ENVIRONMENTAL REMOTE SENSING BY SIMPLE MEANS

Desmond O'Connor and Graeme Wright,
Murdoch University, Western Australia.

It is becoming increasingly commonplace for all countries, industrialised and developing, to introduce environmental protection and management procedures. Precise details and objectives of these procedures vary from place to place, and in fact are in a continuing state of evolution, but most of them require an initial environmental assessment to be made, followed by management and monitoring programmes as development proceeds.

Early environmental impact studies placed considerable emphasis on the initial environmental inventory in a form which consisted of lists of animal and plant species so that rare or unusual types could be protected. Five or six years of expeirence with this approach has proved that it is no longer adequate. Only in recent times have we begun to realise the systems-nature of the environment in terms of the relations and interactions between its various parts, and today environmental science is undergoing quite a revolution in attitudes (Dempsey, 1979). We are no longer concerned with simple lists of natural attributes, but rather with the total ecology of an area - with how it works.

The ecologist is now coming into his own in environmental protective procedures, and there is an even greater demand for environmental information on which to base informed judgments when large developmental projects are being proposed. Unfortunately, reliable environmental information is largely lacking for the greater part of the world at the level of detail required, and this at a time when the world's environment and resources are coming under increasing stress, and where post-construction monitoring and audits are becoming routine practice. Few real problems exist in areas of the world where capital, skills and geography make it feasible to proceed with the orderly acquisition and analysis of environmental data using already proven techniques. However, many areas of the world which need development, and in which development is taking place, are often remote, under-populated and do not have the capability of supporting intensive studies, at least in the initial feasibility stages. Satellite data does not yet yield sufficiently detailed information, particularly for monitoring and management. Information is often needed on individual elements of vegetation and terrain.

This paper outlines a very simple approach to such a situation in the State of Western Australia. Figure 1 gives some idea of the geography of the area. The state is almost 2.6 million square km in area and has a population of approximately 1 million, 85% of which is concentrated in and around the capital city of Perth. Most development activity is taking place in the far north of the State, often 2000 km or more from the capital city where much of the necessary scientific expertise resides. Although many of the remote sensing techniques required for environmental inventories are available in the southern part of

Figure 1. The state of Western Australia and the distances involved.

the state, it is extremely costly to deploy aircraft over such great distances, certainly for preliminary studies. An added difficulty arises from the fact that most applications of remote sensing techniques for vegetation and ecological inventories are based on work in the northern hemisphere and are not always directly applicable to arid zones such as are encountered in much of Western Australia. The ecology of this area, although harsh, is extremely sensitive and fragile. Added to this, most development projects involve construction of port sites and processing facilities on the coast, and as yet few if any studies of the fragile coastal ecology have been made. In fact, in recent times considerable anxiety has been felt over coastal mangrove ecological systems as they are a declining resource and play vital roles in fish life cycles and in maintaining coastal stability. It is this latter point which makes it vital that continuing monitoring programmes be maintained in order that any adverse effects on coastal mangroves can be detected as early as possible. If mangroves die, the coast loses its protection, becomes unstable, and can become a great source of silt and debris which can radically impact on the maintenance of harbour and docking works. The need to monitor at frequent intervals again makes the application of conventional techniques something of a problem in remote areas.

The work described in this paper had comparatively simple objectives. Firstly, it was designed to examine the feasibility of using 35 mm cameras from light aircraft flown at low altitudes in remote areas where temperatures often exceed 40°C, and where refrigeration facilities for film storage are often not available. It has been widely held for many years that infra-red photography offers advantages in vegetation mapping, particularly where vegetation stress is under study. However, little information was available on the use of this technique with arid-zone and coastal vegetation in the northern parts of Australia, so some tests were devised in connection with ground radiometer measurements and micro-densitometer measurements on negatives to verify whether infra-red photography really offered any advantage. Other investigations related to desirable photo scale, time of year, and orientation of the cameras with respect to the sun, the possibility of using vertical photography in association with various obliques, and the general quality of simple obliques as a guide for selection of more complex mapping systems.

