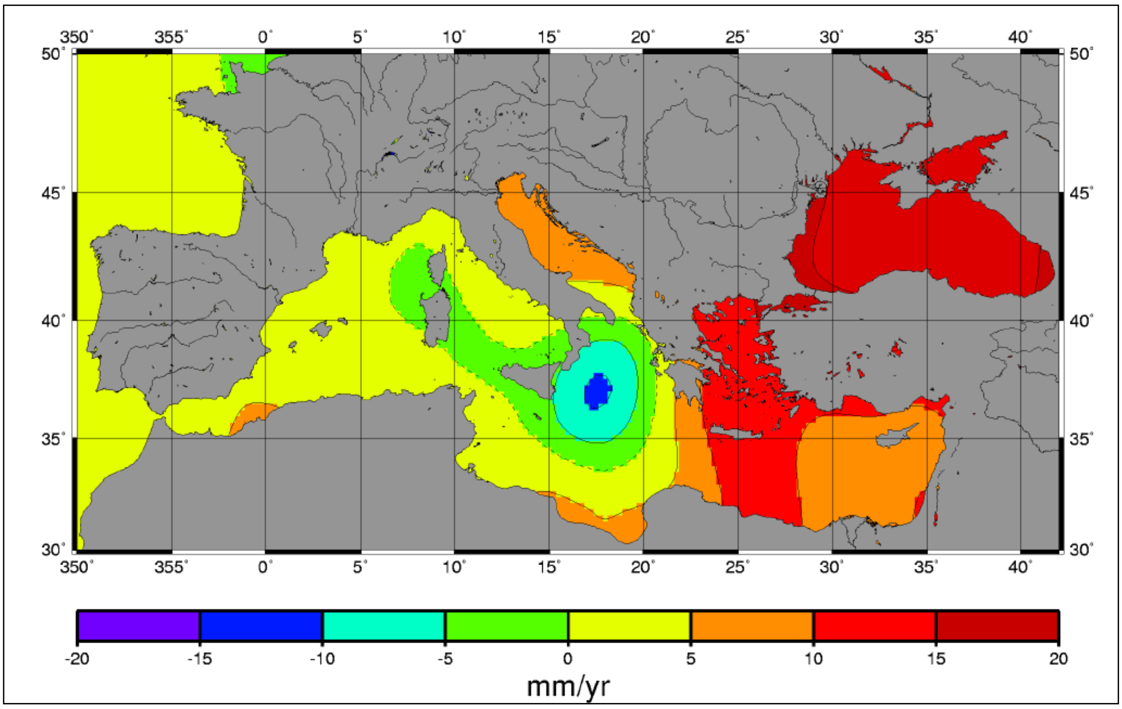

Figure 11-29: Mediterranean basin sea level changes between 1993 and 2000

Source: Ministry of Environment of Lebanon, 2011

Considering the above, the future exposure of the tourism sector of Cyprus to storms, waves and floods characterized as **limited to moderate**.

11.4.5.2. Assessment of adaptive capacity

The measures that have been undertaken in Cyprus and which are considered that are also contributing to the protection of coastal infrastructure are associated with the construction of coastal defense works. Such works have begun to be constructed in Cyprus since 1980, either by Government competent services or by tourist accommodation owners. In total, approximately 80 breakwaters, 15 groynes (mostly illegal) and 4 coastal road revetments have been built in several coasts of Cyprus up to now[7]. It must be noted that wherever these structures have been built, the coastal infrastructure has been significantly protected from storms and floods.

Given the limited estimated exposure of Cyprus' tourism to storms and floods, the future adaptive capacity, as this is defined by the relative measures that have been implemented so far, is considered satisfying thus it is characterized as **moderate to high**.

Following, additional recommended adaptation measures (Shoukri and Zachariadis, 2012) that are considered to further enhance adaptive capacity towards this impact are presented indicatively. Nevertheless, their assessment and final selection for implementation will be made through the use of the Multicriteria Analysis (MCA) tool which will be developed and implemented in the framework of Actions 4 and 5 of the CYPADAPT project.

- Implementation of additional measures to counteract possible extreme weather events and flooding
- Insurance cover (or alternative schemes) for the recovery of infrastructural and other damage
- Reassessment of the design of breakwaters in relation to the intensity and height of storm waves.

11.4.6. Biodiversity attractions

11.4.6.1. Assessment of sensitivity and exposure

Sensitivity

For the assessment of tourism sensitivity to losses in biodiversity, the percentage of tourism which visits Cyprus for its biodiversity as well as the NATURA 2000 areas in Cyprus may be used as indicators. In absence of relative data, it is assumed that the percentage of nature based tourism in Cyprus is very small compared to the share of beach tourism, which constitutes 90% of total tourism. Furthermore, as it can be seen in the following figure which depicts the distribution of NATURA areas in Cyprus, potential losses in biodiversity will affect the whole island, especially the western coastal and mountain part of Cyprus around Troodos. However, the share of tourists visiting the Hill resorts which are located at

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[7] Unpublished information provided by the Department of Public Works (person contacted: Mrs Stavrini Theodosiou)

the Troodos mountain is limited (0.2%) and comprise mainly of local tourists (see also Section 11.2).

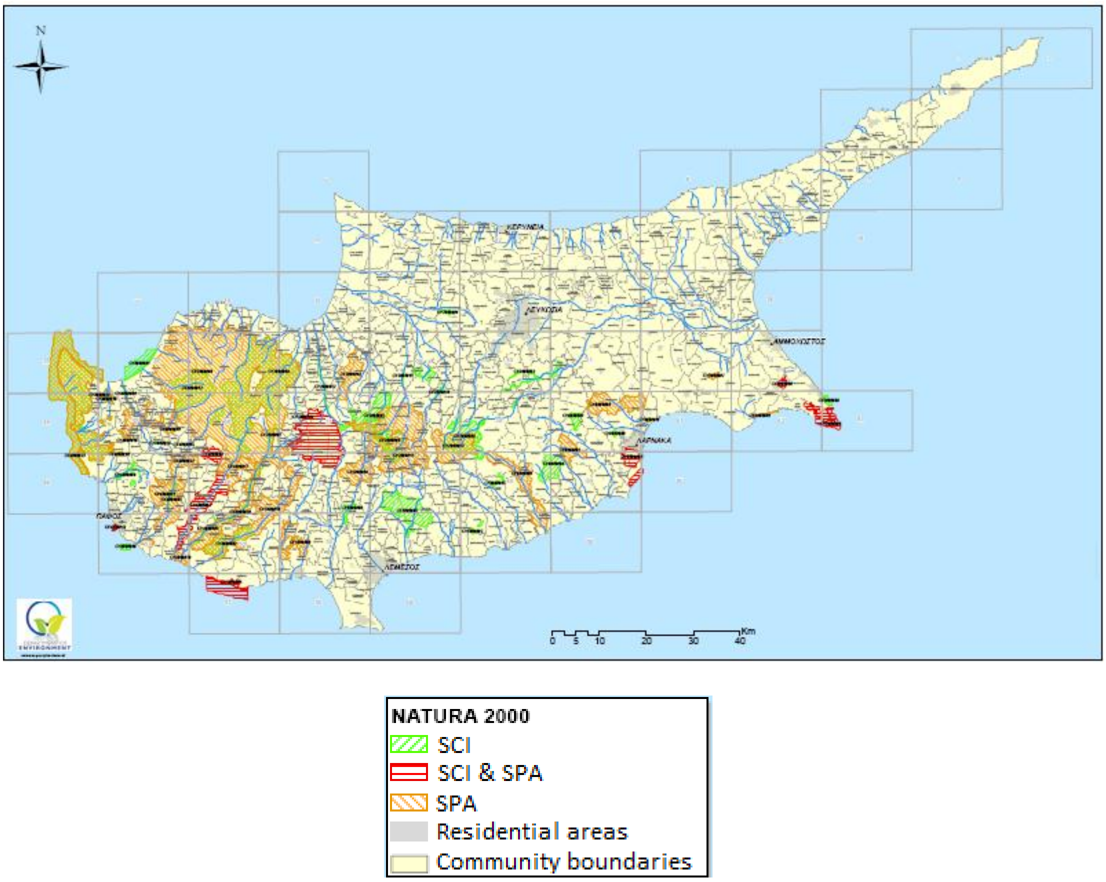

Figure 11-30: NATURA 2000 areas in Cyprus

Source: DoE

Taking into consideration the above, the tourism sector is expected to present **limited** sensitivity to biodiversity losses in the future.

Exposure

Reduced soil moisture, increased sensitivity in desertification, more frequent and larger forest fires and increased sea surface temperatures lead to terrestrial and marine biodiversity loss and subsequently to loss of natural attractions for tourism.

For the assessment of the exposure of terrestrial biodiversity to biodiversity losses, the future climate changes in Cyprus that are considered to have negative impact on biodiversity attractions are presented next.

Reduced precipitation and increased drought periods are expected to reduce soil moisture. Regarding future precipitation changes, all northern coasts are expected to receive less annual total precipitation in the future, than that estimated for the recent past 1961-1990 (Figure 11-31). In all other parts of Cyprus, the annual total precipitation appears to have minor decreases or no changes at all. The only region with an increase in total annual precipitation, minor though (up to 5mm), is the area around Orites Forest, east of Paphos.

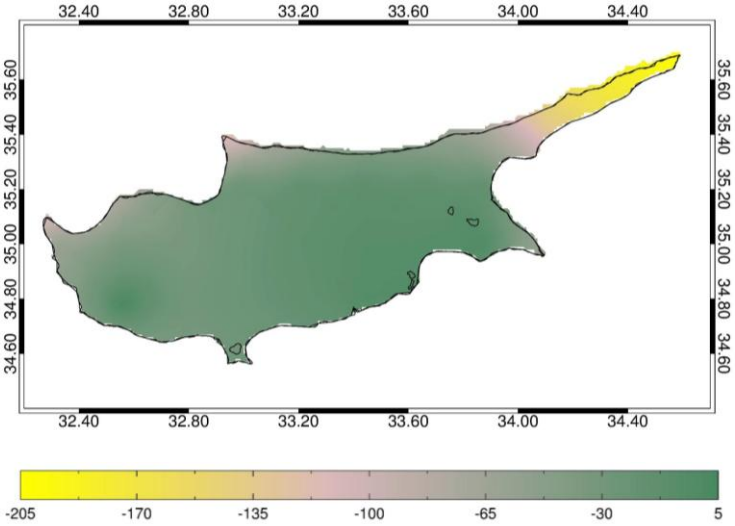

Figure 11-31: Changes in annual total precipitation between the future (2021-2050) and the control period (1961-1990)

As for the changes in seasonal precipitation, a significant precipitation decrease during winter and autumn is expected in Ayia Napa, and in north and west coasts, such as Ayia Irini Forest and Akamas peninsula National Park. However, a slight increase of autumn total precipitation, not exceeding 10mm, is expected in the near future regarding the areas east from Paphos (Orites Forest) and west from Ayia Napa. In spring the strongest drying (10-15mm) is projected at the northern coasts of Cyprus, particularly in Ayia Irini Forest and Karpasia peninsula. On the other hand, southern coasts and especially the area around Limassol Salt Lake may become wetter in spring during the period 2021-2050, with a precipitation increase of up to 15mm. During summer, continental lowlands, higher elevation areas and parts of the northern coasts of Cyprus will receive precipitation decreases, not more than 5mm. On the contrary, a slight precipitation increase occurs in the southwestern areas, reaching 10mm in Limassol Salt Lake and Orites Forest (southwest from Troodos mountains).

As far as the length of dry spells in the future (2021-2050), it is anticipated that the western coastal and higher elevation regions of Cyprus, as well as the area of Ayia Napa, will have slight decreases or no changes in the maximum length of dry spell. On the other hand, the central part of Cyprus will face an increase in the maximum length of dry spell. In particular, the increase of this index will be about 15 days/year in the continental areas near Nicosia and Larnaca and approximately 20 days/year in the eastern part of Troodos (north from Limassol).

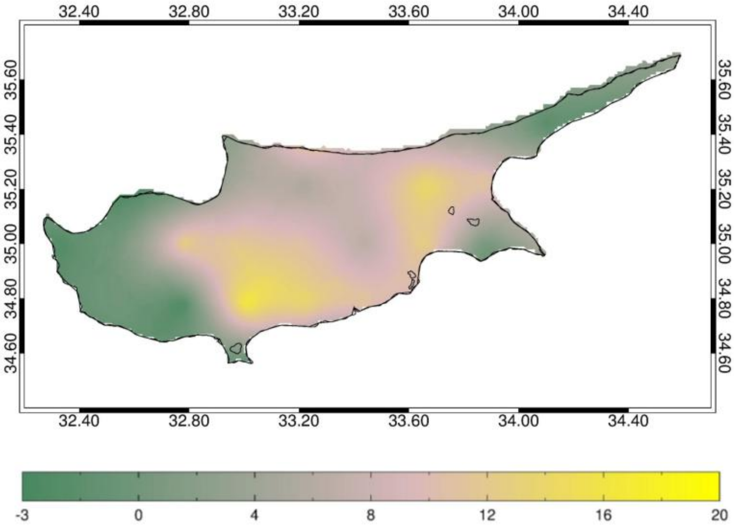

Figure 11-32: Changes in maximum length of dry spell (RR<0.5mm) between the future (2021-2050) and the control period (1961-1990)

Fires have a destructive effect on biodiversity. To assess fire risk, the Fire Weather Index (FWI) was used. It is obvious that the FWI shows the highest values during summer and more specifically during the months July and August. According to PRECIS, the FWI reaches extremely high values of about 50 (extreme high risk) in forested areas during July in the control period (1960-1990). Districts that present these excessive values are Limassol, Nicosia and Larnaca where FWI varies from 40 to 50. In Paphos District, FWI presents lower values of about 10 in Akamas peninsula, where National Park of Akamas is located, and 20-30 in Paphos Forest in the northwestern part of Troodos Mountain. As far as PRECIS near future projections are concerned, a small increase of FWI is estimated all over the Troodos Mountain of about 1-2 in low altitudes and 3-5 in high altitudes (Figure 11-33). August FWI reaches extremely high values, mainly in the forested areas of Cyprus, of about 50 in Troodos Mountain parts of Limassol and Nicosia Districts. Lower values are evident in Larnaca forested areas (Stavrovouni and Rizoelia Forests) of around 40 and even more low values shows Paphos District where FWI varies from 10 in Akamas peninsula to 30 in Paphos Forest. Regarding future projections, PRECIS shows a small increase in FWI of about 2 in forested areas of Limassol, Nicosia and Larnaca Districts. Also, no increase is projected for Paphos District (Figure 11-34).

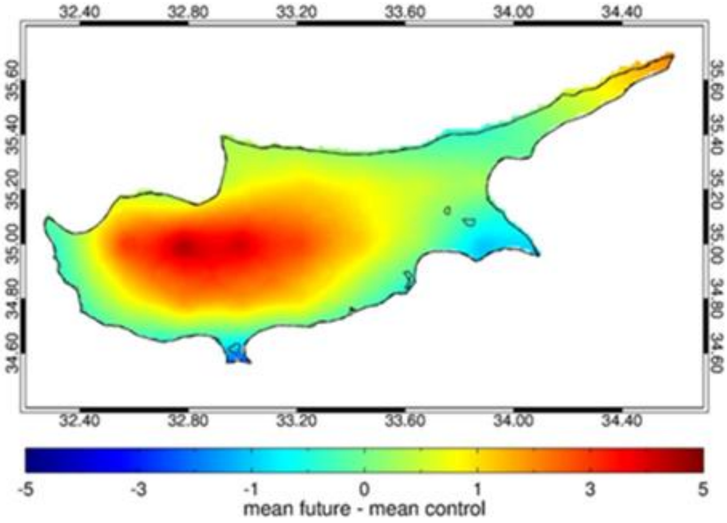

Figure 11-33: Changes in July average FWI in the near future (Future – Control period)

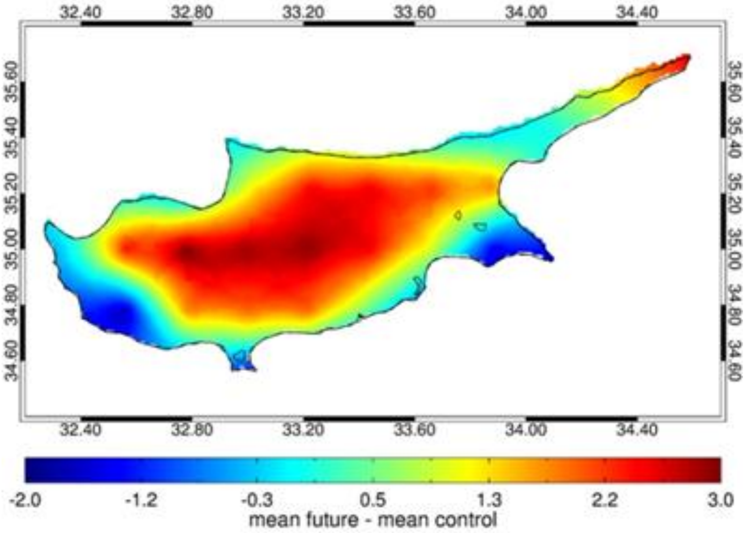

Figure 11-34: Changes in August average FWI in the near future (Future – Control period)

However, fire risk is not confined during the summer period. Due to the increase in temperature and the decrease in precipitation, which may intensify in the near future, there is elevated fire risk in late spring and early autumn. The April (spring) average FWI and October (autumn) average FWI show that in the present-day climate FWI reaches 20 (high risk) in the forested areas of Larnaca District, 10-15 in Troodos Mountain and 7 in forested areas of Paphos District. As far as future changes are concerned, a small increase of about 2 is projected for Troodos Mountain as well as for forested areas of Larnaca District. Paphos District shows no increase (Figure 11-35). The autumn average FWI indicates that Larnaca and Nicosia areas present a high fire risk with FWI varying from 17 to 20. Additionally, the southern parts of Troodos Mountain (Limassol District) as well, present a high fire risk with FWI values varying from 20 to 22. As far as future changes are concerned, PRECIS projections show a small FWI increase of about 1-2 in Troodos Mountain and no increase in Larnaca and Paphos District (Figure 11-36).

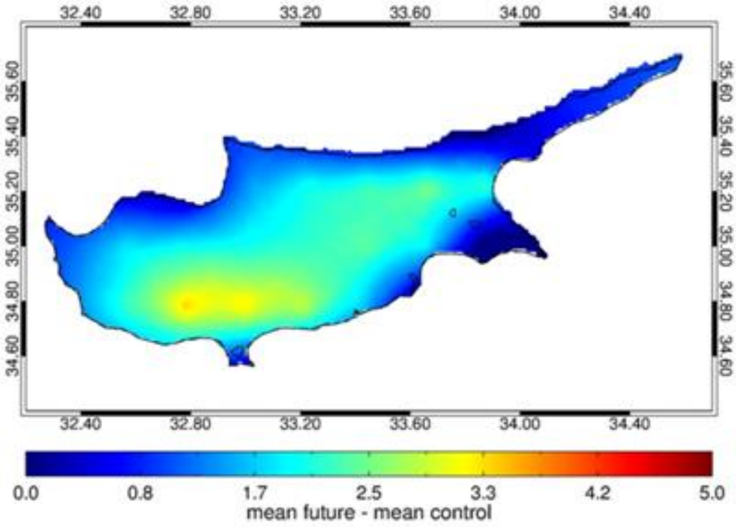

Figure 11-35: Changes in April average FWI in the near future (Future – Control period)

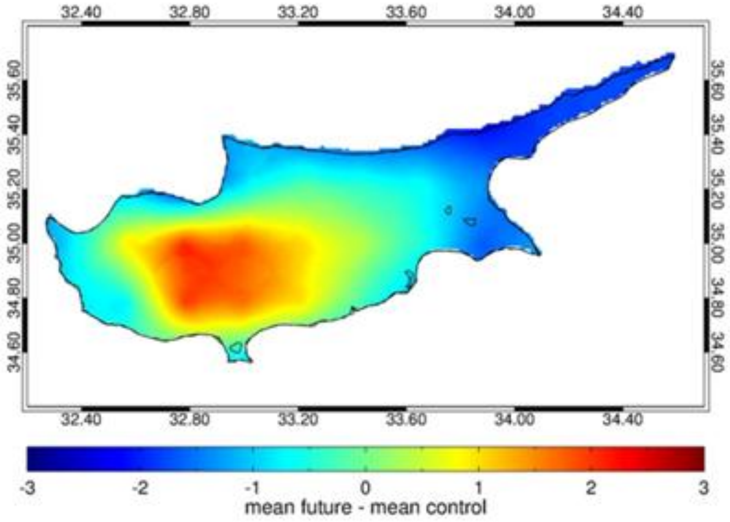

Figure 11-36: Changes in October average FWI in the near future (Future – Control period)

Regarding marine biodiversity, it is expected that Sea Surface Temperature will rise as air temperature rises, with a slower rate though. Satellite and in situ-derived data indicate a strong eastward increasing sea surface warming trend in the Mediterranean basin from the early 1990s onwards. The satellite-derived mean annual warming rate over the period 1985–2008 is about 0.042°C year^{-1} for the eastern sub-basin where the island of Cyprus is located (Skliris et al., 2011).