INTERACTION OF VEGETATION WITH ELECTROMAGNETIC RADIATION

Until quite recently the reflectance mechanism of leaves was not known with any certainty, but there is now emerging a consensus that reflectance in the visible and near infra-red is largely governed by the internal leaf structure, and within the visible portion this is modified by the absorption by chlorophyll. Refractive index discontinuities, including air-cell interfaces, contribute particularly to the reflectance in the near infra-red, and this is also modified by the structures on the leaf surface.

These remarks apply particularly to the individual leaf, but a remotely sensed image is made up of an integration of inputs from leaves, bark, stems, soil background, leaf litter, multiple layers of leaves, and shadows, do that whilst an understanding of the reflectance of individual leaves is essential, the reflectance of a vegetation canopy is dependent upon a complex combination of characteristics which modify the reflectances expected from individual components. This makes it quite difficult to assess the radiation coming from an image as a basis for input to an airborne sensor.

PRELIMINARY INVESTIGATION

In order to obtain an initial idea of the suitability of emulsions, photo scales, etc., a preliminary investigation (Murdoch University 1979) was undertaken in association with a vegetation mapping project of the Western Australian Museum (Muir, 1977). The area was a reserve of 4961 ha, Latitude 32°22'S, Longitude 118°30', with low-fertility lateritic soils and a vegetation of mallee and woodland.

Limited phenological observations suggested that active new growth would be favoured by the warm temperatures and high soil moisture, offering good species discrimination.

Conventional vertical photographs were consequently obtained in November 1975 with Kodak Aerocolour 2445 and Aerochrome Infrared 2443, using UV and B filters respectively, at scales of 1/10,000, 1/5,000, and 1/2,000. In addition to this basic cover, obliques from altitudes 500-1500 feet AGL were taken with twin Rollei 35S cameras (Figure 2), Sonnar 2.8/40 lens, using Ektachrome EPR and IR emulsions, with Rollei UV and orange filters respectively. The orange filter had a sharp cutoff at 0.58 µM. Obliques were taken in August and November 1976, and January and March, 1977. Simple film handling techniques were used. Films were transported in a styrofoam box containing an ice brick.

The following conclusions were drawn from this preliminary trial, based on visual inspection techniques :-

1. Formation identification was the most practical method of mapping this particular vegetation, and formations were more accurately and rapidly identified with false-colour infrared film. Classification using verticals and obliques yielded more information than verticals alone. Plant genera not identifiable on 1/10,000 verticals could be identified on the obliques and the number of strata and the number of sub-formations identifiable on the obliques allowed areas to be studied more intensively.

2. Of the photo-scales examined, 1/10,000 contained sufficient information to classify the vegetation, the 1/5,000 contained sufficient intra-formation detail for intensive studies and yielded as much information as the 1/2,000.

3. False-colour infra-red appeared superior for detecting the presence of vegetation (important in rangeland monitoring), but colour film indicated a wider range of colours for soil types. Species identification of the mallee vegetation was not possible on the colour or false-colour verticals. False-colour provided greater colour variations over the growing season, and the optimum periods for photography were mid-spring and mid-autumn.