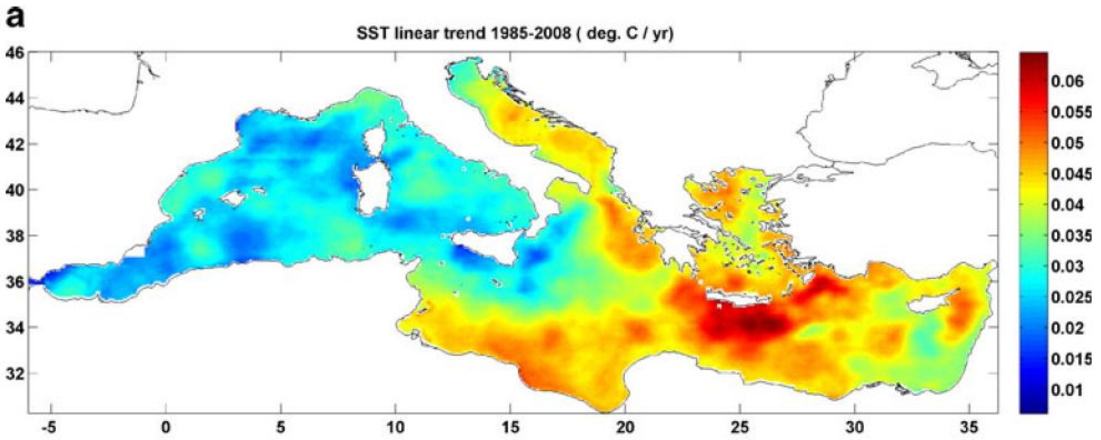

Figure 11-37: Horizontal distribution of satellite-derived SST annual linear trends (°C/year) over 1985–2008

Source: Skliris et al., 2011

However, coral reefs that are more sensitive to high temperatures are not present in the Levantine basin.

As mentioned also in Section 5, there are not sufficient data for estimating the degree of biodiversity loss (magnitude) at the present in Cyprus.

Considering the above, the future exposure of Cyprus' tourism sector to biodiversity loss is considered to be **limited to moderate** exposure.

11.4.6.2. Assessment of adaptive capacity

The tourism sector (tourism accommodation owners, managers as well as the CTO) may implement several adaptation measures in order to increase its adaptive capacity to biodiversity loss, such as

(i) to promote the application of integrated tourism Carrying Capacity Assessment (CCA) techniques (considering physical, economic, environmental, socio-cultural and managerial aspects) in protected areas as a tool for tourism development planning,

(ii) to promote the implementation of Environmental Impact Assessment studies in environmentally sensitive areas, as well as

(iii) to comply with the national laws for the protection of foreshore zone and of the protected nature areas (SPA, SCI, national forest parks, marine protected areas, fishing shelters).

The CTO has promoted the application of Carrying Capacity Assessments [8] (CCA) for the Hill resorts of Cyprus and has integrated its results into the Regional Tourism Strategy for the Hill Resorts. Another carrying capacity assessment has been made for the case of Larnaca, which constituted a pilot study under the framework of the Project CAMP-Cyprus promoted within the wider activities of the Mediterranean Action Plan of the United Nations Environmental Programme (MAP-UNEP). However, CCAs should be applied for all the tourism centers of Cyprus and their results should be binding for the tourism sector.

Although there is a variety of measures and tools for the protection of nature-based tourist attractions, they are not implemented at the degree required due to conflicting interests for the development of tourist attractions.

Thus, the future adaptive capacity of Cyprus' tourism to biodiversity loss is estimated to be **limited to moderate**.

11.4.7. Coastal erosion

11.4.7.1. Assessment of sensitivity and exposure

Sensitivity

Coastal tourism is sensitive to the erosion of coasts as the majority of tourist arrivals in the coastal cities of Cyprus refers to beach tourism. Reduced aesthetics of coasts due to erosion have a negative impact on tourism preferences. In order to assess the sensitivity of the tourism sector in Cyprus to coastal erosion, the concentration of tourism infrastructure and resources to the coastal zone as well as the dependence of Cyprus' tourism on coastal tourism were used as indicators.

Approximately 95% of all licensed tourism hotel accommodation capacity in Cyprus is located at the coast. Of all coastal tourism accommodation capacity, 55% is concentrated in the suburban tourism centers around the cities of Limassol, Larnaca and Paphos and about 40% is located in the rapidly growing coastal village communities that have grown into tourism centers. Detailed data regarding the land use planning zones along the coast per district are not available at the moment. It can be estimated however, that islandwide the extent of tourist zones is approximately 103 km of the total coastal length of the Republic of Cyprus (296 km) (Coccossis et al., 2008).

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[8] The maximum number of people that may visit a tourist destination at the same time, without causing destruction of the physical, economic, socio-cultural environment and an unacceptable decrease in the quality of visitors' satisfaction (World Tourism Organization)

Considering the above, the sensitivity of Cyprus' tourism to coastal erosion is estimated to be **high to very high**.

Exposure

A sea level rise is expected to intensify the phenomenon of erosion in coastal areas. However, Cyprus appears to be experiencing long-term uplift of between 0 and 1 mm year. This uplift is expected to counteract global sea-level rise and given a global rise in sea level of 0.5 m by 2100, relative sea-level rise in Cyprus will be in the range 0.4-0.5 m (Nicholls and Hoozemans, 1996). Low lying areas, such as Larnaca, may be particularly vulnerable to a sea level rise.

In general, the tourist areas mostly exposed to large waves are those located on the west coast of the island (Demetropoulos, 2002). Increased wind speeds result in more extreme wave intensity and coastal erosion. However, according to the projections of the PRECIS climate model, the mean wind speed greater than 5 m/s in Cyprus during the future period 2021-2050 is not expected to present substantial changes, on the contrary, it presents minor decreases in general. With regard to the current exposure to high wind speeds of the coastal tourist areas, PRECIS shows that in western (Pafos, Chrysochou) and southeastern (Larnaca, Ayia Napa) areas the number of days with mean wind speed > 5 m/s is approximately 80 while southern (Limassol) regions present about 40-50 days with mean wind speed > 5 m/s. Figure 11-27 depicts PRECIS projections of the changes in the number of days with mean wind speed greater than 5 m/s. As it is shown, in western, and southeastern coastal areas a decrease of about 12 days is anticipated. Also southern areas present a slight decrease of about 5 days.

As for the exposure of coasts to intense precipitation which is reported to intensify the phenomenon of erosion, the annual maximum total precipitation over one day was used as indicator. However, the PRECIS model showed that there will be no significant changes to this indicator in the future period (2021-2050). In particular, PRECIS projections (Figure 11-28) show that a slight increase of about 2-4 mm is anticipated in western coastal regions while southern and southeastern areas present an even smaller increase of about 1 mm in annual max total rainfall over 1 day.

For the time being, it is estimated that approximately 38% of the coastal zone of Cyprus has been affected by erosion (Research Promotion Foundation, 2006), but not necessarily the tourist areas.

Therefore, Cyprus' tourism exposure to coastal erosion in the future is considered to be **moderate**.

11.4.7.2. Assessment of adaptive capacity

Regarding coastal tourism, the protection of resorts from sea-level rise may be feasible by constructing barriers or by moving tourism infrastructure further back from the coast (Pinnegar et al., 2006).

To deal with the issue of coastal erosion, the Government of Cyprus assigned in 1992 the implementation of a project entitled 'Coastal Protection Management for Cyprus' (1993-1996). The project was carried out by the Coastal Section of the Department of Public Works (DPW) of the Ministry of Communications and Works, and Delft Hydraulics with the objective to identify proper protection methods and improve the quality of beaches without causing serious impacts on the environment. The entire coastline of the Republic of Cyprus was divided in twelve 'sections' or coastal areas based on their morphology. Master Plans, as well as conceptual and detailed designs, were developed for three of the twelve coastal areas (Limassol, Larnaca and Paphos South).

In 1998 the Cyprus government started with the implementation of these Master Plans. Another project also initiated in 2000, for the protection of three (3) new coastal areas in Paphos (Kato Pyrgos Tillirias, Crysochou Bay and Zygi-Kiti). The following years, Cyprus has prepared and implemented a number of additional Master Plans and intends to do the same for the rest of the coastal areas that is deemed necessary (Coccossis et al, 2008).

However, many times tourism activities hinder the protection from coastal erosion either by building illegal breakwaters which may have adverse effects to the coast, or by building illegally on the coast.

Therefore, it is considered that Cyprus' tourism will have **moderate** adaptive capacity to coastal erosion in the future.

However, to further enhance adaptive capacity it is recommended that the design of breakwaters should be reassessed in order to take into account the intensity and height of storm waves.

11.4.8. Assessment of overall future vulnerability

The principal aim of this chapter is to identify the key vulnerabilities of tourism to future climate changes, as well as to assess the magnitude of these vulnerabilities. However, it must be noted that, as there were no sufficient data to evaluate all indicators, further research is required.

In order to quantify the future vulnerability potential of the tourism sector against a climate change impact the values of sensitivity, exposure, adaptive capacity and vulnerability are quantified as follows:

Degree of sensitivity, exposure & adaptive capacity		Degree of vulnerability		Legend
None	0	None	V≤0	⬜
Limited	1	Limited	0<V≤1	🟩
Limited to Moderate	2	Limited to Moderate	1<V≤2	🟨
Moderate	3	Moderate	2<V≤3	🟨
Moderate to High	4	Moderate to High	3<V≤4	🟧
High	5	High	4<V≤5	🟧
High to Very high	6	High to Very high	5<V≤6	🟥
Very high	7	Very high	6<V≤7	🟥
Not evaluated	-	Not evaluated	-	▨

Since vulnerability is defined by the following formula:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity * Exposure$$

“Impacts” and “Adaptive capacity” should be evaluated on the same scale (1-7). For this to be achieved, the square root of “Sensitivity x Exposure” is used. The results of the future vulnerability assessment for the tourism sector in Cyprus are summarized in Table 11-16.

Table 11-16: Overall future vulnerability assessment of the tourism sector in Cyprus to climate changes

Impact		Sensitivity	Exposure	Adaptive Capacity	Vulnerability
Warmer summers		High to Very high (6)	None (0)	Moderate (3)	None (-3)
Warmer winters		Moderate (3)	Limited (1)	Moderate (3)	None (-1.3)
Heat waves		High (5)	High (5)	Moderate (3)	Limited to Moderate (2)
Water availability	**For drinking water supply**	High (5)	High (5)	Moderate (3)	Limited to Moderate (2)
	For irrigation and other uses	High to Very High (6)	High (5)	Limited (1)	High (4.5)
Storms, waves and floods		High to Very high (6)	Limited to Moderate (2)	Moderate to High (4)	Limited (0.5)
Biodiversity attractions		Limited (1)	Limited to Moderate (2)	Limited to Moderate (2)	None (-0.6)
Coastal erosion		High to Very high (6)	Moderate (3)	Moderate (3)	Limited to Moderate (1.2)

As it can be seen from the table above, the first vulnerability priority of the sector to climate changes is the decrease in water availability for meeting the water demand for irrigation and other uses, considering that the available water resources are significantly under pressure. In addition further development and upgrading tourism industry (e.g. golf courses) is based on water availability. But the adaptive capacity for meeting the demand for irrigation water from non-freshwater resources is limited to the use of recycled water and the private production of desalinated water. The second place is occupied by the impact of drinking water availability and heat waves. Drinking water availability especially during summer when the majority of tourists visits Cyprus is usually low. However, the vulnerability towards this impact is reduced due to the adaptive capacity of Cyprus for increasing drinking water supply mainly with the use of desalination plants. Heat waves are a common phenomenon in Cyprus during summer when the majority of tourists visits Cyprus. However, the impact on tourism is not so intense considering that the most sensitive population groups to heat waves (i.e. the elderly people), prefer to take their holidays during the cooler seasons of the year. The adaptive capacity of the sector towards this impact is restricted mainly to the provision of a cool indoor environment for relieving heat discomfort. The third vulnerability of Cyprus is related to the impact of coastal erosion on tourism since the majority of tourism infrastructure is located at the coasts. Nevertheless, the coastal protection works which have taken place have alleviated the problem in a great extent. Finally, storms waves and floods constitute the last vulnerability priority for the tourism of Cyprus regarding climate changes. However, due to the fact that sea floods, which constitute the major threat for tourism infrastructure, are not so common in Cyprus, the vulnerability of this impact was considered low. Warmer summers and warmer winters are considered to have a positive impact on beach tourism and sightseeing tourism respectively.

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12 INFRASTRUCTURE

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Abbreviations and Acronyms

FWI	Fire Weather Index
ICT	Information and Communications Techology
IPCC	Intergonmental Panel on Climate Change
MCA	Multi Criteria Analysis
PRECIS	Providing Regional Climates for Impact Studies
RCM	Regional Climate Change
SUDS	Sustainable Urban Drainage Systems
SLR	Sea Level Rise
UWDS	Uncontrolled Waste Disposal Sites

12.1 Climate change and infrastructure

Cyprus is an island situated in the north-eastern part of the Mediterranean Sea. Administratively, Cyprus is divided into the following six (6) districts: (a) Nicosia (capital), (b) Limassol, (c) Larnaca, (d) Paphos, (e) Famagusta and (f) Kyrenia (Constantinides, 2002).

The island has a total of 772 km of shoreline, of which: (a) 404 km in the occupied zone; (b)72 km within the British Military Bases; and (c) 296 km under Government control. The critical infrastructure of Cyprus has been developed near the coastal area, except for Nicosia which is located near the center of the island

In general, the infrastructures in Cyprus are not considered very vulnerable to climate changes. Impacts of climate change on Cyprus infrastructure arise mainly from decreased rainfall and increased temperature, droughts, fluctuations in intense precipitation events, sea level rise, increased atmospheric CO_2 and changes in fire regimes.

The impact, vulnerability and adaptive measures for the infrastructure sector in Cyprus regarding climatic changes was assessed in Deliverable 1.2. The main vulnerability priority of the sector to climate changes for the current situation has been related to the damages caused by urban floods. However, it must be noticed that specific measures have been undertaken in order to reduce the severity of this impact (drainage works, SUDS etc.). Vulnerability priority followed was related to the damages to infrastructure caused by sea floods. Considering that a great number of infrastructures important to Cyprus economy is located in the coastal areas of the island and that Cyprus has not experienced any severe floods from the sea in the past, the vulnerability towards this impact is considered limited. The vulnerability of infrastructure systems to landslide could not be evaluated due to limited availability of data.

Future climate change impact, vulnerability and adaptation measures in the sector of infrastructure will be reassessed for the case of Cyprus, in the framework of this study, in order for the future vulnerability potential of infrastructure against climatic change impact to be quantified. Future vulnerability priorities for the infrastructure will be identified in order appropriate adaptation measures to be implemented.

Each climatic parameter (temperature, precipitation, and extreme events which include dry spell, flooding, heavy rain and wind) is analyzed for the future situation with the use of the PRECIS regional climate model through comparison between a control period (1961–1990) and a future period (2021–2050). Regional Climate Models of the ENSEMBLES project have also been used. The results of models were used as an ensemble mean for testing and comparing the respective results of PRECIS. Detailed information is available in Deliverable 3.2 while the main model used in this report is the PRECIS (Providing Regional Climates for Impact Studies) regional climate model. The reason is that while, in the other simulations models, Cyprus is placed in the south-eastern part of the domain in PRECIS simulations, Cyprus lies at the center of the study domain. The future period 2021-2050 has been chosen specifically for the needs of stakeholders and policy makers to assist their planning in the near future, instead of the end of the twenty-first century as frequently used in other climate impact studies.

12.2 Baseline situation

According to the Intergonmental Panel on Climate Change (IPCC), the infrastructure is defined as 'the basic equipment, utilities, productive enterprises, installations and services essential for the development, operation and growth of a city or nation'.

In infrastructure the following are involved:

- Utility services:
    - Water supply;
    - Energy supply (power plant and electricity networks);
    - Wastewater and waste collection, treatment and disposal
- Transport;
- Information and Communications Techology (ICT) infrastructure;
- Industry; and
- Buildings (residential and tourist accommodation units).

The main impacts on the infrastructure sector include: (i) material damages to infrastructure, possibly linked with extreme events and floodings, (ii) disturbances in normal community function such as interruption and obstruction of passenger or freight transport, (iii) human safety. Following an outline of the major infrastructure in Cyprus that could be affected from climatic changes is presented.

12.2.1 Power plants and electricity network

In Cyprus, the power production is characterized by aspects such as thermal power plants and renewable power plants (photovoltaic systems, wind farms and bio-power plants) and ellipsis of hydropower production and nuclear power production.

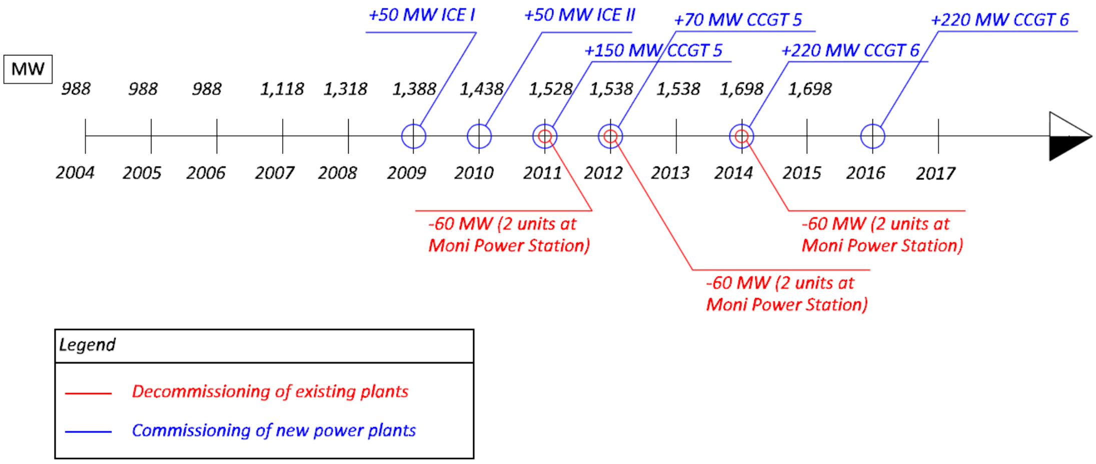
To this end the main energy infrastructure comprises (a) thermal power plants producing electricity and (b) electrical lines for the transmission and distribution of electricity. A small fraction of electricity is produced by renewable energy. The total amount of electrical energy is produced by oil fired power stations (with a small contribution of renewable energy production). The oil is imported as there are no indigenous energy resources. Cyprus is obliged to keep oil strategic stocks for 90 days consumption.

12.2.1.1 Thermal power plants

Three main power stations provide the electrical requirements of the island, namely: Moni power station; Vasilikos power station; and Dekelias power station. All free station are situated within the coastal zone with their discharging infrastructure situated into the sea. Analytical description of these stations can be found in Chapter 13 of Deliverable 1.2.

12.2.1.2 Decomissioning of existing power units/ commissioning of new gas-fired plants

In Figure 12-1 the upcoming changes in the energy infrastructure are described. In specific, the decommissioning of existing power plants is marked with red, while the commissioning of new (notably gas-fired) plants remain within the coastal zone and is marked with blue.



Source: Own production (NTUA working team)

Figure 12-1: Installation of new power plants and decommissioning of existing units until 2017.

12.2.1.3 Electrical grid

The network connects the power stations of the main producer of the island (Electricity Authority of Cyprus) with the load centers and finally to the end-consumers **Figure 12-2**. The electrical grid consists of the transmission (high and medium voltage) network and the distribution (low voltage) network. Both of the networks consist of overhead and underground electrical lines as dscribed in **Figure 12-2**. The network connects may be disposed to climatic change.