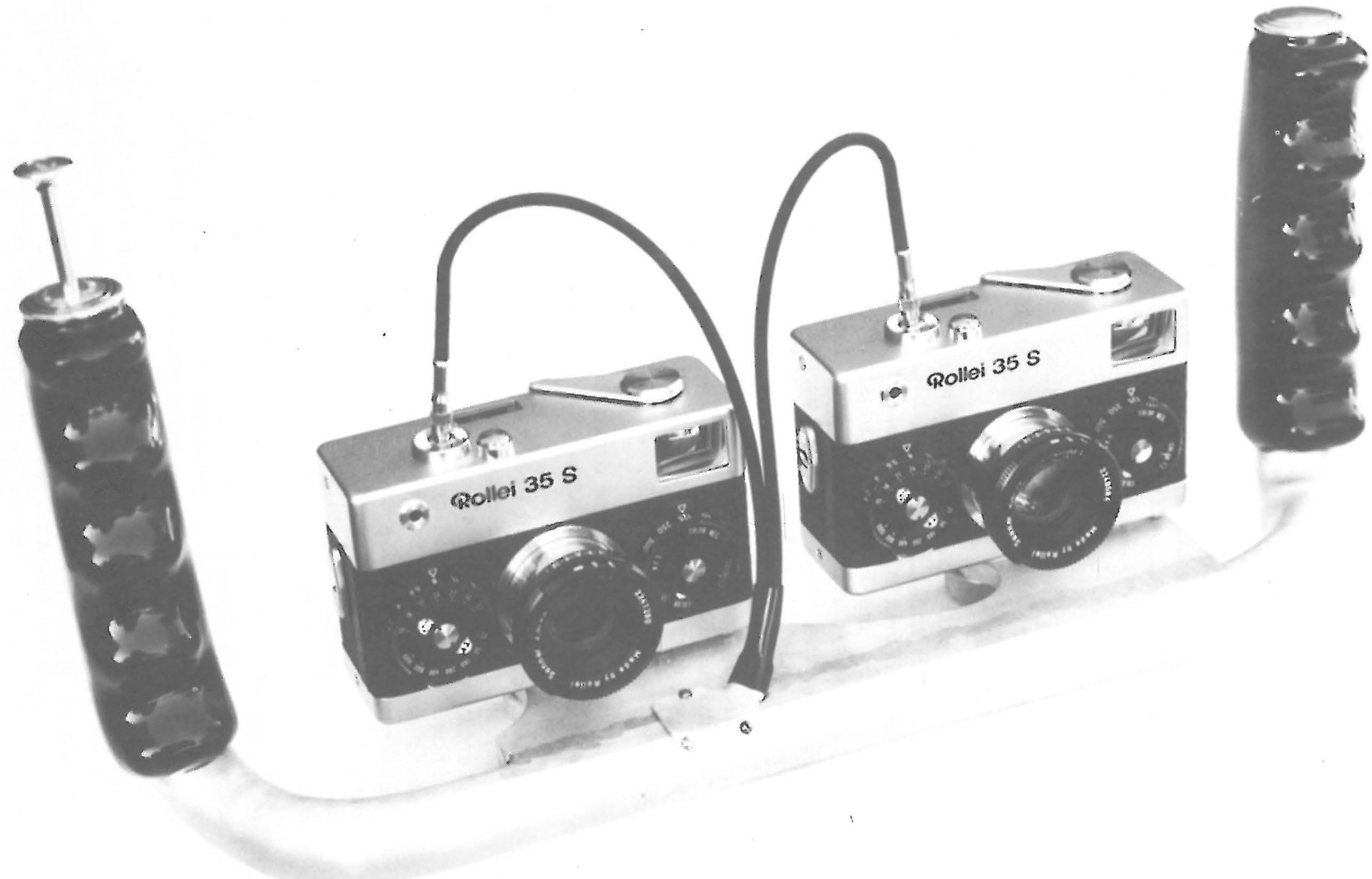

Figure 2. The twin camera system.

GENERAL DISCUSSION OF THE PRELIMINARY RESULTS

Of the two methods of vegetation mapping considered floristics and structure (formation), it seemed quite clear that the use of formation is the only practical method of mallee vegetation when aerial photographs are used. For floristic mapping, all species must be identified, and this was not possible in aerial photographs of the scales used. Identification of some species was facilitated by false-colour infra-red photographs, but this required an experienced interpreter, familiar with the site and species present. According to Muir, only four classes are necessary for the classification of vegetation in this area. Photographs at 1/10,000 showed these four classes, and all formations could be identified. Examination of the available 1/40,000 black and white photographs yielded only three classes and some of the formations identifiable on the 1/10,000. Table I shows a summary of the information obtained from the various vertical photographs. The floristic relative score is based upon the maximum number of genera identified, which was 10 in the 1/2,000 photographs.