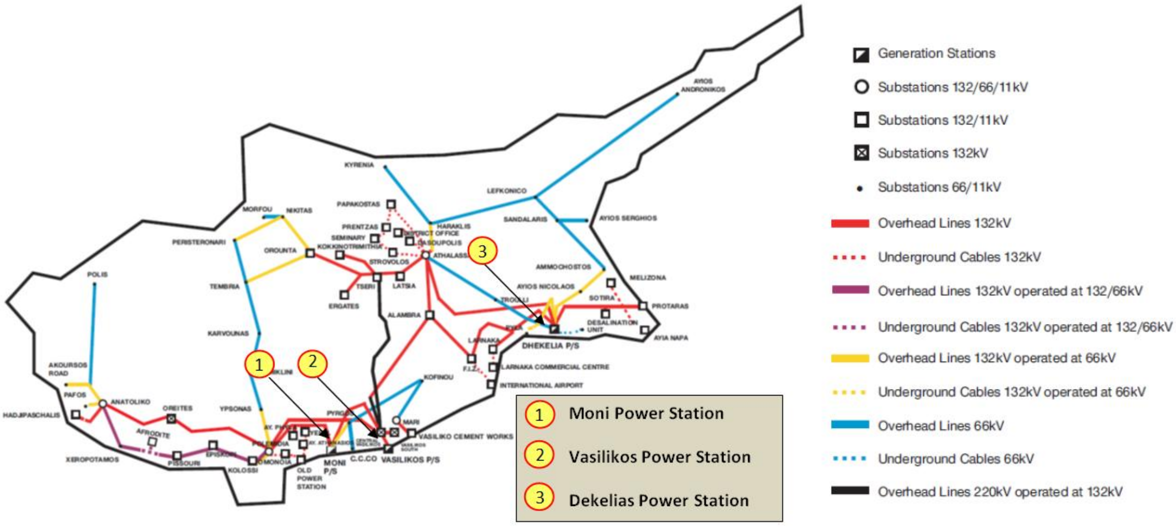


Figure 12-2: Power stations and electrical grid in Cyprus

Source: EAC, 2010

12.2.2 Water supply infrastructure

In Cyprus, the water demand is balanced by the following water sources:

- Water reservoirs (dams): more of 100 dams have been constructed until now with a total capacity of 327.5 million cubic meters (WDD, 2009). The surface water coming from the dams undergoes treatment in water treatment plants before consumption from the end-users;
- Boreholes (pumping groundwater);
- Desalination plants (252,000 m^3/d or 92 Mm^3 in 2012);
- Recycled water, which originates from the treatment of waste-water treatment plants which provides recycling water (there are off stream reservoirs for the storage of surface and recycling water).
- The water conveyance infrastructure which is consisted of the following underground pipe network (WDD, 2011b):

MAJOR WATER SUPPLY PROJECTS

- Southern conveyor project (161 km[1]) The connected dams are two (2) with total water capacity 121,8 million m^3: Kouris Dam (115 million m^3) and Achna Dam (6.8 million m^3);
- Paphos conveyor project. The amounts of water supply

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[1] Total length of southern conveyance system: 161 km (Dhiarizos diversion tunnel: 14.5km, Southern conveyor: 110 km and Tersephanou-Nicosia conveyor: 36.5km). This part of conveyance infrastructure is known as "the southern conveyor project" and it involves water supply both for irrigation and drinking water distribution purposes.

originate from three (3) dams of total water capacity 72.6 million m^3;

- Chrisohous conveyor project. The amounts of water supply originate from four (4) dams of total water capacity 27.2 million m^3 and are used for irrigation purposes;
- Pitsilias project.;
- Large number of small projects within the rural area

Two different routes are followed for the delivery of fresh/drinking water to end consumers (see also **Figure 12-3**):

1. Dams → water treatment plants → water conveyor system → consumption;
2. Desalination plants → water conveyor system → consumption

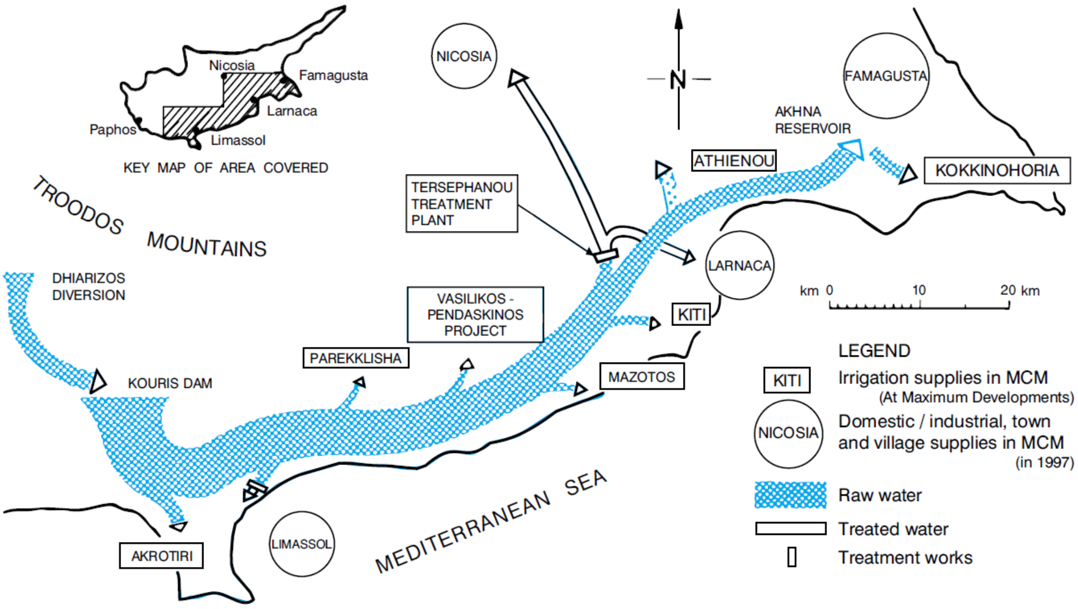

Figure 12-3: Schematic representation of water distribution in the southern part of Cyprus

Excluding the southern conveyance network, it must be noticed that no information, regarding the total pipeline length, has been published from the competent authorities (Water Development Department of Republic of Cyprus). However, it is estimated that till the end of 2012, the WDD will have built a pipe network GIS system mapping a large part of the network (~80-90%)[2]. The same applies for the case of wastewater collection network.

The water supply facilities are summarized below:

Water desalination plants:

The desalination capacity in Cyprus has increased from 40,000 m^3/d in 1997 when the first desalination plant in Cyprus operated to 182,000 m^3/d in 2011 and reached a capacity of 252,000 m^3/d or 92 Mm^3 in 2012. Table 12-1 summarizes the desalination plants and their respective capacities for the years 1997, 2011 and 2012 (WDD, 2011c). Within this framework, the Water Development Department put in operation 5 Permanent Desalination Plants by 2012, with a total production of 252,000 m^3/day. The contribution of desalination plants to domestic water supply for 2010 amounted to 65% which equals 55.5 Mm^3 (WDD, 2011a).

Table 12-1: Desalination plants in operation for the years 1997, 2011 and 2012

Desalination plant	Capacity (Mm^3/y)		
	1997	2011	2012
Dekelia	14.6	21.9	21.9
Larnaca	-	22.63	22.63
Lemesos	-	-	14.6
Pafos	-	-	14.6
Moni (mobile)	-	7.3	-
Pafos (mobile)	-	10.95	-
Vasiliko	-	-	18.25
Garilli (mobile)	-	3.65	-
Total	**14.6**	**66.4**	**92.0**

It must be noticed that most of the desalination plants are located in low-land in the coastal areas (see also **Figure 12-6**).

Water reservoirs:

In Cyprus, there exist:

- 56 large dams; and
- 51 small dams.

Most of dams in Cyprus are of the earth-fill type, mainly attributed to the nature of the topography and geology of the region where the dam is situated. Economic reasons have

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[2] This information has been obtained through communications with the Water Development Department. Contact person: Helena Phinikaridou, e-mail: hphinikaridou@wdd.moa.gov.cy

also played an important role for selecting this type of dams in Cyprus (WDD, 2009). Earth-filled dams are more prone to water flooding disasters since overflow over the crests will result in their collapse, while heavy precipitation may cause severe erosion damages.

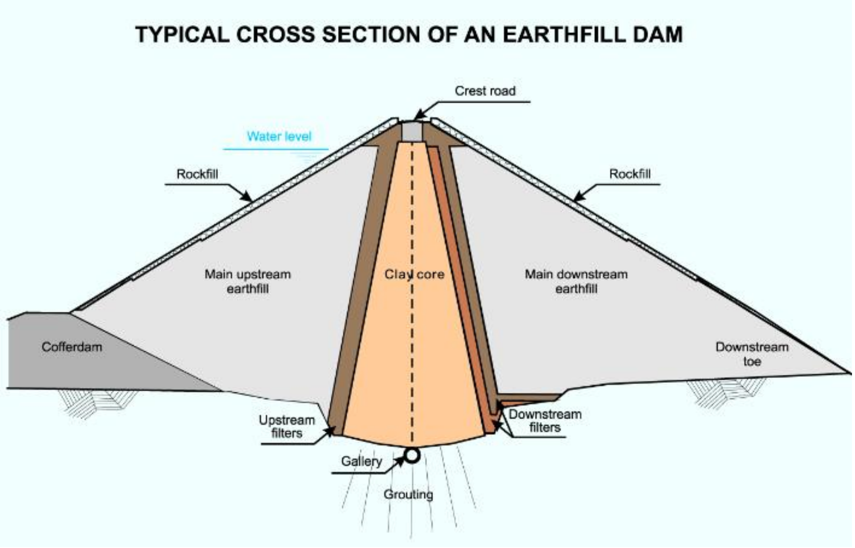

Figure 12-4: Typical cross section of a clay core earth-fill dam.

Source: WDD, 2009

The location of each dam can be seen in **Figure 12-5**, whereas the reader can find an extensive list with supplementary information (such as catchment area[3] of each dam) in *WDD, 2009*. Nevertheless the major dams are located a few kilometers upstream of urban centairs.

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[3] The catchment area of a reservoir is that portion of the country naturally draining into it. In the table of the relevant reference (WDD, 2009) it is referred to as 'water-shed' and is expressed in km^2.

Figure 12-5: Dams of Cyprus

Source: WDD, 2009

The surface water from the dams is treated for drinking purposes in the following water treatment plants (data obtained by WDD):

- Pafos;
- Chirokoitia;
- Limassol;
- Tersephanou; and
- Kornos.

It must be noticed that none of the dams are used for the production of hydropower. They are used explicitly for water supply purposes.

Water supply treatment plants are situated mainly inland at locations which pose no risk of flooding.

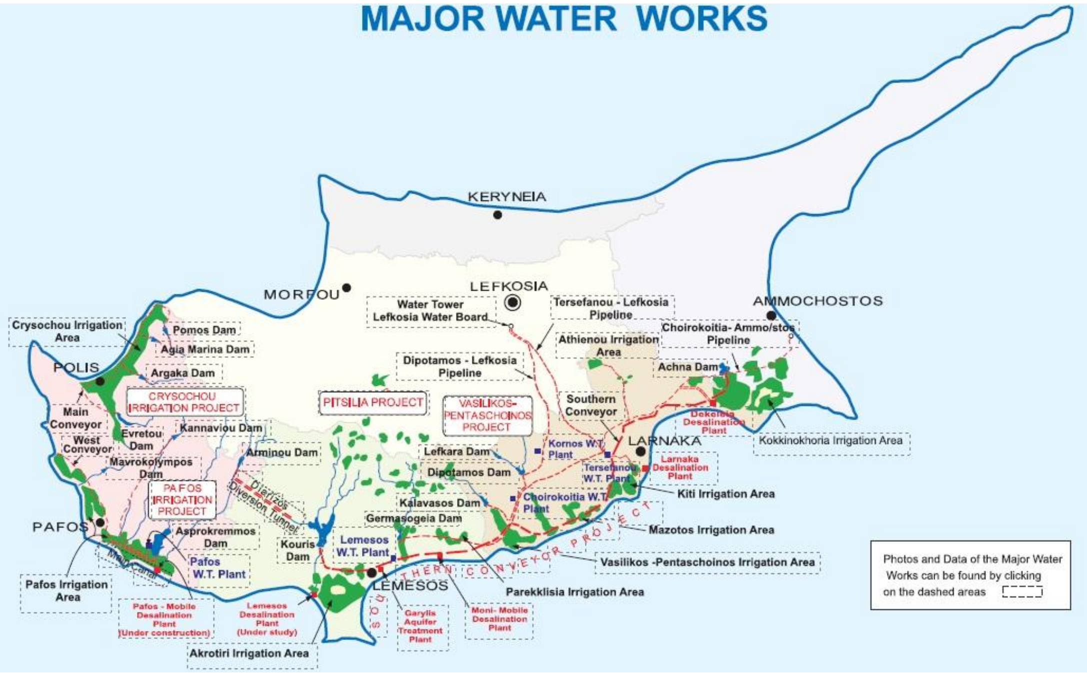


Figure 12-6: Major Water works plants in Cyprus

Source: WDD

As depicted in the above figure, a number of water plants are located within less than a kilometer from the shoreline, something that poses concern regarding the potential rising of sea level, as discussed in Section 12.4.1.

Water supply for irrigation purposes, comes from dams, boreholes and wastewater treatment plants.

<u>**Wastewater treatment plants:**</u> at present, there exist seven (7) plants in urban areas and seven (6) plants in rural areas and in specific (see also **Figure 12-7**) (MANRE, 2010b):

Urban areas (MANRE, 2010b):

- Limassol (40,000 m^3/day);
- Anthoupolis (13,000 m^3/day);
- Vathia Gonia (22,000 m^3/day);
- Larnaca (8,500 m^3/day);
- Paphos (8,000 m^3/day);
- Paralimni - Agia Napa (8,000 m^3/day); and
- Vathia Gonia, industrial waste waters (2,100 m^3/day);

Four out of the seven aforementioned plants are located in or near coastal areas (Limassol, Paphos, Larnaca and Paralimni – Agia Napa plants). However, it must be noted that the plant of Agia Napa is located in higher elevation than Limassol, Paphos and Larnaca plants, which are located in low land areas.

Rural areas (all located at inland of Cyprus) (MANRE):

- Limassol - Amathountas
- Paphos (S.A.P.A.)
- Agia Napa
- Paralimni
- Anthoupoli
- Larnaca
- Vathia Gonia
- Agros
- Dali
- Kyperounda
- Pelendri
- Platres
- Lythrodontas
- Alasa
- Ascas
- Kakopetria
- Anglisides
- Palaichori
- Kofinou
- Leivadia
- Arediou
- Nicosia New Hospital
- Hospital Larnaca
- Limassol Hospital
- Camp Malountas
- Camp Klirou
- Camp Cornou
- Camp Lefkara
- Camp St John Malountas
- Camp Stavrovouni
- Camp Troodous
- Camp Frenarous
- Camp Mathiatis

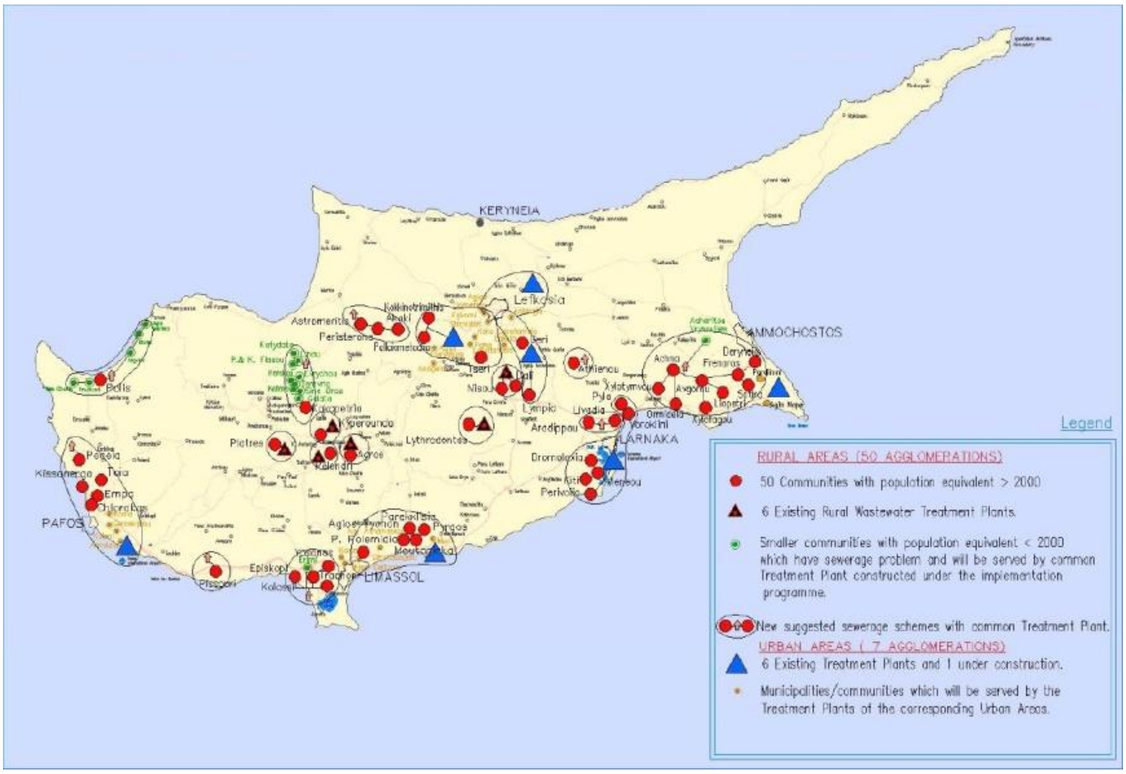


Figure 12-7: Urban wastewater treatment plants in Cyprus

Source: MANRE, 2010b

12.2.3 Solid waste management

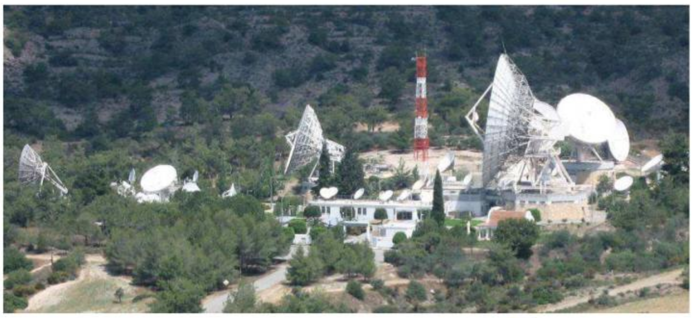
In Cyprus, waste management schemes involve Waste collection, Waste management (Mechanical treatment, biological treatment and Thermal treatment) and Waste disposal. At present, two landfills are used in Cyprus (MANRE, 2011) Pafos landfill and Koshi landfill (serving the needs of Larnaca and Ammochostos Districts). In addition, it must be mentioned that there are approximately 117 Uncontrolled Waste Disposal Sites (*UWDS*) in Cyprus. "The Integrated Solid Waste Management Unit in Larnaca – Famagusta", which operated in 2010 with a ten years plan, is one of the most important technology projects in Europe as part of Waste Management. There is an ongoing plan for the safe decommissioning and restoration to the original state of the sites. It is expected that this plan shall have been completed by 2013 (MANRE, 2010).

12.2.4 Information and Communications Technology (*ICT*)

The communications of Cyprus can be divided into the following two (2) categories:

- Internal communication: this is achieved with the use of an overhead cable network and by means of frequency network; and

- Trans-national communication: this is achieved with the use of two critical infrastructure and in specific (a) the fibre optic cables network, which is submerged into the sea, interconnecting Cyprus with diverse international nodes (Italy, Lebanon, Syria, Israel, Greece)[4] (b) the satellite "Makarios" which is located near Larnaka District (see following figures).



Makarios teleport site

National transmission network with international connection

12.2.5 Transport

The transport infrastructure can be divided into three (3) categories:

- Roads;

The main means of transport in Cyprus is the car. It is reported that, the per 1,000 people car ownership rate in Cyprus is the highest in the world (742 cars/1,000 people), shedding light on the high energy use of the transportation sector which accounted for 55.1% of the final energy consumption in 2009. Besides car transportation, the share of public transport is estimated at 3%, followed by bicycle use (less than 2%). Moreover, it must be noticed that there is no railway transportation in Cyprus, pointing out that motorways substitute the only significant infrastructure of the island (excluding seaports and airports) (MANRE, 2011).

The total length of motorways in 2009 totaled 257 km (Eurostat). Finally, it must be noticed that in Cyprus there are a number of small bridges in the road network.

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[4] http://www.cytaglobal.com/cytaglobal/userfiles/IRIS2.pdf

Figure 12-8: Road map of Cyprus

Source: MCW, 2006

- Seaports (Limassol port and Larnaca port)
- Airports: International (Larnaca and Paphos) and Military (RAF Akrotiri and Kingsfield Air Base
- Marina (Limassol, Larnaca)
- Fishing shelters

12.2.6 Other infrastructure

Under the other infrastructure category Industry, Hotels and Buildings can be included. Further analysis follows.

12.2.6.1 Industry

The main industrial activity in Cyprus comprises (MLSI, 2011) Cement production (2 installations), Ceramics production (8 installations), Lime production (1 small-scale production plant), Foundries (1 installation).

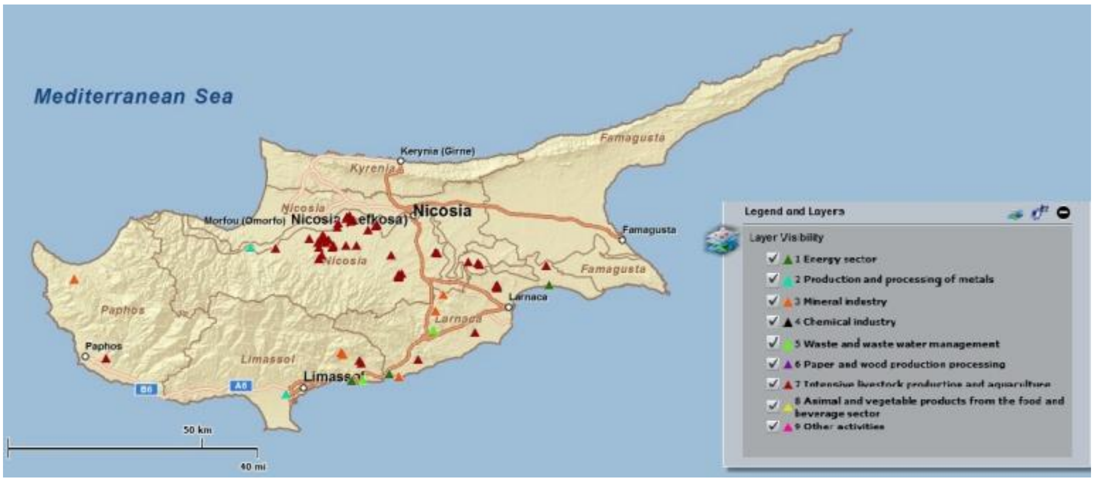

Figure 12-9: Industry facilities by sector in Cyprus

Source: http://prtr.ec.europa.eu/IndustialActivity.aspx

12.2.6.2 Hotels

More than 800 tourist accommodations are in operation today (CARBONTOUR, 2010). As it can be seen by the following figure, these accommodation units have been developed near the urban centers of Cyprus the vast majority of which are located near the coast line of the island, which corresponds to a 95% share of the total tourist accommodation units of Cyprus (the rest are located in Nicosia and the mountain resorts) (Constantinides, 2002).