Scale	Density classes	Formations identified (structure and density)	Floristic relative score (General)	Intraformation variation (Sub-formations)
1: 2000	6	all	10	all
1: 5000	6	all	7	all
1:10000	4	all	5	some
1:40000	3	some	3	nil

Note: 1:40000 photographs were black and white, all other scales used were colour and false-colour infra-red.

TABLE I. Summary of photographic scale and interpretation results.

The Table confirms that the 1/10,000 scale yielded the best results in this particular situation, which is similar to that where a preliminary environmental assessment would have to be made. At scale of 1/2,000 and 1/5,000 six classes can be identified, but this is unnecessary for this purpose.

Intensive studies of particular areas could be carried out at 1/5,000 and these photographs would show all the intra-formaton variation and more detail on different densities and canopy covers. The 1/5,000 scale contains all the details of the 1/2,000, so there is no advantage in using the larger scale.

Identification of the structural and density parameters of formations was more accurately and more rapidly carried out on the false-coloured infra-red photographs. Although formations were identifiable on both emulsions, identification on the colour in most cases could only be carried out after the formations had been observed initially on the false-colour infra-red. Colour differences between formations on colour photographs appeared to be more subtle than those on the false-colour infra-red. This bears out the subjective impression one gets of the vegetation in this part of the world which appears drab and colourless unless inspected at very close range. This applied at all the scales examined. False-colour infra-red film has the effect of enhancing canopy, thus the interpretation of structure parameters is facilitated. The leaves appear red and the bark and stems blue-white, whereas on colour film the leaves are green and the bark and stems green-brown so the canopy is partly camouflaged by its own branches.

No advantage was found in trying to identify individual species from either colour or false-colour infra-red colour photographs. Because of the diversity of species present in the mallee system, this could only be carried out by extensive ground reference data collection. Although between-species variation in the infra-red reflectance is greater than in the visible, colour differences on the infra-red could not be uniquely related to a species because of variations caused by water stress, insect damage or disease.

In arid-zone rangeland management there are situations where it is useful to know whether vegetation is present or not. If the vegetation is low and sparse it is difficult to distinguish from rocks or the surface of the soil. However with false-colour infra-red film, the slight traces of red present indicate with certainty that vegetation of some description is present. This has proved to be important in looking at regeneration after a fire has passed through an area. The signs of initial regeneration are very obvious on false-colour film but very difficult to see on colour film. Also in an area where a recent fire has passed, there is very clear distinction between the burnt and unburnt vegetation in false-colour infra-red photographs.

Classification of soils has proved easier on colour photographs than on false-colour infra-red. Infra-red reflectance of soils is very low, and because of the relative spectral responses of false-colour infra-red and colour film, colour films depict soils with a wider tonal range. In cases where vegetation patterns follow soil patterns, a vegetation map compiled from false-colour infra-red photographs may indirectly indicate soil patterns.

Information derived from this preliminary study has highlighted several important uses of oblique photographs. Since the making of a vegetation map for ecological and environmental inventory does not require the same accuracy as that required for a topographic map, oblique photographs are found to be particularly helpful for this purpose. By using common features on the oblique and vertical photographs, and the spatial relationships derived principally from the verticals, vegetation formations and fire boundaries could be mapped from the high obliques on to a planemetric base.

The obliques were particularly useful in the test area for monitoring the effects of bush fires. The fire regeneration maps are used in the management of areas for many purposes, including the estimation of the number of vertebrates likely to be present. For certain animals to exist it is found that certain regeneration stages must be present.

The use of the obliques for updating 1/40,000 black and white photographs does not have the same potential as for updating 1/10,000 photographs. An accurate base map could not be obtained containing all the fomration information from the 1/40,000 photographs as mentioned earlier, because the identification of common formations between the obliques and the 1/40,000 photographs became difficult and even impossible.

As mentioned earlier, no quantitative radiation measurements were taken during the preliminary tests, but it was found that photographic aspect in relation to solar direction played an important part in the general image quality. For the higher solar intensities encountered during summer, aspect was important, while in winter it did not appear to be as important. In this case, better results were obtained with the camera facing north towards the sun.

Based on this study it seems reasonable, then, to conclude that quite detailed enviornmental assessments may be made of arid zone vegetation using simple and inexpensive means with very simple film handling and transportation techniques. Using oblique photography, a regular and inexpensive environmental monitoring programme can be established and used to produce management plans at regular intervals. The advantage of this system is that current information for management is available, and an accurate assessment of programmes can be made as often as necessary without elaborate equipment. The results were considered sufficiently promising to warrant a quantitative trial involving spectral radiometer measurements in the field and on negatives in the laboratory.

QUANTITATIVE INVESTIGATION

Wright selected an area of coastal dune vegetation at Cape Peron Western Australia, Latitude 32°16'S, Longitude 115°41'E (Wright, 1978). The Western Australian Department of Conservation and Environment sponsored the study. Vertical photography at a scale of 1/4,000 was taken with Kodak Aerocolour negative film and Aerochrome infra-red film using Zeiss UV and minus blue filters respectively.

Oblique photography was as in the preliminary test, but from a height of 500 feet A.M.S.L.

The orange filter used in the oblique photography had a sharp cutoff at 0.58 μM, so the infra-red obliques were exposed to radiation in the near infra-red only, whereas the verticals were exposed to radiation in the green and near infra-red regions.

Ground reflectance data were collected using a Gamma Scientific spectroradiometer. The collecting telescope had a minimum focussing distance of 1.8 metres. Two monochrometer assemblies were available with scan ranges 0.2 to 0.8 micrometers and 0.3 to 1.1 micrometers, together with photomultiplier tubes of range 0.25 to 0.75 micrometers and 0.5 to 1.1 micrometers.

A colour densitometer was also used to evaluate the efficiency of colour and false-colour films of coastal zone vegetation. The device uses many of the units of the spectroradiometer.

An aluminium panel 0.75 m. square, coated with British paints Supa-flat Pure White paint (Laboratory Certified Test No. 281889) served as a standard reflectance panel, and a means of determining the spectral distribution of the illuminating radiation. The paint properties proved to be identifical with titanium dioxide impregnated paint (Borden, U.S.A.) within the precision of the measurements.

The vegetation samples chosen were:

Bromus maximum
Rhagodia baccata
Acacia rostellifera
Olearia axillaris
Pelargonium capitatum.

By comparing the actual reflectance of a target with the response of the emulsions via a colour microdensitometer, it was hoped to devise an objective evaluation of emulsion performance.

RESULTS

Detailed conclusions and results are given by Wright (1978) but some of his conclusions relating to the preliminary studies should be noted here.

Table 2 shows the range of reflectance values between species at various wavelengths. It is these differences in reflectance that are used to differentiate between species on aerial photographs.

Species	Reflectance (%)			
	Blue 0.45 um	Green 0.55 um	Red 0.65 um	Near infra-red 0.8 um
Bromus maximus	1	5	3	50
R. baccata	3	10	4	87
A. rostellifera	3	7	5	29
O. axillaris	4	9	6	49
P. capitatum	2	9	4	49
Range	3%	5%	3%	58%

TABLE 2. Summary of reflectance characteristics of the 5 coastal dune species studied, determined by radiation measurements.

The dominance of reflectance in the near infra-red region is obvious. Wright's study enables the following pertinent conclusions to be drawn:

1. Solar radiation variables may be controlled through test panel observations;

2. Although all species of plants studied had the expected spectral characteristic of vegetation, reflectance in both the visible and near infra-red vary significantly from species to species, and this was most evident in the case of the near infra-red portion of the spectrum.

3. False colour infra-red film produced a wider range of chroma in the near infra-red than either film in the visible, from corresponding targets. The false colour obliques produced transmittance values over a range of 25% compared with 15% in the green region on colour film.