Figure 12-10: Hotels in Cyprus

Source: googlemaps

12.2.6.3 Buildings

The total building stock of Cyprus amounts approximately to 242,000 houses. It has been estimated that single house has the highest share (44%), followed by apartments (21%), duplex houses (17%) and other type of buildings[5](Panayiotou, 2010).

Spatial development in Cyprus is characterized by rapid population growth in the suburbs of the urban centers (sub-urbanisation). According to the Statistical Service of the Republic of Cyprus (Statistical Service, 2009), the urban areas[6] by district are the following:

1.	**Nicosia**:	Municipal boundaries of Lefkosia Town, Strovolos, Aglantzia, Agios Dometios, Egkomi, Kato and Pano Lakatameia, Latsia and Geri.
2.	**Famagusta**	Does not include any urban areas
3.	**Larnaca**:	Municipal boundaries of Larnaca Town, Aradippou and Livadia, Dromolaxia, Meneou, Oroklini and Pyla coastal Zone;
4.	**Lemesos**:	Municipal boundaries of Lemesos Town, Agios Athanasios, Mesa Geitonia, Kato Polemidia and Germasogeia, Amathounta, Pano Polemidia, Ypsonas.
5.	**Pafos**:	Municipal boundaries of Pafos and Geroskipou, Chlorakas, Lempa, Empa, Tremithousa, Mesogi, Mesa Chlorio, Anavargos, Konia, Agia Marinouda, Koloni, Acheleia, Tala, Kissonerga, Coral Bay.

As obvious, the urban centers of Cyprus (excluding Nicosia) are all situated in or near coastal areas. This indicated the other dominant feature of the spatial development of the island which is coastalization. To this end, the majority of settlements, as well as other critical infrastructure including hospitals and schools, is situated in coastal areas.

Finally, the land use in coastal areas is as follows (Konstantinides, 2003):

- Tourist zones: ~103 km;
- Open areas/protected archaeological zones: ~125 km;
- Agricultural zones: 36 km;
- Residential zones: ~17 km; and
- Industrial zones: ~9 km.

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[5] The survey concerned a sample of 500 houses

[6] The urban area is determined by the municipal boundaries of the main towns and adjacent suburbs, all other areas are classified as rural.

12.3 Future Impact Assessment

The climatic factors that are likely to induce impact on the infrastructure sector in the future are the extreme events. More importantly, heavy rain, sea level rise, flooding and wind speed comprise the most important climatic factors among extreme events that should be examined for estimating the impact on infrastructure. Regarding annual mean wind speed changes in the near future, PRECIS projections show a slight decrease of about 0.10-0.20 m/s. Concerning future changes of extreme wind events, PRECIS projections show a decrease for the future period of about 5-12 days for the number of days with mean wind speed greater than 5 m/s. Finally the climate projection model used does not provide estimates for storms, waves and floods. Nevertheless, there is an indicator referring to the annual maximum total precipitation over one day indicating heavy rainfall, that is not anticipated to be significant, which could also be associated with flood risk.

In this section the climate impacts on the infrastructure sector, as these have been identified in Deliverable 1.2 will be reviewed in light of the climate projections for the future (2021-2050). In the context of the quantitative impact assessment the Relationship between potential climate changes and impacts on the infrastructure sector relationship between potential climate changes and impacts on the infrastructure sector is presented in Table 12-2.

Table 12-2: Relationship between potential climate changes and impacts on the infrastructure sector

Potential climate change in Cyprus	Future impacts on infrastructure		Selected Indicators
	Type of Infrastructure	Impact	
Heavy rain	All types	• Flood • Landslides	• Severity of material damages to infrastructure
	Water infrastructure (wastewater collection and treatment)	• Risk for flooding of Sewerage Treatment Plants • Risk for sewer flooding	
	Transport infrastructure	• Increased demand for car use • Flooding of underground networks • Flood damage • Bridge collapse and associated implications (transport communication, safety risks etc.)	
	Communications	• Reliability of the signal • Disturbances to	• Disruption frequency • Duration of disruption

Potential climate change in Cyprus	Future impacts on infrastructure		Selected Indicators
	Type of Infrastructure	Impact	
		overhead cable networks	
Storm surge	All types (located at coast)	• Flood • Periodic flooding of coastal infrastructure	• Percentage of critical infrastructure located in or near coastal areas • Disruption frequency in daily operations (social activity and trade) • Duration of disruption
Sea Level Rise	All types (located at coast)	• Permanent asset loss at coastal sites •	• Percentage of critical infrastructure located in or near coastal areas
	Transport infrastructure (ports)	• Limited access to ports • Threat to port operation	• Coastal infrastructure asset losses due to Sea Level Rise
High winds	Transport	• Transport disruption (caused by blown down trees etc.) • Impede aircraft operation	• Disruption frequency in daily operations (social activity and trade) • Duration of disruption
Temperature increase	**Transport**	• Deformation of road and airport asphalt surfaces • Passenger discomfort	
	Communications	• Decreased wireless transmission signal	
Extreme events	**All types**	• Risks for human safety	• Number of accidents related to extreme weather events • Population living in disaster prone areas (areas prone to flooding and landslides) • Changes in the proportion of built-over land in disaster prone areas
	Transport infrastructure	• Asset failure due to long, hot, dry periods	

Potential climate change in Cyprus	Future impacts on infrastructure		Selected Indicators
	Type of Infrastructure	Impact	
		followed by intense rain causing flash floods. • Stability of foundations of transmission masts and towers, mostly attributable to increased risk of subsidence (more susceptible during drier summers and wetter winters) • Damage to underground cables(more susceptible during drier summers and wetter winters)	

Normal precipitation will not have an impact on infrastructure. In specific, according to PRECIS projections (future period 2021-2050), precipitation is expected to decrease in seasonal level and to a lesser degree in annual level. However, heavy rain may affect all types of infrastructure due to the risk of flooding, land sliding and collapsing.

The aforementioned impacts induced by future climate change are presented in detail next by type of infrastructure.

12.3.1 Water infrastructure

Water infrastructure in Cyprus consists of "Water supply, treatment and storage infrastructure" and "Wastewater collection, treatment and disposal infrastructure".

In Cyprus, water supply infrastructure and water supply treatment facilities cover all population needs. Surface water, coming from more than 100 situated dams, undergoes treatment in water treatment plants before consumption from the end-users. The total length of collection network (including the piping length that is planned to be added to the existing network) amounts to 4,313 km, with urban agglomerations having a share of 64.2% (2,770km). WDD expects to have built a pipe network GIS system, mapping therefore a large part of the network (~80-90%). Development of all water supply infrastructures is under the responsibility of the Water Development Department and the Water Boards

Wastewater treatment infrastructure consists of collection networks, treatment facilities, storage reservoirs and distribution networks. Climatic parameters likely to affect the water supply system are the (a) decreased precipitation; (b) sea-level rise; (c) heavy rain and extreme events (SEFRA, 2011); (d) intention in surge waves and (e) wind speed changes.

The main impacts associated with climate change on the wastewater infrastructure are summarized in **Table 12-3**.

Table 12-3: Impacts associated with climate change on water infrastructure

Potential climate change	Future Impacts on water infrastructure
Extreme events	
Heavy rain	Risk of failure of water supply infrastructure
	Increase of infiltration to networks
	Risk for sewer flooding
	Risk for flooding of Sewerage Treatment Plants
	Risk of flood damage of infrastructure in river banks
	Risk for water pollution and public health in case wastewater reaches an underground water reservoir which is used for water supply of the community.

Following, an indicative list of damages caused to water supply facilities is presented. It must be noticed that these impacts cannot be directly connected with climate change. However, the monitoring of the number of events/disasters over a particular time period (e.g over a year), can provide a basis (indicator), which will allows the climate-induced impacts and the vulnerability of the sector to be measured.

According to the records kept by the Water Development Department (WDD, 2011) since 1859, a number of floods have occurred. The incidents, which are related to water supply infrastructure damage and occurred during the last century, are the following:

- **1918**: The water supply infrastructure at the region Pediaio, Limassol (Arab-Ahmet aqueduct) was damaged;
- **1936**: The water supply infrastructure of Lemesos (Tzitromilin aqueduct) was damaged;
- **1968**: Two water tanks with a total capacity of 40 million gallons were destroyed, causing damages to agricultural crops situated nearby;
- **1979**: one dam (water retaining facility) collapsed due to extreme flow[7], resulting to serious damages in households and road infrastructure;

However, in Cyprus many dams are situated near upstream of urban centers. In order for the impact of a possible failure to be measured, it is essential to examine the safety factors of dam design in relation to the magnitude of the predicted floods.

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[7] The extreme flow was caused by heavy rain which lasted around 3 ½ hours ($13^{30} – 17^{00}$pm).

Heavy rain events have been monitored since 1930 by the Meteorological Service of Cyprus (see Figure 12-11). In specific, the analysis of the data has shown a rising trend between 1930 and 2007. There is evidence that this rising trend is related with climate change.

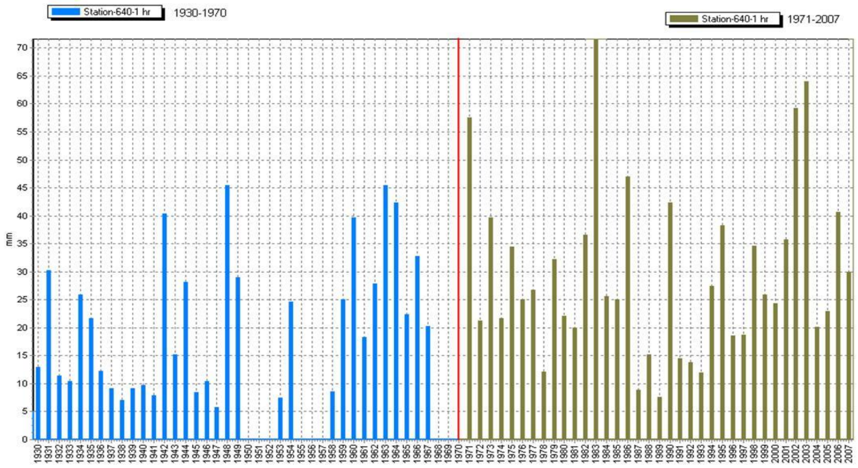


Figure 12-11: Highest amounts of rainfall in 1 hour, in Cyprus

Source: Pashiardis, 2011

Flooding which is associated with heavy rain also follows the same pattern. In specific, an increase, both in terms of frequency and magnitude, in flood events has been observed (see Figure 12-12) especially in the last seven years (2000-2007).

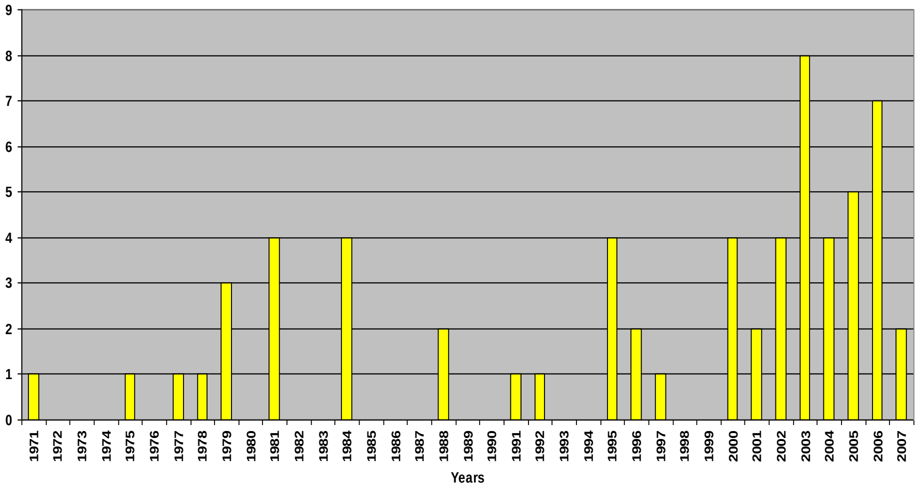


Figure 12-12: Number of flooding events per year

Source: Pashiardis, 2011

Heavy rain is anticipated to have an impact on infrastructure. PRECIS predictions show that future changes of annual max total rainfall over 1 day, have a minor increase of about 2-4 mm in western and higher level regions. Additionally, southern and southeastern areas present an increase of about 1 mm in annual max total rainfall over 1 day. This increase appears to be minor and will not affect the safety factor of the dam design.

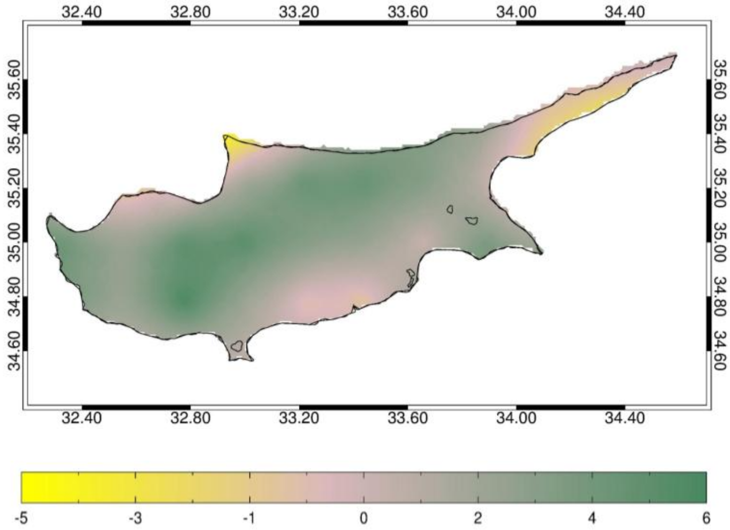


Figure 12-13: Changes in annual maximum total precipitation over 1 day between the future (2021-2050) and the control period (1961-1990)

Concerning wastewater infrastructure the anticipated effect of increase in heavy rain events is minor. The reason is that wastewater infrastructure in Cyprus is using a separate system for waste water and drainage water is collected separately.

As for the exposure of water infrastructure to floods, annual maximum total precipitation over one day, could also indirectly be associated with flood risk. However, as already mentioned, the PRECIS model showed that there will be no significant changes to this indicator in the future period (2021-2050). It must be noted though that this indicator alone is not sufficient for estimating flood risk since other factors play an important role as well.

Decreased precipitation

Impact of anticipated changes in precipitation on infrastructure may not be significant since changes in precipitation are predicted as mild for all areas. Regarding future precipitation changes, all northern coasts are expected to receive less annual total precipitation in the future, than that estimated for the recent past 1961-1990. In all other parts of Cyprus, the annual total precipitation appears to have minor decreases or no changes at all. The only region with an increase in total annual precipitation, minor though (up to 5mm), is the area around Orites Forest, east of Paphos.

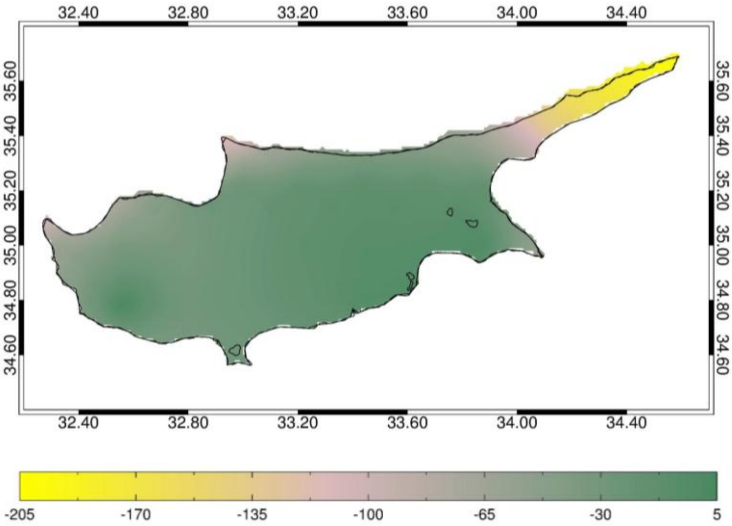


Figure 12-14: Changes in annual total precipitation between the future (2021-2050) and the control period (1961-1990)

Regarding seasonal precipitation changes the impact on infrastructure is not anticipated to be outstanding as well. In winter rainfall the average decrease in precipitation is anticipated to be up to 20mm and in autumn up to 15mm respectively, while for other seasons the changes are less significant.

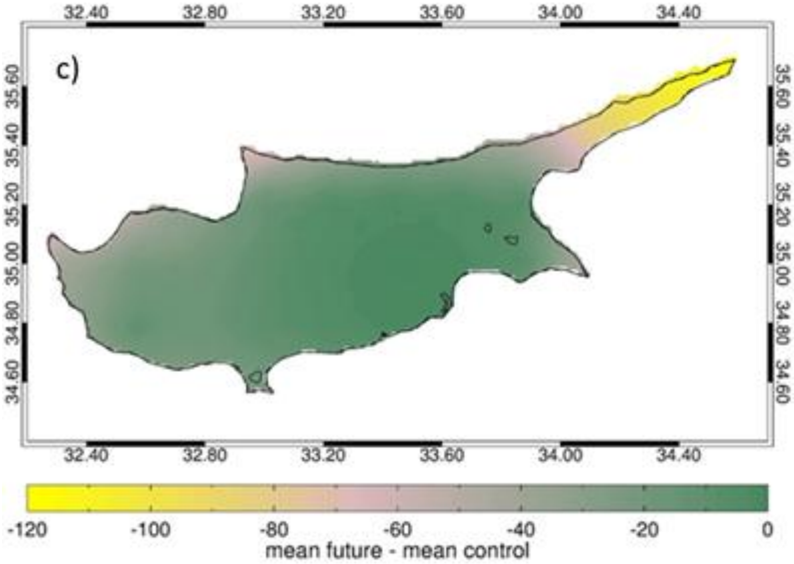


Figure 12-15: Changes in winter total precipitation in the near future (Future – Control period) using PRECIS RCM model

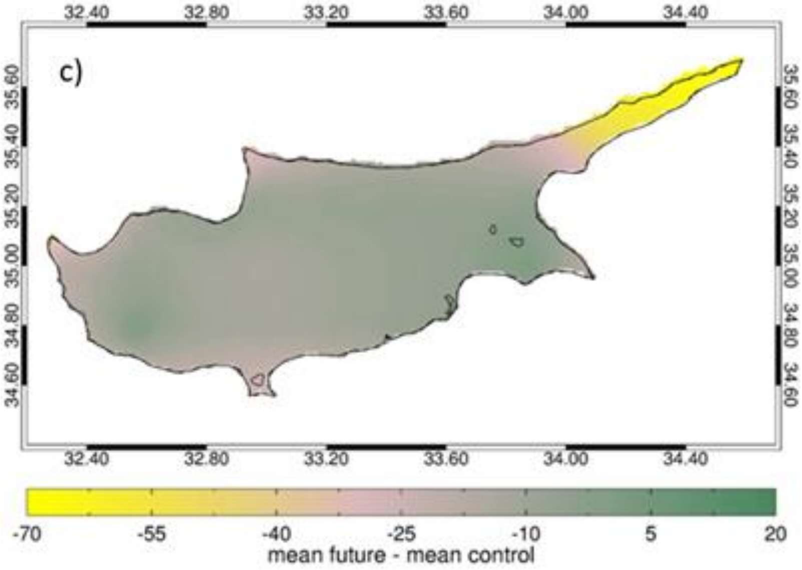


Figure 12-16: Changes in autumn total precipitation in the near future (Future – Control period) using PRECIS RCM model

Decreased precipitation is mainly linked with consequent decreased water availability, rather than with vulnerability of water infrastructure (see Section "Water Resources") so the impact is expected to be minor.

Sea-Level Rise

Sea-level rise, may affect both water availability (as a result of increased salt intrusion into coastal underground systems) and flooding of water infrastructure near coastal areas. For the case of Cyprus, sea level rise is expected to be moderate (EC, 2009), while water infrastructure in coastal areas is limited. Furthermore it must be added that, based on archaeological data, Cyprus appears to be experiencing long-term uplift of between 0 and 1 mm per year. This uplift is expected to counteract sea-level rise and given a global rise in sea level of 0.5m by 2100, relative sea-level rise in Cyprus will be in the range 0.4-0.5m (Nicholls and Hoozemans, 1996). The sea level changes in Cyprus as observed during the period between 1993 and 2000 show an increase of 5-10 mm/year. As a result water infrastructure will not be affected by sea level rise.

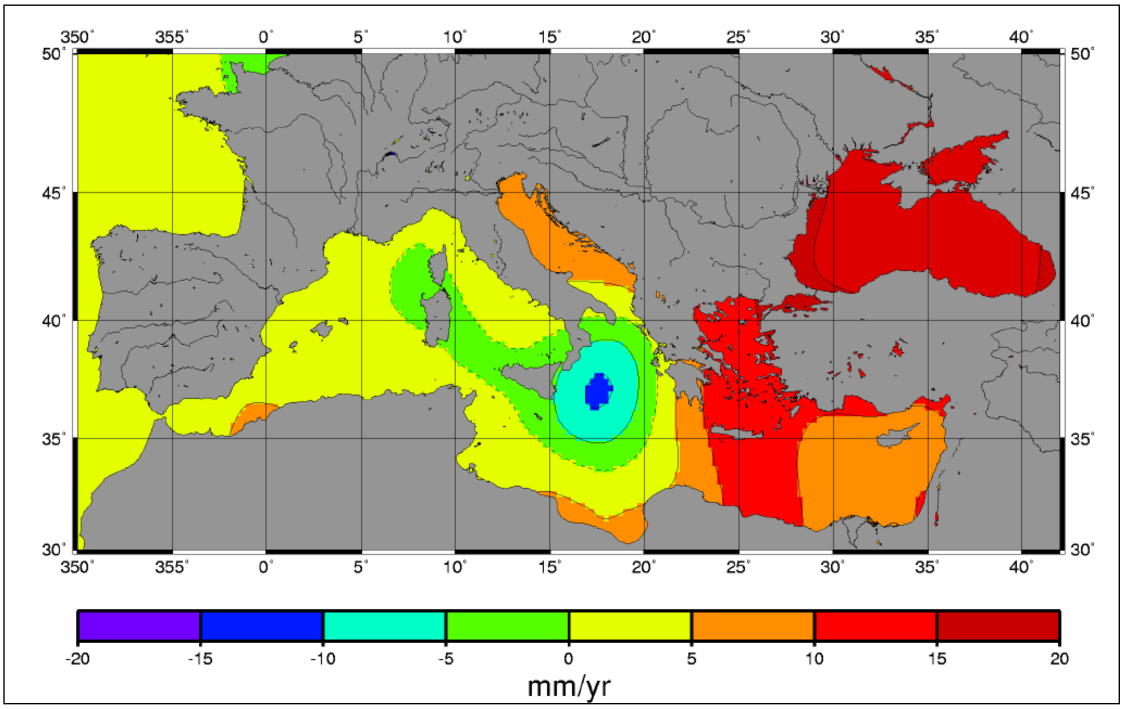


Figure 12-17: Mediterranean basin sea level changes between 1993 and 2000

High wind events- Flood risk

While changes in storminess may contribute to changes in extreme coastal high water levels, the limited geographical coverage of studies to date and the uncertainties associated with overall storminess changes mean that a general assessment of the effects of storminess changes on storm surge is not possible at this time (IPCC, 2012). Results from embedded high-resolution models and global models show a likely increase of peak wind intensities and notably, increased near-storm precipitation in future tropical cyclones. Most recent published modelling studies investigating tropical storm frequency, simulate a decrease in the overall number of storms, though there is less confidence in these projections and in the projected decrease of relatively weak storms in most basins, with an increase in the numbers of the most intense tropical cyclones. Model projections show fewer mid-latitude storms averaged over each hemisphere, associated with the poleward shift of the storm tracks that is particularly notable in the southern hemisphere, with lower central pressures for these poleward-shifted storms. The increased wind speeds result in more extreme wave heights in those regions (Meehl et al., 2007). However, according to the projections of the PRECIS climate model, the mean wind speed greater than 5 m/s in Cyprus during the future period 2021-2050 is not expected to present substantial changes, on the contrary, it presents minor decreases in general. With regard to the current exposure to high wind speeds of the coastal areas, PRECIS shows that in western (Pafos, Chrysochou) and southeastern (Larnaca, Ayia Napa) areas the number of days with mean wind speed > 5 m/s is approximately 80 while southern (Limassol) regions present about 40-50 days with mean wind speed > 5 m/s. Following figure depicts PRECIS projections for the changes in the number of days with mean wind speed greater than 5 m/s. As it is shown, in western, and southeastern coastal areas a decrease of about 12 days is anticipated. Also southern areas present a slight decrease of about 5 days. Additionally water infrastructure in coastal areas is limited.

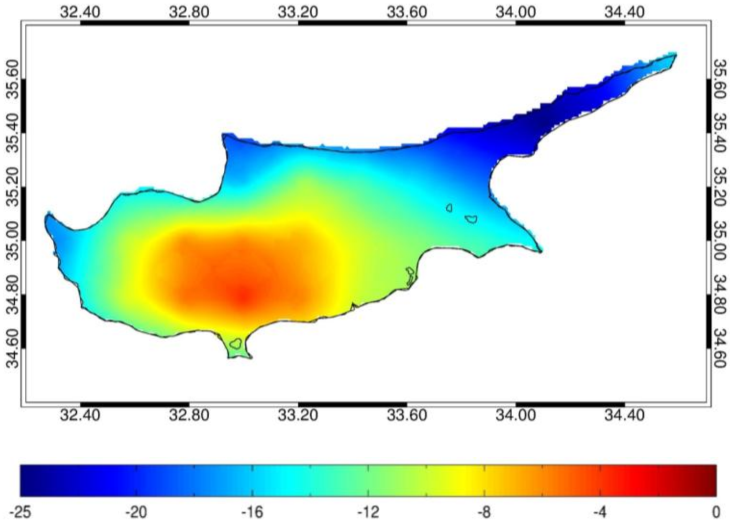


Figure 12-18: Changes in the number of days with mean wind speed > 5m/s between the future (2021-2050) and the control period (1961-1990).

Consequently, it is expected that the future impact of storm surges to water infrastructure is limited.

12.3.2 Transport

The transport sector can be divided into the following categories, as already discussed:

- Road transport;
- Rail transport;
- Sea-ports, marinas, fishing shelters and
- Airports.

The main impacts on the transport sector are presented in **Table 12-4** (DfT, 2010).

Table 12-4: Climate change factors and associated future impacts on the transport infrastructure sector

Potential climate change in Cyprus	Future impacts on transport infrastructure
Increase in temperature	Deformation of road and airport asphalt surfaces

	Passenger discomfort
Extreme events	
Heavy rain	Flood damage
	Increased demand for car use
	Flooding of underground networks
	Bridge collapse and associated implications (transport communication, safety risks etc.)
Sea Level Rise (SLR)	Permanent asset loss at coastal sites
	Periodic flooding of coastal infrastructure
	Limited access to ports
	Threat to port operation
High winds	Transport disruption (caused by blown down trees etc.)
	Impede aircraft operation
Combined extreme events (drought & flash floods)	Asset failure due to long, hot, dry periods followed by intense rain causing flash floods.

Temperature increase: According to the PRECIS output, a quite significant increase is anticipated in the average maximum summer temperature in Cyprus in the future period 2021-2050 compared to the control period 1960-1990, ranging from 1.6°C to 2.6°C. In addition, the mean number of hot days (T>30^{o}C) per year are projected to increase by 17 to 24 days on average while the number of tropical nights (T>20°C) is expected to increase by 20 to 45 days per year. The mean number of days per year with daily maximum temperature higher than 35°C (heat wave days) is expected to increase from 2 days to 34 days on average. As it can be seen, there will be a considerable increase in high temperatures in Cyprus in the future. However, the magnitude of the impact of such an increase on the deformation of road and airport asphalt surfaces and passenger discomfort is not known.

Heavy rain: The impact of heavy rain on transport infrastructure could indirectly be associated with flood risk with the use of the annual maximum total precipitation over one day as an indicator. However, as already mentioned, the PRECIS model showed that there will be no significant changes to this indicator in the future period (2021-2050). It must be noted though that this indicator alone is not sufficient for estimating flood risk since other factors play an important role as well.

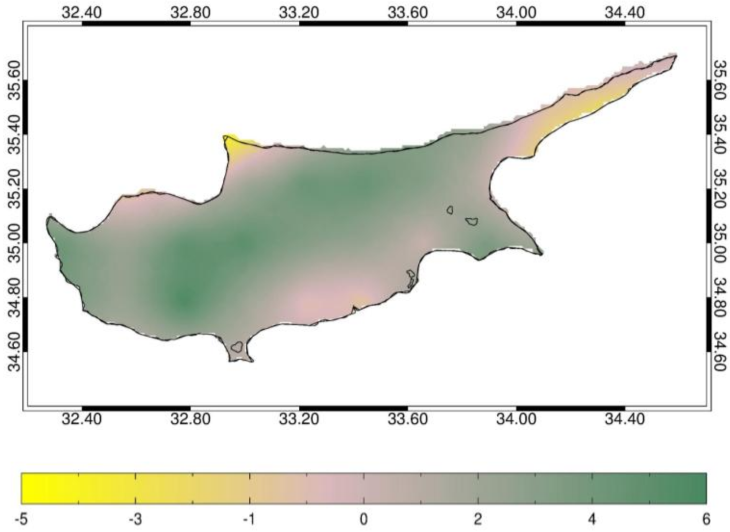


Figure 12-19: Changes in annual maximum total precipitation over 1 day between the future (2021-2050) and the control period (1961-1990)

Sea-Level Rise

Sea-level rise, may affect flooding of transport infrastructure near coastal areas. However as already mentioned for the case of Cyprus, sea level rise is expected to be moderate (EC, 2009. Furthermore it must be added that, based on archaeological data, Cyprus appears to be experiencing long-term uplift of between 0 and 1 mm per year. This uplift is expected to counteract sea-level rise and given a global rise in sea level of 0.5m by 2100, relative sea-level rise in Cyprus will be in the range 0.4-0.5m (Nicholls and Hoozemans, 1996). The sea level changes in Cyprus as observed during the period between 1993 and 2000 show an increase of 5-10 mm/year.

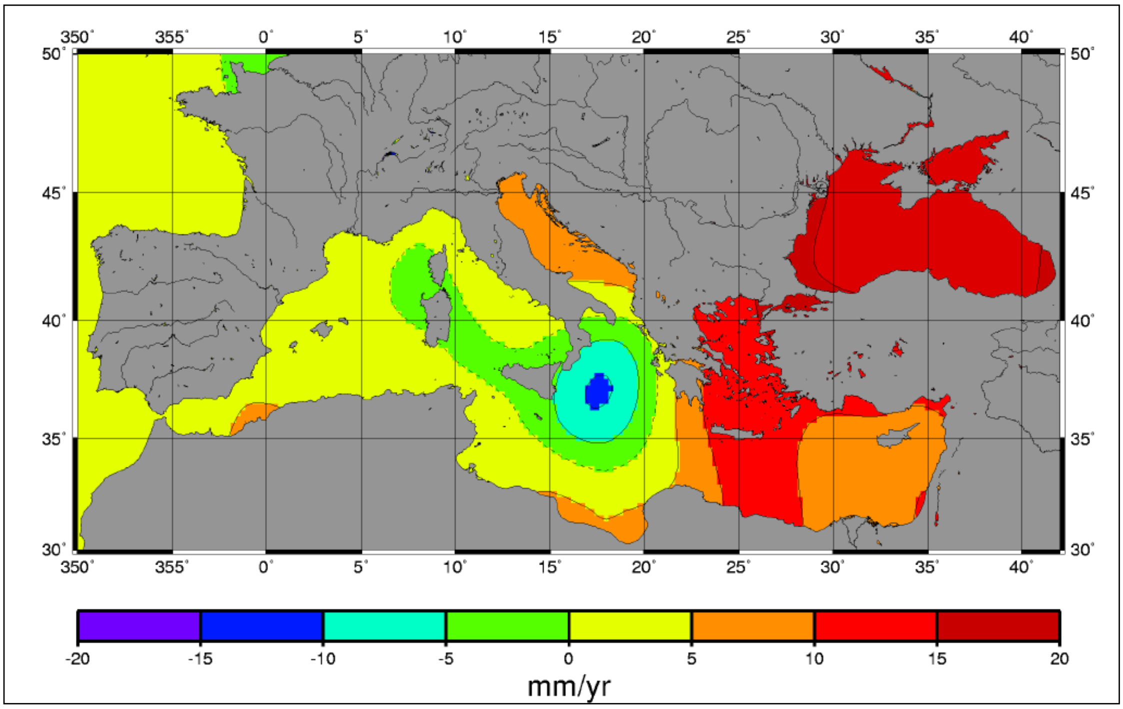


Figure 12-20: Mediterranean basin sea level changes between 1993 and 2000

High wind events-Flood risk

While changes in storminess may contribute to changes in extreme coastal high water levels, the limited geographical coverage of studies to date and the uncertainties associated with overall storminess changes mean that a general assessment of the effects of storminess changes on storm surge is not possible at this time (IPCC, 2012). Results from embedded high-resolution models and global models show a likely increase of peak wind intensities and notably, increased near-storm precipitation in future tropical cyclones. Most recent published modeling studies investigating tropical storm frequency, simulate a decrease in the overall number of storms, though there is less confidence in these projections and in the projected decrease of relatively weak storms in most basins, with an increase in the numbers of the most intense tropical cyclones. Model projections show fewer mid-latitude storms averaged over each hemisphere, associated with the poleward shift of the storm tracks that is particularly notable in the southern hemisphere, with lower central pressures for these poleward-shifted storms. The increased wind speeds result in more extreme wave heights in those regions (Meehl et al., 2007). However, according to the projections of the PRECIS climate model, the mean wind speed greater than 5 m/s in Cyprus during the future period 2021-2050 is not expected to present substantial changes, on the contrary, it presents minor decreases in general. With regard to the current exposure to high wind speeds of the coastal tourist areas, PRECIS shows that in western (Pafos, Chrysochou) and southeastern (Larnaca, Ayia Napa) areas the number of days with mean wind speed > 5 m/s is approximately 80 while southern (Limassol) regions present about 40-50 days with mean wind speed > 5 m/s. Following figure depicts PRECIS projections of the changes in the number of days with mean wind speed greater than 5 m/s. As it is shown, in western, and southeastern coastal areas a decrease of about 12 days is anticipated. Also southern areas present a slight decrease of about 5 days. Consequently, it is expected that the future impact of storm surges to transport infrastructure is limited.

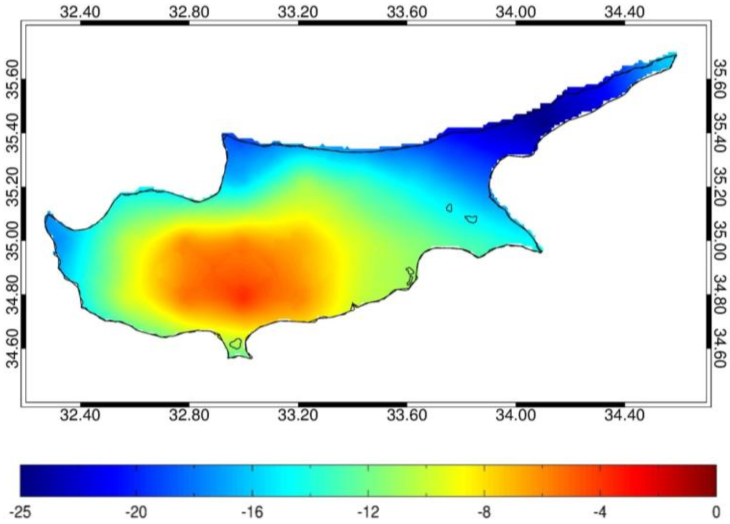


Figure 12-21: Changes in the number of days with mean wind speed > 5m/s between the future (2021-2050) and the control period (1961-1990).

12.3.3 Energy infrastructure

The impacts on the energy infrastructure can be grouped into “Power generation”, “Electricity transmission and distribution” and “Fuel processing and storage”.

Table 12-5: Climate change factors and associated future impacts on the transport infrastructure sector

Potential climate change in Cyprus	Future impacts on energy infrastructure
Increase in temperature	Adaptation of power generation infrastructure in reduced thermal coefficient of efficiency of power plants
Extreme events	
Heavy rain	Risk of system reliability
	Flooding risk of power plants and protect existing infrastructure
High winds	Risk of disruption of overhead cables used for electrification

12.3.3.1 Power generation infrastructure

The main concerns regarding power generation infrastructure lie in fossil-fuel and nuclear power plants. Whereas, fossil-fuel powered plants relate exclusively with implications for infrastructure damage and disruption in electrification, nuclear power plants pose also safety risks. However in Cyprus there are no nuclear plants.

It is worth noticing that climate change is likely to affect power generation. As a result the network connects may be disposed to climatic change and more specifically to temperature increase. According to PRECIS projections for the future period 2021-2050, the average annual temperature in Cyprus is expected to increase by 1 - 2^{o}C with respect to the control period 1960-1990.

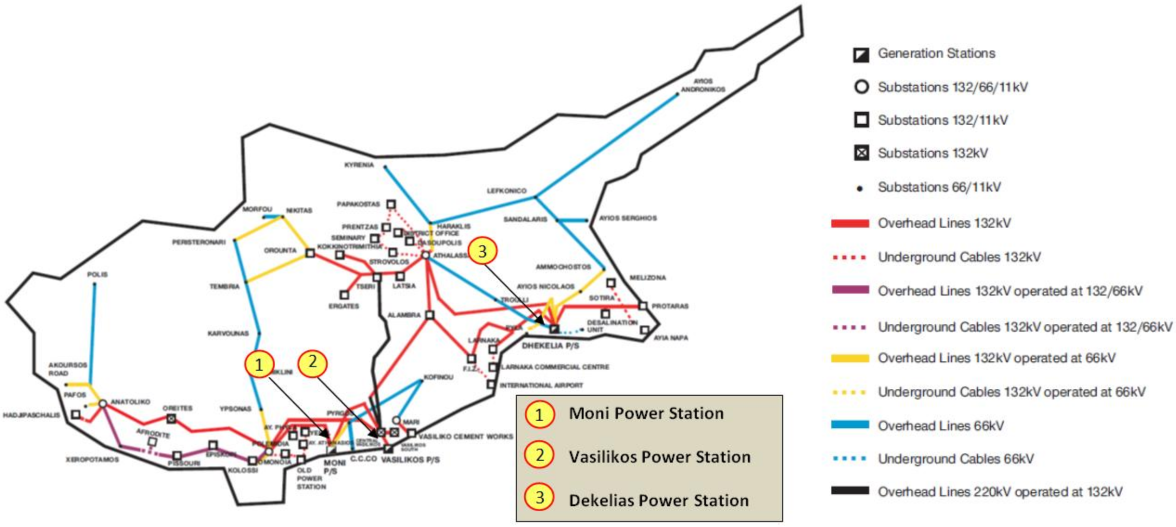


Figure 12-22: Power stations and electrical grid in Cyprus

In specific the southern coastal area east from Limassol where the two main power plants are located is characterized by a temperature change of about +1.7°C while the southeastern coastal area between Limassol and Larnaca where the third main power plant is located, is characterized by a lower increase in temperature change of about 1.3°C. As for the changes in water temperature, these are related to the changes in air temperature and are also expected to increase with a lower rate though.

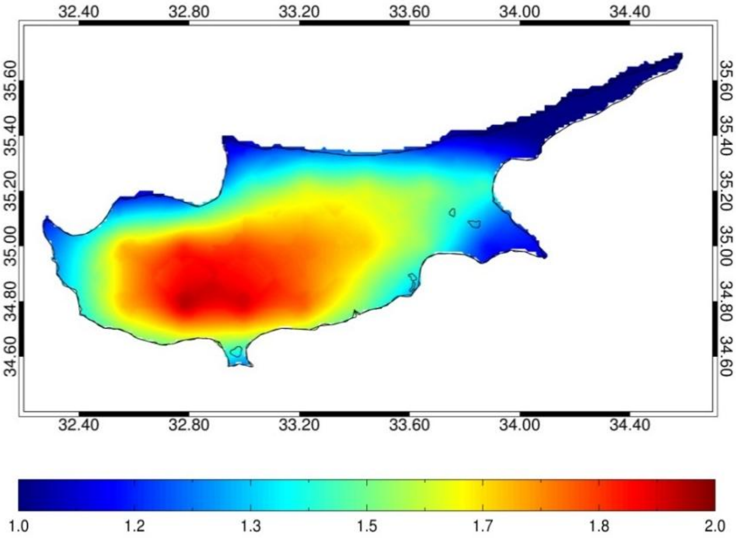


Figure 12-23: Changes in average annual maximum TX between the future (2021-2050) and the control period (1961-1990)

However, it is not known whether a change in temperature of this magnitude will have an impact on the efficiency of thermal power plants and as a result on power generation infrastructure.

In order to obtain a better understanding of the correlation of temperature with the power plants efficiency, the thermodynamic efficiency of the Carnot cycle can be used:

$$\boldsymbol{n_{th,Carnot} = 1 - \frac{T_b}{T_a} n_{th,Carnot} = 1 - \frac{T_b}{T_a}}$$

Where:

- T_b, the temperature where the heat rejection occurs; and
- T_a, the temperature (K) at which heat is transferred to the working media.

From the equation, it can be easily deduced that with increased cooling temperatures (T_b) the thermodynamic efficiency of the power generation cycle decreases. It must be noticed that the reduction of the coefficient of efficiency is not dependent on the type of cooling technology employed. However, in order to minimize this impact, the selection of the appropriate technology must be made on a case specific basis.