4. The use of obliques taken from light aircraft is extremely cost effective, and may be undertaken by non-professionals. Table 3 gives comparative costs for a mission to the Cape Peron area, 30 km from base, involving a flying time of 1 hour.

	Vertical	Oblique
Format	230mm x 230mm	35mm
Exposures	20 (10 colour,10 IR)	40 (20 colour,20 IR)
Aircraft hire	$180	$72
Film	77	6
Processing*	30	5
Mounting	30 (border information)	5
Printing	90	N/A
Total	$407	$88

* Films are processed to the cheapest format. Vertical photographs are processed to negatives, and contact printed. Oblique photographs are processed to positive transparencies and viewed using slide projector/viewer.

TABLE 3. Comparative costs involved in taking oblique and vertical photographs of an area assuming a total flying time of one hour.

CONCLUSIONS

Preliminary environmental assessments of arid zone mallee and dune vegetation may be made more effectively with false-colour infra-red emulsion. Formation identification is the most practical method, and classifications using verticals and obliques yielded more information than verticals alone. For preliminary assessment, false-colour infra-red verticals, 1/10,000 scale contains sufficient information to identify the four classes of vegetation considered necessary. The optimum times for photography were mid-autumn and mid-spring.

The simple, twin camera system used produced more discreet information than the standard mapping camera. For optimum interpretation of vegetation of the type studied, film/filter can be selected so that maximum reflectances are imaged on separate films, even with very simple systems. Although spectral measurements on the ground before a mission are desirable for system design, experimental photography can give quite good indications of suitable combinations.

Since the oblique photographs used in this experiment produced spectral resolution superior to the system used in taking the standard verticals, it would appear safe to conclude that they can be used for monitoring and inventory of dune and mallee vegetation.

Planimetric information can be obtained from associated verticals, even black and white, and updated monitoring information can be transferred through the comparison of detail. It has been found particularly simple and effective to project the obliques side by side on to a wall in front of the interpreter who is viewing verticals through a stereoscope and making the necessary annotation on those verticals for subsequent inclusion on a map.

Large areas of coastal mangroves are currently being monitored in this way. The directions of the obliques are indexed on a master map, and it is a very simple matter to run through a succession of photographs taken over quite a long period. This is found to be particularly useful in areas subject to intense public use. At early stages of environmental degradation it is often necessary to monitor individual trees.

The study has shown that many of the well known beneficial attributes of infra-red film obtained in the northern hemisphere can be translated to the arid zones. Oblique photos taken with small cameras and light aircraft can no longer be regarded only for their panoramic value. They are a useful, cost-effective aid in vegetation management and monitoring. False-colour infra-red emulsions appear to be more efficient than normal colour emulsions in translating scene reflectance characteristics. The response of false-colour infra-red film to near infra-red radiation produces a wider range of chroma than either film in the visible spectrum, thus showing greater potential for the discrimination of targets in this spectral region.

Small format (35 mm) colour and false-colour infra-red films are readily available and the image qualities are excellent for evaluating emulsion properties prior to large scale photographic missions. The cost of experimentation would be insignificant compared with the overall cost of the mission, but it may highlight the need to use specific filters or emphasise that no advantage is to be gained using a particular emulsion.

REFERENCES

DEMPSEY, S. (1979) "Adaptive Environmental Management - an Industrial Viewpoint" AMAX Environmental Services Inc., Denver, Colorado, U.S.A.

MUIR, B.G. (1977) "Vegetation - West Bendering Reserve" In Biological Survey of Western Australian Wheatbelt. Rec. West. Aust. Mus. Suppl. No. 3: 3-142.

MURDOCH UNIVERSITY (1979) "An Application of Aerial Photography to Vegetation Mapping". Murdoch University, Murdoch, W.A., 6153.

WRIGHT, G. (1978) "The Evaluation of Photographic Remote Sensing Applied to Coastal Vegetation" Bachelor of Science Honours Thesis, Murdoch University, Murdoch, Western Australia, 6153.