Moreover, in order to attain the same cooling effect with increased temperatures, larger quantities of the cooling medium have to be used. This is translated into higher pumping requirements which lead to decreased net power plant capacity. As it can be seen from Figure 12-24, the net electricity offered to the public network equals to the gross electricity produced minus the own electrical consumption of the power plant. To this end, the capacity of the power plants is expected to decrease.

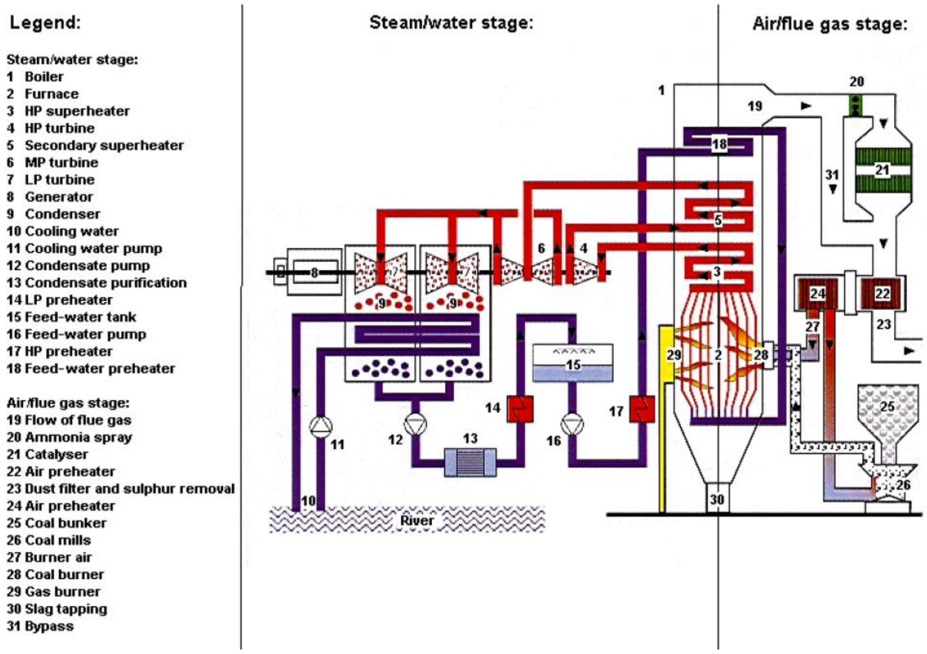


Figure 12-24: Possible configuration of a steam plant

Source: EC, 2006

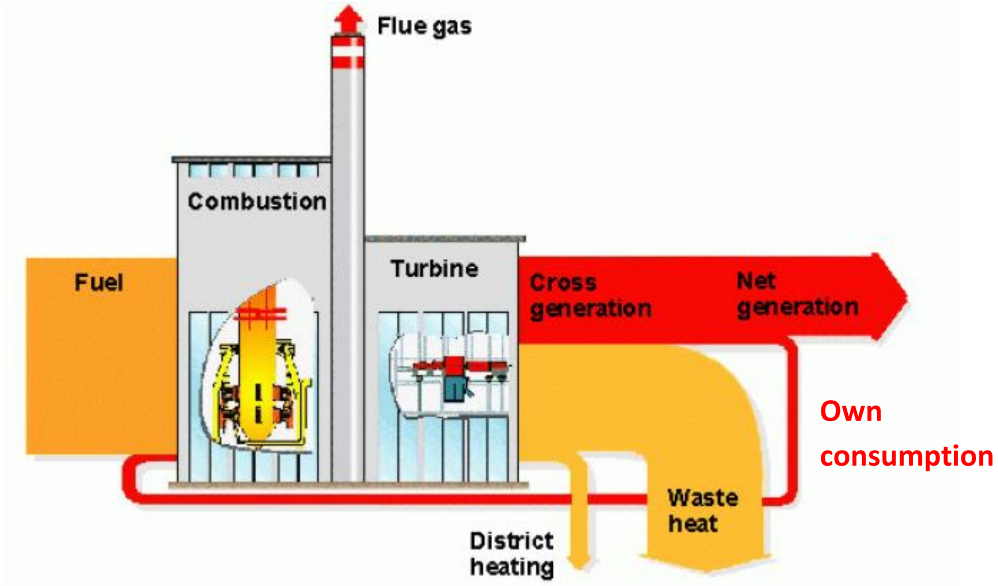
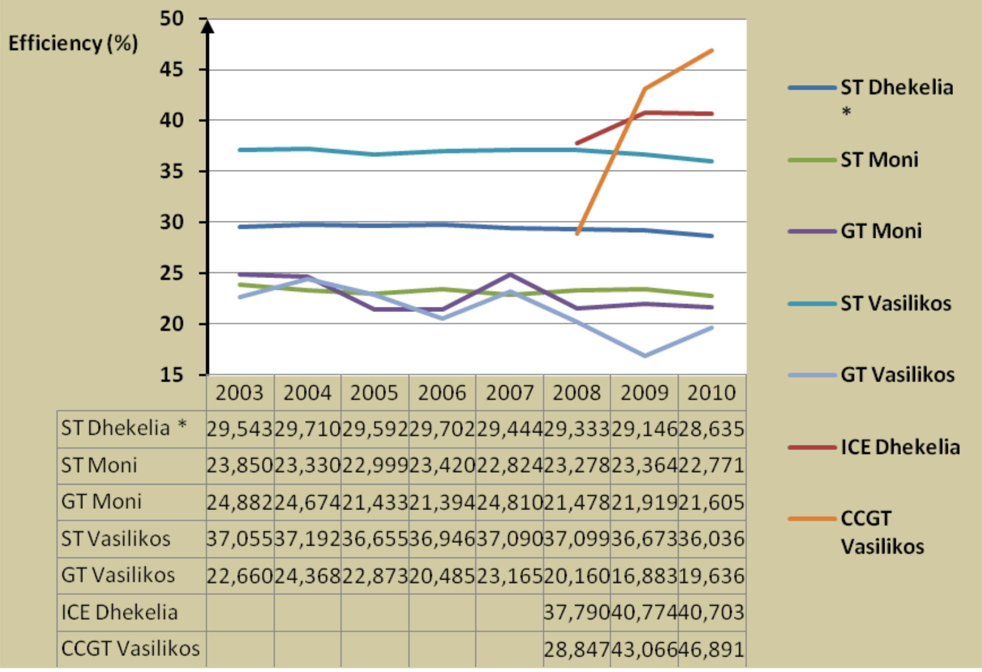


Figure 12-25: Energy conversion in a typical thermal power plant

Source: EC, 2006

Situation in Cyprus

Apart from the mean value of thermal coefficient of efficiency (36.1%), the efficiency of each unit should be monitored. The changes that have been recorded in the efficiency of the different thermal power plants are presented in Figure 12-26. As it can be seen, the efficiency of the thermal power plants drops over time. However, from the communication with the EAC's competent department[8], it was deduced that there is no clear relation between climate change (temperature increase) and drop of the thermal coefficient of the power plants in Cyprus, as the latter would still drop over time due to ageing of the power units.



	2003	2004	2005	2006	2007	2008	2009	2010
ST Dhekelia *	29,543	29,710	29,592	29,702	29,444	29,333	29,146	28,635
ST Moni	23,850	23,330	22,999	23,420	22,824	23,278	23,364	22,771
GT Moni	24,882	24,674	21,433	21,394	24,810	21,478	21,919	21,605
ST Vasilikos	37,055	37,192	36,655	36,946	37,090	37,099	36,673	36,036
GT Vasilikos	22,660	24,368	22,873	20,485	23,165	20,160	16,883	19,636
ICE Dhekelia						37,790	40,774	40,703
CCGT Vasilikos						28,847	43,066	46,891

Figure 12-26: Observed changes in the efficiency of thermal power plants in Cyprus

*Note: (1) CCGT: Combined Cycle Gas Turbine, ST: Steam Turbine, GT: Gas Turbine, ICE: Internal Combustion Engine, (2) the increase in CCGT and ICE units are related with the installation of new units

It must be noted that the data presented have been obtained through communication with the Electricity Authority of Cyprus (EAC) and have not been published yet.

More information is available in the Chapter of the Energy Sector.

As relative research is still lacking, further work on the field is recommended.

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[8] Contact person: Menelaou Charalambos (Assistant Generation Manager), Tel: 00357 22 201513, CMenelao@Eac.com.cy

12.3.3.2 Electricity transmission and distribution

The impacts on electricity transmission and distribution involve: (a) the reliability of the system and (b) reduced electricity capacity.

In Cyprus, a minor part of transmission cables (~9%[9]) and a more significant part [~37.6% for medium voltage (MV) equipment and 32.5% for low voltage (LV) equipment[10]] of distribution equipment [22,427.64km which corresponds to 95.7% of the route length of electricity (transmission and distribution) equipment], has been installed underground.

Due to the observed warming in Cyprus in our days, energy consumption may change as energy requirements for heating during winter will fall while during summer energy demand for cooling will grow largely due to high temperatures. This constitutes the most important impact of climate change in relation to energy. Since the energy consumption has increased in recent years, further increasing demand for energy during summer should somehow be offered.

In specific a further increase in the maximum and minimum temperature in the future in Cyprus is expected to affect both cooling and heating demand. In particular, it is projected according to PRECIS that the mean annual maximum temperature will increase by 1.3-1.9°C during the period 2021-2050 and the mean annual minimum temperature will also increase by 1.3-1.8°C on average for all the domain of the study. Consequently, an increase in cooling demand and a decrease in heating demand is expected. This means there will be a need to install additional generating capacity over and above that needed to cater for the underlying economic growth.

Should extreme climate phenomena happen, such as flooding, heat waves and droughts, maximum length of dry spells and heat wave days, the energy supply infrastructure must be able to withstand the changes and guarantee that the electrification shall not be put at risk.

Concerning future changes of annual max total rainfall over 1 day, PRECIS projections show that a slight increase of about 1-4 mm is anticipated. Furthermore, PRECIS projections for the future period show that the maximum length of dry spells (precipitation<0.5mm) is expected to increase 10 to 13 days on average while heat wave days (temperature >35°C) will be increased about 10-30 days on average and annual basis. In this frame impact of anticipated changes of climatic parameters (dry spells, heat wave days and heavy rainfall) on electricity transmission and distribution requires further research.

Furthermore, when referring to reduced electricity capacity, it must be stressed that according to thermodynamics, there is a small increase in line resistance with increasing mean temperatures (Santos et al., 2002).

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[9] Total route length of transmission equipment: 997.76 km (906.32 km overhead cables, 91.44km underground cables)

[10] Total route length of distribution equipment: 8787.76 km MV (5,482.38km overhead cables, 3,305.38km underground cables) and 13,639.88 km LV (9,205.98 overhead cables, 4,433.9km underground cables)

Moreover, according to WDD (WDD, 2011) the electrification has been disrupted due to heavy rain as it occurred in 21/11/1994, when several villages experienced electricity cut and in 10/10/1996 when the electrical infrastructure (distribution equipment such as electric cables and pylons) were seriously damaged.

Another potential source of disruption of overhead cables used for electrification (and also for communication purposes), is storm winds through falling trees. Nevertheless regarding extreme wind events, PRECIS projections show a decrease for the future period of about 5-12 days for the number of days with mean wind speed greater than 5 m/s.

Finally, the electrical losses of the electrical energy system of Cyprus accounted approximately for 2.8% (145,718 MWh). Even though no impact has been observed until now associated with climate change, it must be noticed that there exist studies (Saarelainen, 2009) showing that this figure is expected to increase in the coming years, requiring possible redesigning of the cables.

Given that power plants and significant part of the electricity transmission equipment are situated near the coastline of the island further research is required concerning strategy to avoid flooding risk of power plants and the protection in existing infrastructure.

12.3.3.3 Fuel processing and storage

The main impact lies in flood risk of fuel processing and storage facilities. Further research is required for anticipated changes in flood events and their impact on fuel processing and storage facilities.

Cyprus has no longer fuel processing industries, while it is obliged to keep oil strategic stocks. The facilities which will be used for the oil stocks are expected to be installed at Vasilikos.

More particularly, the following facilities shall be installed:

- Energy center of Vasilikos: the energy center is expected to accommodate also facilities for natural gas exploitation (liquification plant);
- One terminal installed by a private company (VITOL) which will be built in the industrial zone of Vassilikos, the completion of which is expected in the second half of 2012. The terminal will be consisted of 19 tanks and will supply the domestic market in Cyprus by means of truck access.

It must be noticed that the above mentioned facilities will be situated close to Cyprus shoreline.

12.3.4 Information and Communications Techology (*ICT*) infrastructure

ICT infrastructure can be grouped into the following categories:

- Wireless infrastructure; and
- Copper and fiber optic cables.

Following, the climate factors that are likely to have an impact on ICT infrastructure are presented (SEFRA, 2011).

Table 12-6: Climate factors and associated impacts on wireless and cable network infrastructure

Climate factor/impact	Impacts on wireless I/f	Impacts on cable network I/f
Temperature increase	Decreased wireless transmission signal	-
Extreme events		
Heavy rain	Reliability of the signal	Disturbances to overhead cable networks
Sea Level Rise (SLR)	Permanent asset loss at coastal sites	
Drier summers and more wet winters	Stability of foundations of transmission masts and towers, mostly attributable to increased risk of subsidence	Damage to underground cables

According to the PRECIS output, a quite significant increase is anticipated in the average maximum summer temperature in Cyprus in the future period 2021-2050 compared to the control period 1960-1990, ranging from 1.6°C to 2.6°C. In addition, the mean number of hot days ($T>30^{o}C$) per year are projected to increase by 17 to 24 days on average while the number of tropical nights (T>20°C) is expected to increase by 20 to 45 days per year. The mean number of days per year with daily maximum temperature higher than 35°C (heat wave days) is expected to increase from 2 days to 34 days on average. As it can be seen, there will be a considerable increase in high temperatures in Cyprus in the future. However, the magnitude of the impact of such an increase on the efficiency of the wireless transmission signal is not known.

12.3.5 Waste management

Waste management is one of the main municipal utility services and therefore it is essential to be carefully addressed.

The main impacts associated with waste management involve waste leachate, waste erosion and risk of flooding.

In Cyprus, no such impacts have been studied.

12.3.6 Buildings

Even if the industry sector and hotels have been separately presented in Section 12.2, they can be all seen under buildings category with regard to the impacts induced by climate change.

The impacts on the buildings sector involve damages in the infrastructure mainly attributable to extreme events such as intense wind, snow and floods. It must be mentioned that flooding of buildings can be caused due to heavy rain as well as due to sea-level rise.

12.3.7 Conclusions

As described in the above sections, the sector of infrastructure is expected to be affected mainly by the following two main categories of impacts:

- Material damages; and
- Disruptive operation.

For the case of Cyprus, the above mentioned impacts are related with flooding events induced by heavy rain (flash floods). However, there is no evidence that these events are directly connected with climate change and as a result the impacts due to climate change on the infrastructure sector are limited to uncertain. The available data were not conclusive and could not be used as a basis for measuring the future impact of climate change on infrastructure. To this end, at most cases no values are attributed to indicators.

It is worth saying, however, that there is an increasing trend in the appearance of flooding events, the intensity of which, both in terms of frequency and severity, is likely to exacerbate due to climate change.

In general, it must be noticed that sensitivity of the sector is increasing in flood and landslide prone areas (MoE, 2011). In this respect, in Section 12.4, a discussion is provided over these concerns for potential future vulnerabilities of the Cypriot infrastructure system.

12.4 Future vulnerability assessment

In this section, the vulnerability of the infrastructure sector is assessed in terms of its sensitivity, exposure and adaptive capacity based on the available quantitative and qualitative data for Cyprus and the climate projections for the period 2021-2050. In particular, sensitivity is defined as the degree to which the infrastructure sector is affected by climate changes, exposure is the degree to which the infrastructure sector is exposed to climate changes and its impacts while the adaptive capacity is defined by the ability of the infrastructure sector to adapt to changing environmental conditions which is also enhanced by the measures implemented in Cyprus in order to mitigate the adverse impacts of climate change on the sector.

The indicators used for the assessment of future sensitivity, exposure and adaptive capacity of Cyprus infrastructure to climatic change impacts, are those used for the assessment of current vulnerability of infrastructure. Indicators to be used for the Cypriot infrastructure sector are summarized in Table 12-7.

Table 12-7: Indicators used for the vulnerability assessment of climate change impacts on the infrastructure sector of Cyprus

Future Vulnerability Variable	Selected Indicators
Damage of infrastructure from urban floods	
Sensitivity	– Severity of damages caused to infrastructure
Exposure	– Change in frequency, intensity and severity of extreme events – Changes in the proportion of built-over land in disaster prone areas – Changes in land use
Adaptive capacity	– Flood protective measures (drainage works, SUDS etc.)
Damage of infrastructure from sea floods	
Sensitivity	– Severity of damages caused to infrastructure
Exposure	– Number of critical infrastructure located in or near coastal areas – Change in frequency, intensity and severity of extreme events – Changes in the proportion of built-over land in disaster prone areas – Frequency of sea flooding events

Future Vulnerability Variable	Selected Indicators
Adaptive capacity	– Land lift-up (Autonomous adaptive capacity for SLR) – Flood protective measures (coastal defense works, breakwaters, retaining walls, fishing shelters, etc.)
Damage of infrastructure from landslides	
Sensitivity	- Slope stability (geology, soil composition)
Exposure	– Proportion of built-over land in landslide prone areas
Adaptive capacity	- Relocation of settlements - Landslide protection measures (road protections measures for landslides, retention walls etc.)

The relationship between sensitivity, exposure and adaptive capacity is based on the following qualitative equation:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity * \ Exposure$$

Sensitivity, exposure and adaptive capacity are evaluated on a 7-degree qualitative scale ranging from “none” to “very high”.

To assess the future vulnerability of infrastructure sector, the following impacts were considered:

1. Infrastructure damage due to floods (urban and sea floods); and
2. Infrastructure damage due to landslides.

It must be noted that, there are no sufficient scientific evidence and data to evaluate or correlate all impacts and indicators to future climate changes. Consequently, further research is required in order to provide concrete information for a more detailed and descriptive assessment of the future vulnerability of the sector. Nevertheless, an attempt was made to provide a preliminary assessment of the vulnerability. In case additional data are provided by the competent authorities of Cyprus, the future vulnerability of the sector could be re-assessed.

12.4.1 Damages of infrastructure due to floods

The vulnerability of the Cypriot infrastructure was assessed regarding the following two types of floods:

- Sea floods;
- Urban floods.

12.4.1.1 Assessment of sensitivity and exposure

Sensitivity: Extreme events, mainly flooding and storm winds may cause severe damages to infrastructure.

Sea floods
Given that Cyprus is an island characterized by coastal infrastructure development, the main concern relates to sea flood events due to storm surge or sea-level rise (mainly affects coastal infrastructure). However, no significant sea flood events have been recorded while for future projections further research is required.

Urban floods
Urban floods are directly connected with heavy rain. Various flood events have been recorded until now. According to the records kept by the Water Development Department (WDD, 2011), between 1859 and 2011, Cyprus has suffered over 200 floods that have caused implications in multiple levels such as damages to road infrastructure, disruption of economic, social and cultural activities and in turn financial losses.

Timing: In the time-scale of climate change projections (50 – 100 years) no significant changes in the occurrence of flood events are expected (WDD, 2011). Information for a more specific prediction is very scarce and uncertain (WDD, 2011d).

Failure of dams (Antoniou, 2007)

The failures of dams are of particular importance, since the magnitude of the disasters that they can cause is enormous, both in terms of loss of lives and of property damage. This is attributed to the destructive power of the flood wave caused by the sudden collapse of a large dam.

When studying the effects of a dam the following two discrete aspects must be taken into consideration:

- ❖ **Risk:** The risk is defined as the probability of a dam to fail. Regardless of how well the dam is constructed and maintained, the risk of failure cannot be reduced to zero. A dam may have little risk of failure but may cause high downstream hazard when the failure occurrs, especially when large numbers of people live in the flood zone of the dam.
- ❖ **Hazard:** is defined as the potential effects of a dam failure, including the possible loss of life or damage to property downstream of the dam, caused by overflow of dams or by waters released due to partial or total failure of the dam.

All dams have some risk for failure, no matter how low this is, but the hazard to the public or property must always be taken into consideration

As a result, although the failure of a dam may be a rare phenomenon (low risk), it may induce safety risks (loss of lives and destruction of property) in downstream inhabited areas (downstream hazard).

To sum up, taking into account the current situation as well as the relative future climate changes the sensitivity of infrastructure due to floods was ranked as **moderate** to **high**.

Exposure:

Sea floods

In order to estimate the future exposure to floods from the sea, it is essential to examine which infrastructure is located in or near coastal areas. In Cyprus this infrastructure includes:

- **Electricity supply**
    - ❖ **Power stations**: all three power stations are situated near the coastline. These are: (a) Moni power station, (b) Dhekelia power station and (c) Vasilikos power station.
    - ❖ **Energy center at Vasilikos**;
- **Water supply**
    - ❖ **Water treatment plants**. Major water plants are located near the shorelines (within less than a kilometer) such as the plants located at Limassol, Dhekelia, Khirokitia, and Tersephanou (Arku, 2009);
    - ❖ **Wastewater treatment plants**. The plants located in the shoreline of Cyprus are: Limassol, Larnaca, Paphos and Paralimni - Agia Napa. The first three are situated in low-land area while the last in higher elevation compared to sea level;
    - ❖ **Desalination plants**. Dhekelia, Larnaca, Paphos, Vasilikos and Limassol plants; (see also **Figure 12-6**)

- **The international airport of Larnaca**. It must be noticed that Larnaca is the most low-lying region of Cyprus, rising concern over flood risk (EC, 2009);
- **Larnaca port**;
- **Marinas and fishing shelters**;
- **Industries.** Moni and Vassilikos cement plants, which are situated near Limassol;
- **Buildings.** The bulk of buildings situated in or near coastal areas are tourist accommodation units and in specific, the part of coastline dedicated to tourist activities is approximately 103 km while for residential only 17 km (see also Section 12.2.6.3). What is more, it must be noticed that the vast majority of tourist infrastructure is located near the coastline (~95%), pointing out the sensitivity of tourist economy to climate induced impacts related with flooding from sea on the sector.

Sea-Level Rise

Sea-level rise, generally, may affect infrastructure located in or near coastal areas. For the case of Cyprus, however, sea level rise is expected to be moderate (EC, 2009). Furthermore it must be added that, based on archaeological data, Cyprus appears to be experiencing long-term uplift of between 0 and 1 mm per year. This uplift is expected to counteract sea-level rise and given a global rise in sea level of 0.5m by 2100, relative sea-level rise in Cyprus will be in the range 0.4-0.5m (Nicholls and Hoozemans, 1996). The sea level changes in Cyprus as observed during the period between 1993 and 2000 show an increase of 5-10 mm/year. As a result infrastructure located in or near coastal areas will not be affected by sea level rise.

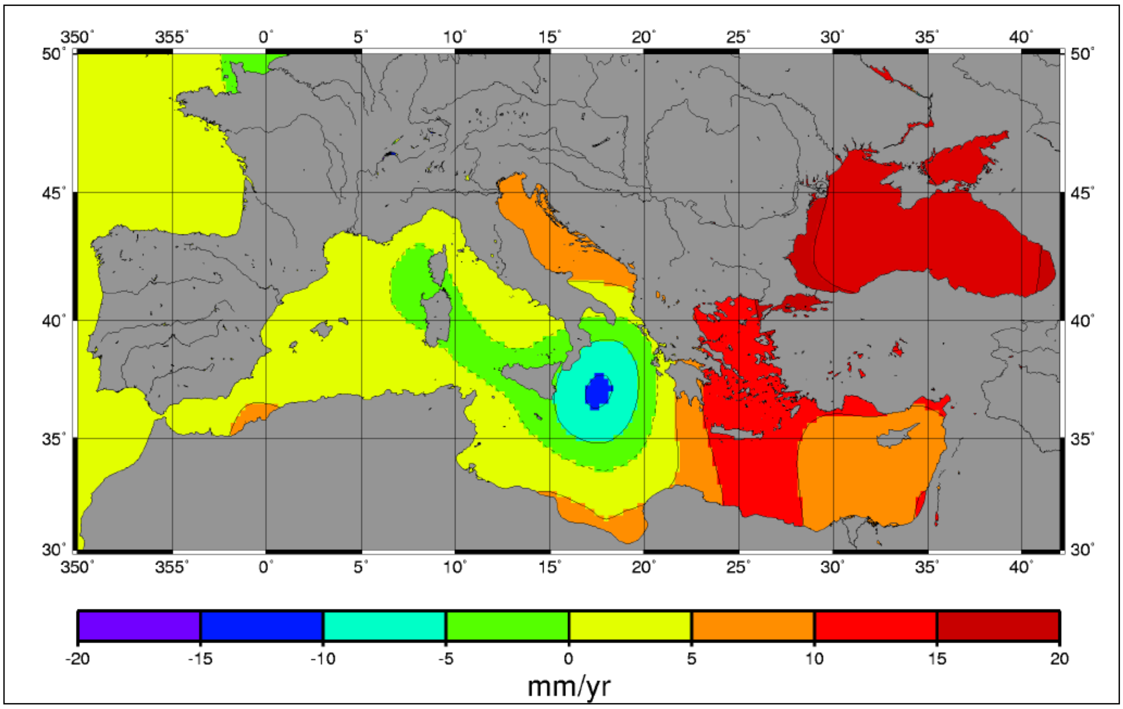


Figure 12-27: Mediterranean basin sea level changes between 1993 and 2000

Storm surges

While changes in storminess may contribute to changes in extreme coastal high water levels, the limited geographical coverage of studies to date and the uncertainties associated with overall storminess changes mean that a general assessment of the effects of storminess changes on storm surge is not possible at this time (IPCC, 2012). Results from embedded high-resolution models and global models show a likely increase of peak wind intensities and notably, increased near-storm precipitation in future tropical cyclones. Most recent published modelling studies investigating tropical storm frequency, simulate a decrease in the overall number of storms, though there is less confidence in these projections and in the projected decrease of relatively weak storms in most basins, with an increase in the numbers of the most intense tropical cyclones. Model projections show fewer mid-latitude storms averaged over each hemisphere, associated with the poleward shift of the storm tracks that is particularly notable in the southern hemisphere, with lower central pressures for these poleward-shifted storms. The increased wind speeds result in more extreme wave heights in those regions (Meehl et al., 2007). However, according to the projections of the PRECIS climate model, the mean wind speed greater than 5 m/s in Cyprus during the future period 2021-2050 is not expected to present substantial changes, on the contrary, it presents minor decreases in general. With regard to the current exposure to high wind speeds of the coastal areas, PRECIS shows that in western (Pafos, Chrysochou) and southeastern (Larnaca, Ayia Napa) areas the number of days with mean wind speed > 5 m/s is approximately 80 while southern (Limassol) regions present about 40-50 days with mean wind speed > 5 m/s. Following figure depicts PRECIS projections for the changes in the number of days with mean wind speed greater than 5 m/s. As it is shown, in western and southeastern coastal areas a decrease of about 12 days is anticipated. Also southern areas present a slight decrease of about 5 days. Additionally water infrastructure in coastal areas is limited. Consequently, it is expected that the future impact of storm surges to infrastructure located in or near coastal areas is limited.

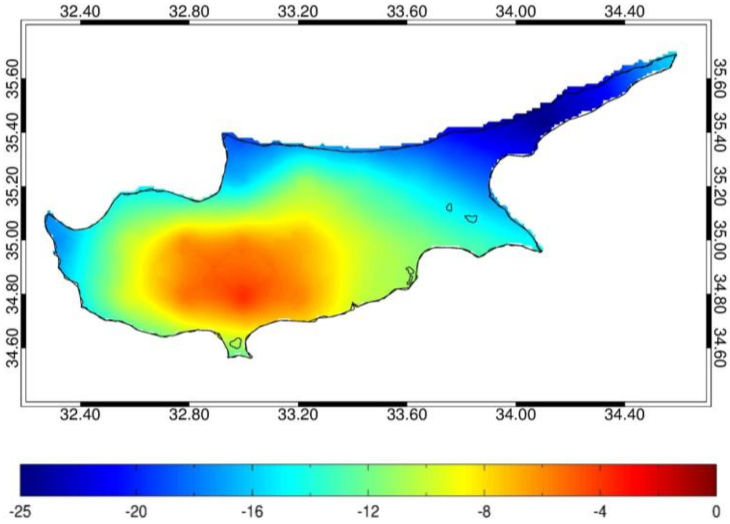


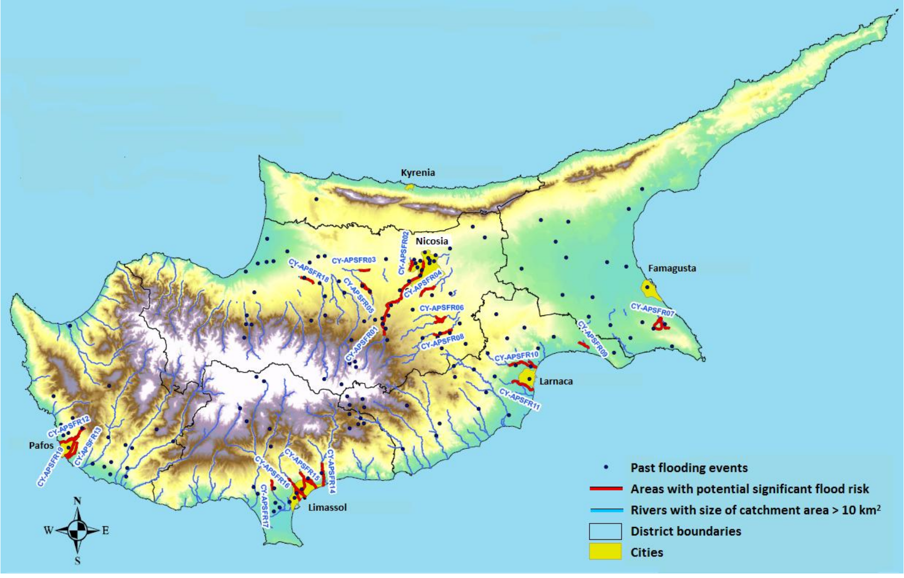
Figure 12-28: Changes in the number of days with mean wind speed > 5m/s between the future (2021-2050) and the control period (1961-1990).

To sum up, taking into account the current situation as well as the relative future climate changes the exposure of infrastructure sector to flood events is ranked as **very high.**

Urban floods

The urban centers of Larnaca, Limassol and Nicosia are sensitive to flood risks mainly due to their dense structuring and the restriction of green space, the elimination of natural waterways for the construction of roads, the deficient or even absent stormwater drainage system and the covering of waterways and drain entrances with garbage. On the other hand, mountain areas are less sensitive to floods, given that the inclination of terrain together with the infiltration capacity of forested areas do not allow for flooding events to take place.

In compliance with the Floods Directive 2007/60/EC, the Water Development Department of MANRE through its report "Preliminary Flood Risk Assessment" identified 19 areas around the island as "Areas with Potential Significant Flood Risk". Those areas have a total length of 135 km and are distributed uniformly to all urban centers of Cyprus (no mountain areas included). They mainly refer to river parts that pass through built-up areas and are characterized by frequent and significant flash floods. In addition, the areas of Larnaca, Tremithos and Alambra are included in order to be taken into consideration in the next 5-year planning in case the projected flood protection works in Larnaca and Alabra and the existing protection zone of Tremithos river bed do not reduce the problem (WDD, 2011d).



Source: WDD (10)

Figure 12-29: Areas with potential significant flood risk in Cyprus

As it can be seen from the map (Figure 12-29) the areas susceptible to floods are mainly the urban centers.

The climate projection model used for the case of Cyprus does not provide estimates for the frequency and intensity of floods in the future. Nevertheless, there is an indicator referring to the annual maximum total precipitation over one day indicating heavy rainfall, which could also be associated with flood risk. However, the PRECIS model showed that there will be no significant changes to this indicator in the future period (2021-2050). In particular, a slight increase of about 2-4 mm is anticipated in western, inland and mountain regions. Additionally, southern and southeastern areas present an increase of about 1 mm. It must be noted though that this indicator alone is not sufficient for estimating flood risk since other factors play an important role as well.

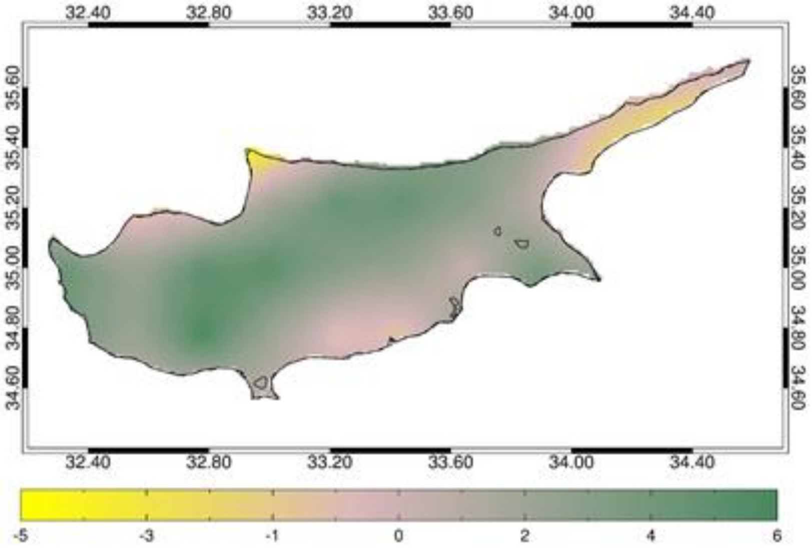


Figure 12-30: Changes in annual maximum total precipitation over 1 day between the future (2021-2050) and the control period (1961-1990).

Furthermore in order to assess the exposure of the infrastructure to flood events it is essential to examine future changes in land use and their implications for flood risks. Changes in land use persist over last years, especially in touristic areas such as Paralimni, where have been observed remarkable changes from agricultural to residential land use (see Figure 12-31).

Land use changes can induce significant flood risk through changes in the runoff coefficient. Runoff coefficient which reflects the percentage of precipitation that appears as runoff, is affected from the ground cover of an area as different materials, such as different type of soils and concrete present different properties concerning water (e.g infiltration). Ground slope plays also an important role in estimating the runoff coefficient of an area.

For example, the runoff coefficient for an unimproved, undeveloped area may be in the order of 0.1 to 0.3, while the respective figure for a developed area may vary from 0.4 to 0.7.

This fact implies the increased flood risk in urban centers and in areas with poor urban planning.

To this end, in order for a potential future flood event to be considered, the change in runoff coefficient must be evaluated, taking into account not only the current situation but also the prospects and future development trends of the particular area.

Figure 12-31: Land use change in the touristic area of Paralimni between April 2003 (on the left) and June 2010 (on the right).

Source: WDD, 2011

To sum up, taking into account the current exposure of the sector to urban floods as the relative future climate changes the future exposure is ranked as **high**.

12.4.1.2 Assessment of adaptive capacity

In order to reduce the impact of floods, the Cyprus Government has undertaken a series of flood protective measures including but not limited to the following:

(a) Hard coastal defense works (*for sea flood protection*),
(b) Fishing shelters and artificial reefs (*for sea flood protection*),
(c) Dams (*for urban flood protection*)
(d) Sustainable Urban Drainage systems (*for urban flood protection*).

Sea Floods

Flood protection measures

(a) **Hard coastal defense works**

Hard engineering structures such as seawalls, coastal revetments and breakwaters, help prevent coastal flooding. However, seawalls and revetments are not considered attractive for bathing beaches where the tourism infrastructure is located and thus breakwaters and groynes are the predominant defense works, although the latter are considered less drastic measures in case of a severe storm or flooding event.

(b) **Fishing shelters and artificial reefs** (*sea flood protection*).

Fishing shelters are constructed for the protection of fishing boats against extreme events such as storms and large waves, also provide for the protection of coastal infrastructure. Currently, there are eleven fishing shelters in operation in Cyprus.

Artificial reefs which are actually submerged breakwaters also provide protection from flooding by absorbing part of the incident wave energy before it reaches the coast. The DMFR will create up to 4 artificial reefs in the marine areas of Famagusta, Limassol and Paphos (Source: Strategy for the creation of artificial reefs, Cyprus).

Land uplift of Cyprus

For the case of Cyprus there are no available data which indicate that there will be an increase in relevant extreme events. More significantly, even if Sea Level Rise (SLR) in Cyprus was expected to be moderate (between 5 and 10 mm/year), this is not likely to arise in the coming years. According to research studies (EC, 2009; Nicholls & Hoozemans, 1996), Cyprus is experiencing a land lift-up[11], something that shall offset at a certain degree a potential sea level rise.

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[11] According to Nicholls & Hoozemans (1996), the rate of land lift-up is estimated at 0 - 1mm/year.

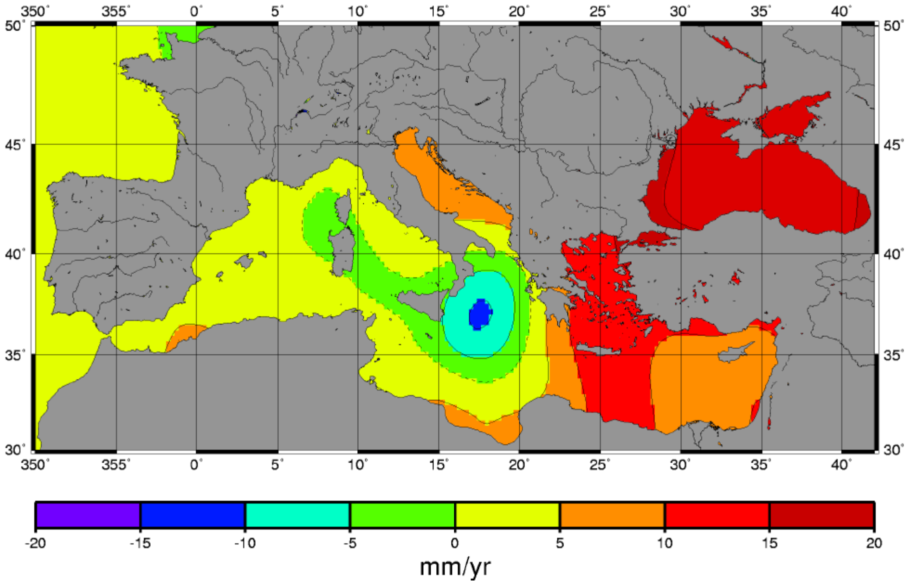

Figure 12-32: Mediterranean Sea level changes as observed during the period between 1993 and 2000

Source: MoE, 2011

Taking everything into account, the adaptive capacity for sea floods was ranked as **limited** to **moderate**.

Urban floods

Flood protection measures

(c) Dams

The purpose of building a dam is not limited to water supply but also for flood risk minimization, as its storage contributes to the attenuation of flood peaks.

According to the detailed river basin management plan (Annex I) of the Water Development Department (WDD, 2011b), 36 out of the 107 constructed dams in Cyprus are designed for flood risk minimization.

Moreover, they have been designed according to high flood protection standards (1 to 500 or 1 to 1000 chance of flooding).

It is stressed that even if dams do not comprise vulnerable infrastructure, their monitoring is considered of particular importance as they may induce safety risks.

(d) Sustainable Urban Drainage Systems

Regarding urban floods, the Cyprus government has taken measures for the reduction of urban flood risks, by developing Sustainable Urban Drainage Systems (SUDS). When referring to these systems, it must be noticed that they comprise stormwater retention ponds which are used both for flood protection and for aquifer recharge. In Cyprus, such systems have been installed at Limassol and Paralimni. Finally, Paphos has been identified as a suitable area for the implementation of SUDS (WDD, 2009).

What is more, the complete separation of the sewerage and drainage system is underway, as the latter is being expanded in most urban centers, providing therefore the basis for reducing to a large degree the flooding risk of the sewerage system.

Due to lack of sufficient data on the future impacts of climate change on the infrastructures of Cyprus, the analysis on the effectiveness of the already applied measures as well on the necessity for additional measures for the protection of infrastructure could not be conducted. Further research is suggested to take place on the subject.

Taking everything into account, the adaptive capacity for urban floods was considered to be **moderate**.

12.4.2 Damages of infrastructure due to landslide damage

12.4.2.1 Assessment of sensitivity and exposure

Sensitivity:

Cyprus is well-known for its interesting and often complex geology, particularly in the south-west part of the island. The reason for the increased susceptibility of this area to landslides is the remains of former sea-floor deposits and massive submarine slides, which tend to be heavily deformed and are rich in the types of clay minerals that are prone to land sliding. This tendency is exacerbated by the steep terrain and the long history of powerful earthquakes in the region (British Geological Survey). In addition**,** climate change increases the likelihood for land displacements. More specifically changes in temperature and precipitation could be relevant for more landslides. In this regard the sensitivity was ranked as **limited**. However further research is required in order to provide concrete information for the future.

Exposure:

According to the Geological Survey Department of Cyprus, there has never been conducted a complete survey regarding landslides in Cyprus and the risk of infrastructure. Precipitation and temperature changes can have an impact on lanslide occurance (Crozier, 2009). Variability in precipitation and temperature can cause more frequent wetting and drying cycles that increase fissuring and widening of joint systems and reduction in cohesion and rock mass joint friction and can result landslide events. Further research is required concerning future variability in precipitation and temperature.

Landslides are common in certain areas of Cyprus, but it was not until recently that the Ministry of Agriculture and Natural Resources and Environment undertook a relevant research project entitled ‘Study of landslides in areas of Paphos District’ for recording the landslide events. The project used aerial photography and QuickBird satellite imagery, supported by field verification and Terrain Classification mapping in order to identify and map 1842 landslides, cataloguing them within a GIS-based landslide inventory. This has shown that landslides cover approximately 24% of the 546km^2 project study area, with the largest (compound) landslides reaching almost 3km width and 4,5 km length, comprising spreads of calcareous cap-rock, block slides and substantial earth flows (Hart et al., 2010).

The recent project ‘Study of landslides in areas of Paphos District’showed that landslides cover approximately 24% of the 546km^2 project study area, with the largest (compound) landslides reaching almost 3km width and 4.5 km length, comprising spreads of calcareous cap-rock, block slides and substantial earth flows (Hart et al., 2010). In addition, another study for the evaluation of landslide risk in Europe show that in some places of Cyprus (in specific areas near Paphos and the mountains of Troodos), the landslide risk varies from moderate to high with respect to their landscape susceptibility.

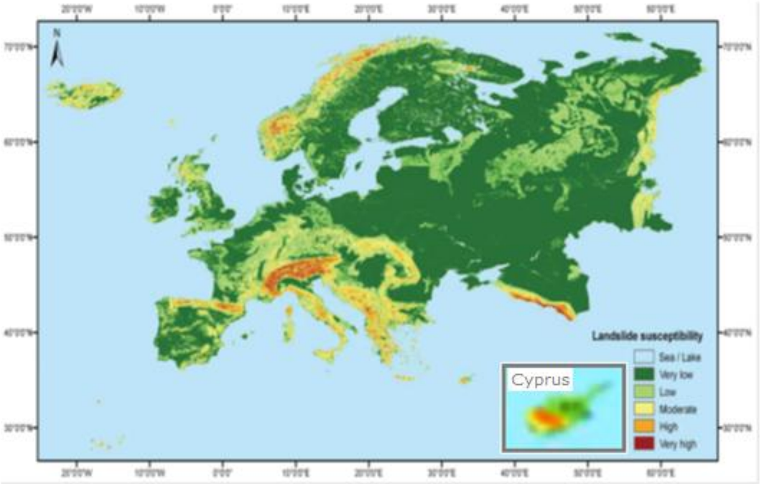

Figure 12-33: Classified landslide susceptibility map of Europe

Source: Van Den Eeckhaut et al., 2010

Temperature and precipitation changes can have an impact on lanslide occurance (Crozier, 2009) and thus affect infrastructure. An increase in temperature can cause reduction in antecedent water conditions through evapotranspiration, a rapid snow melt-runoff and infiltration and increased sea level. This could lead to lower antecedent water status-more rain required to trigger slides, build-up of porewater pressure and strength reduction and enhanced basal erosion on coasts, increase in groundwater levels on coastal slopes respectively. The anticipated increase in temperature works to the above mentioned direction.

Although further research is required to correlate possibility of landslide events and temperature increase in Cyprus climatic predictions are presented as a baseline for a future study.

In specific, Cyprus will experience, in the near future, a warming of about 1 – 2 °C. Winter minimum and summer maximum temperatures forecasted for the future period (2021-2050) are presented in the following as the most extreme cases.

Southeastern regions, well-known for its interesting and often complex geology, are anticipated to have an increase about 2.3°C in summer maximum temperature and about 0.8°C in winter maximum temperature. In Pafos district and Troodos mountain, where landslide risk is high, temperature is anticipated to reach 6.1°C and 6°C on average in winter respectively and 34 °C and 32°C on average in summer. In those areas risk of infrastructure damages due to landslide damages will be more intense. However infrastructure in those areas is limited.

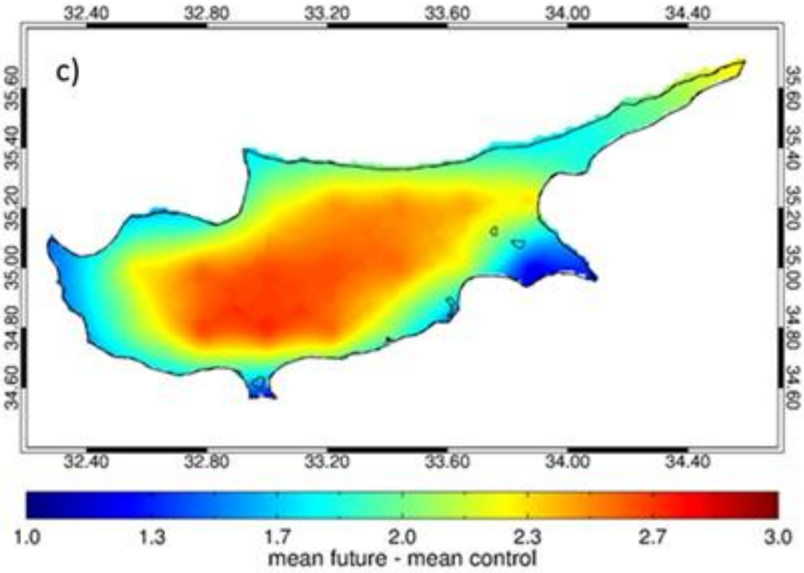

Figure 12-34: **Changes in average summer maximum temperature in the near future (Future – Control period) using PRECIS RCM model**

Maps presented in Figure 12-33 and Figure 12-34 can lead to the conclusion that in areas with high landslide risk is anticipated the higher increase in average summer maximum temperature. As a result risk of infrastructure damages due to landslide damages will be more intense. However infrastructure in those areas is limited.

Furthermore winter minimum temperature is anticipated to have an increase of 1°C in western regions, mountain regions, inland and southern regions and an increase of 0.8°C in southeastern regions.

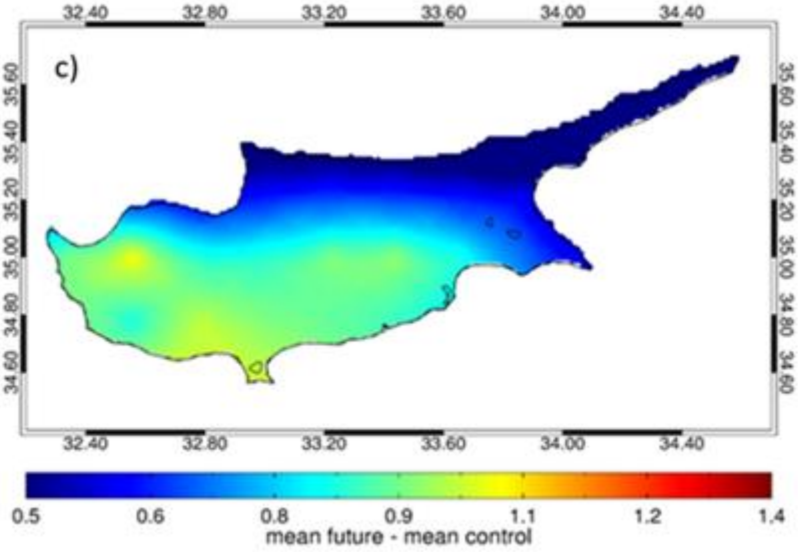

Figure 12-35: Changes in average winter minimum temperature in the near future (Future – Control period) using PRECIS RCM model

Maps presented in Figure 12-33 and Figure 12-35 can lead to the conclusion that areas with high landslide risk anticipate an increase in average winter maximum temperature that may not affect risk of infrastructure damages due to landslide damages. However infrastructure in those areas is limited.

Another climatic change that may affect exposure to landslides is change in anticipated heat wave days. PRECIS predicts an increase of about 10 days in western regions, 20-30 days in mountain regions where landslide risk is high, and 30 days in inland, southern and southeastern regions that have a complex morphology. Thus future heat wave days will be around 20 days, 40-60 days and 60 days respectively.

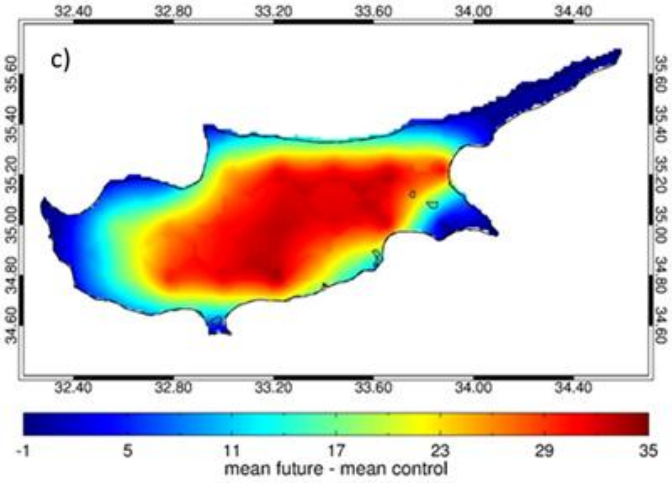

Figure 12-36: Number of heatwaves days in the near future (Future – Control period) using PRECIS RCM model

Maps presented in Figure 12-33 and Figure 12-36 can lead to the conclusion that areas with high landslide risk anticipate a significant increase in heat wave days. In those areas risk of infrastructure damages due to landslide damages will be more intense. However infrastructure in those areas is limited. Further research is required.

Increase in precipitation can lead to landslide triggering by reduction in effective normal stress leading to reduction in shear strength and increase in cleft water pressures. Furthermore increase in intensity of precipitation can cause increase in throughflow and finally increase in seepage and drag forces, particle detachment and piping. Thus future changes of annual max total rainfall over 1 day should be encountered. PRECIS projections show that a slight increase of about 2-4 mm is anticipated in western, inland and mountain regions. Additionally, southern and southeastern areas present an increase of about 1 mm in annual max total rainfall over 1 day.

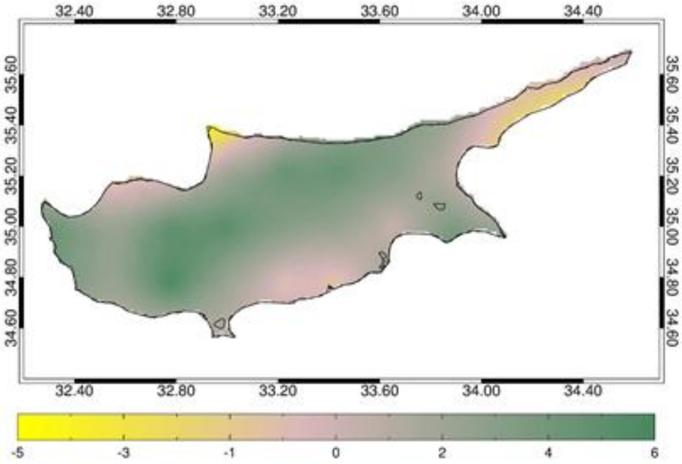

Figure 12-37: Changes in annual maximum total precipitation over 1 day between the future (2021-2050) and the control period (1961-1990).

Increase in heavy rainfall is more important in mountain regions that the risk of landslide is high, deteriorating the situation even more. Maps presented in Figure 12-33 and Figure 12-37 can lead to the conclusion that areas with high landslide risk anticipate a significant increase in heat wave days that may increase risk of infrastructure damages due to landslide damages. However infrastructure in those areas is limited. Further research is required.

Variability in precipitation and temperature can cause more frequent wetting and drying cycles that increase fissuring and widening of joint systems and reduction in cohesion and rock mass joint friction and can result landslide events. Further research is required concerning future variability in precipitation and temperature in order to assess degree of exposure.

To sum up, taking into account the current infrastructure as well as the relative future climate changes the exposure of infrastructure to landslide damages for the future period (2021-2050) can be characterized as **limited**. Further research is required.

12.4.2.2 Assessment of adaptive capacity

Given the serious risk of landslides[12], GSD has undertaken a research project entitled ‘Study of landslides in areas of Pafos District’, the main purpose being to promote a more efficient and secure urban development. It must be emphasized that it is appropriate such studies to be elaborated in order to allow the adaptive capacity to increase.

Also, few landslide protection measures have been undertaken such as road protection measures, retention walls and terraces.

Due to lack of sufficient data on the future impacts of climate change on the infrastructures of Cyprus, the analysis on the effectiveness of the already applied measures as well on the necessity for additional measures for the protection of infrastructure could not be conducted. Further research is suggested to take place on the subject.

To this end, the adaptive capacity is ranked as **limited**.

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[12] It has been recorded that some villages have been relocated to safer places in the past

12.4.3 Assessment of overall vulnerability

The principal aim of this chapter is to identify the key future vulnerabilities of the infrastructure sector to climate changes, as well as to assess the magnitude of these future vulnerabilities. However, it must be noted that, as there were no sufficient data to evaluate all indicators further research is required.

In order to quantify the vulnerability potential of the infrastructure sector against a climatic change impact, the values of sensitivity, exposure, adaptive capacity and vulnerability are quantified as follows:

Degree of sensitivity, exposure & adaptive capacity		Degree of vulnerability		Legend
None	0	None	$V \leq 0$	
Limited	1	Limited	$0 < V \leq 1$	🟩
Limited to Moderate	2	Limited to Moderate	$1 < V \leq 2$	🟨
Moderate	3	Moderate	$2 < V \leq 3$	🟨
Moderate to High	4	Moderate to High	$3 < V \leq 4$	🟧
High	5	High	$4 < V \leq 5$	🟧
High to Very high	6	High to Very high	$5 < V \leq 6$	🟥
Very high	7	Very high	$6 < V \leq 7$	🟥
Not evaluated	-	Not evaluated	-	⬜

Since vulnerability is defined by the following formula:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity * Exposure$$

“Impacts” and “Adaptive capacity” should be evaluated on the same scale (1-7). For this to be achieved, the square root of “Sensitivity x Exposure” is used. The results of the vulnerability assessment for the infrastructure sector in Cyprus are summarized in **Table** 12-8.

Table 12-8: Overall vulnerability assessment of the infrastructure sector in Cyprus to climate changes

Impact	Sensitivity	Exposure	Adaptive Capacity	Vulnerability
Damage from urban floods	Moderate to High (4)	High (5)	Moderate (3)	Limited to Moderate (1.5)
Damage from sea floods	Limited (1)	Very High (7)	Limited to Moderate (2)	Limited (0.6)
Damage from landslides	Limited (1)	Limited (1)	Limited (1)	None (0)

In general, the infrastructures in Cyprus are not considered very vulnerable to future climate changes. In specific, the first vulnerability priority of the sector to climate changes is related to the damages caused by urban floods. However, it must be noticed that specific measures have been undertaken in order to reduce the severity of this impact (drainage works, SUDS etc.). The second vulnerability priority is related to the damages to infrastructure caused by sea floods. Considering that a great number of infrastructures important for Cyprus is located in the coastal areas of the island and that Cyprus has not experienced any severe floods from the sea in the past, the vulnerability towards this impact is considered limited. The vulnerability of infrastructure systems to landslide cannot be evaluated due to limited availability of data.

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ANNEX I

Annex I: Future vulnerability scores

Sector	Impact	Sensitivity	Exposure	Adaptive Capacity	Vulnerability
Water resources	Water availability for domestic water supply in mountain areas	Very high (7)	Very high (7)	Limited to Moderate (2)	High (5)
Water resources	Water availability for irrigation in mountain areas	Very high (7)	Very high (7)	Limited to Moderate (2)	High (5)
Soils	Desertification	Very high (7)	Very high (7)	Limited to Moderate (2)	High (5)
Tourism	Water availability for irrigation and other uses	High to Very high (6)	High (5)	Limited (1)	High (4.5)
Water resources	Droughts	Very high (7)	Very high (7)	Moderate (3)	Moderate to High (4)
Water resources	Water availability for irrigation in plain & coastal areas	Very high (7)	Very high (7)	Moderate (3)	Moderate to High (4)
Water resources	Water quality of groundwater bodies	High to Very high (6)	High to Very high (6)	Limited to Moderate (2)	Moderate to High (4)
Forests	Dieback of tree species, insect attacks and diseases	Very high (7)	Very high (7)	Moderate (3)	Moderate to High (4)
Forests	Fires	Very high (7)	Very high (7)	Moderate (3)	Moderate to High (4)
Agriculture	Crop yield alterations	Very high (7)	High (5)	Limited to Moderate (2)	Moderate to High (3.9)
Biodiversity	Distribution of plant species in terrestrial ecosystems	High (5)	High (5)	Limited to Moderate (2)	Moderate (3)
Biodiversity	Distribution of animal species in terrestrial ecosystems	High (5)	High (5)	Limited to Moderate (2)	Moderate (3)
Public health	Deaths and health problems related to heat waves and high temperatures	High (5)	Moderate to High (4)	Limited to moderate (2)	Moderate (2.5)

Sector	Impact	Sensitivity	Exposure	Adaptive Capacity	Vulnerability
Agriculture	Damages to crops from extreme weather events	High (5)	Moderate to high (4)	Limited to Moderate (2)	Moderate (2.5)
Soils	Soil erosion (by wind and/or rain water)	Moderate to High (4)	High (5)	Limited to Moderate (2)	Moderate (2.5)
Tourism	Heat waves	High (5)	High (5)	Moderate (3)	Limited to Moderate (2)
Tourism	Water availability for drinking water supply	High (5)	High (5)	Moderate (3)	Limited to Moderate (2)
Energy	Energy demand	Very High (7)	Very High (7)	High (5)	Limited to Moderate (2)
Agriculture	Soil fertility alterations	Moderate (3)	High (5)	Limited to Moderate (2)	Limited to Moderate (1.9)
Coastal zones	Coastal erosion	High (5)	Moderate to High (4)	Moderate (3)	Limited to Moderate (1.5)
Infrastructure	Damage from urban floods	Moderate to High (4)	High (5)	Moderate (3)	Limited to Moderate (1.5)
Soils	Soil salinization - sodification	Moderate to High (4)	Moderate (3)	Limited to Moderate (2)	Limited to Moderate (1.5)
Tourism	Coastal erosion	High to Very high (6)	Moderate (3)	Moderate (3)	Limited to Moderate (1.2)
Biodiversity	Marine biodiversity	Moderate (3)	High to Very high (6)	Moderate (3)	Limited to Moderate (1.2)
Water resources	Water availability for domestic water supply in urban areas	Very high (7)	Very high (7)	High to Very high (6)	Limited (1)
Fisheries	Quantity and diversity of fishstocks	Moderate (3)	Moderate (3)	Limited to Moderate (2)	Limited (1)
Coastal zones	Coastal storm flooding and inundation	Moderate to High (4)	Limited to Moderate (2)	Limited to Moderate (2)	Limited (0.8)
Infrastructure	Damage from sea floods	Limited (1)	Very High (7)	Limited to	Limited (0.6)

Sector	Impact	Sensitivity	Exposure	Adaptive Capacity	Vulnerability
				Moderate (2)	
Fisheries	Cost implications for fishermen	Moderate (3)	Moderate (3)	Moderate (3)	None (0)
Public health	Air pollution-related diseases	Moderate (3)	Moderate (3)	Moderate (3)	None (0)
Biodiversity	Freshwater biodiversity	Moderate (3)	Moderate (3)	Moderate (3)	None (0)
Infrastructure	Damage from landslides	Limited (1)	Limited (1)	Limited (1)	None (0)
Water resources	Water quality of surface water bodies	Moderate to High (4)	Limited to Moderate (2)	Moderate (3)	None (-0.2)
Energy	Efficiency of thermal power plants	Limited (1)	Moderate (3)	Limited to Moderate (2)	None (-0.3)
Tourism	Storms, waves and floods	High to Very high (6)	Limited to Moderate (2)	Moderate to High (4)	Limited (0.5)
Public health	Flood-related deaths and injuries	Limited to Moderate (2)	Moderate(3)	Moderate (3)	None (-0.6)
Public health	Fire-related deaths and injuries	Moderate (3)	Limited to Moderate (2)	Moderate (3)	None (-0.6)
Soils	Landslides	Moderate (3)	Limited to Moderate (2)	Moderate (3)	None(-0.6)
Tourism	Biodiversity attractions	Limited (1)	Limited to Moderate (2)	Limited to Moderate (2)	None (-0.6)
Fisheries	Fishstock physical environment	Limited (1)	Limited (1)	Limited to Moderate (2)	None (-1)
Water resources	Floods in urban areas	Moderate to High (4)	Limited (1)	Moderate (3)	None (-1)
Tourism	Warmer winters	Moderate (3)	Limited (1)	Moderate (3)	None (-1,3)
Soils	Soil contamination	Limited (1)	Moderate (3)	Moderate (3)	None (-1.3)
Public health	Landslide-related deaths and injuries	Limited to Moderate (2)	Limited (1)	Moderate (3)	None (-1.6)

Sector	Impact	Sensitivity	Exposure	Adaptive Capacity	Vulnerability
Public health	Vector-borne and rodent-borne diseases	Limited (1)	Limited to Moderate (2)	Moderate (3)	None (-1.6)
Energy	Renewable energy yield	Limited to Moderate (2)	Limited (1)	Moderate (3)	None (-1.6)
Public health	Water-borne and food-borne diseases	Limited (1)	Limited to Moderate (2)	Moderate to High (4)	None (-2.6)
Tourism	Warmer summers	High to Very high (6)	None (0)	Moderate (3)	None (-3)
Water resources	Floods in mountain areas	Limited (1)	Moderate (3)	High (5)	None (-3.3)
Public health	Climate-related effects upon nutrition	Limited to Moderate (2)	Limited (1)	High (5)	None (-3.6)
Forests	Floods	Limited (1)	Limited (1)	High (6)	None (-5)
Agriculture	Increase in pests and diseases	Not evaluated	Not evaluated	Not evaluated	-
Agriculture	Alterations in livestock productivity	Not evaluated	Not evaluated	Not evaluated	-
Agriculture	Increase in costs for livestock catering	Not evaluated	Not evaluated	Not evaluated	-
Coastal zones	Degradation of coastal ecosystems	Moderate to High (4)	Not evaluated	Not evaluated	-
Forests	Forest growth	Not evaluated	Very high (7)	Moderate (3)	-