Vegetation Monitoring

Karijini National Park

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Executive Summary

This report is for the Pilbara Region of the Department of Conservation and Land Management (CALM), and describes the research findings and the use of satellite data over Karijini National Park. The major emphasis of the research was to evaluate the Landsat TM data to locate, map and vectorise fire scar boundaries for 1996 within the park. An extension to the research was also to quantify biomass build-up within the park.

The research was initiated by CALM in collaboration with Remote Sensing Services (RSS) from the Department of Land Administration (DOLA).

The findings were:

1. Fire scars for 1996, within Karijini National Park, were successfully located and mapped. The fire scar boundaries were digitised and imported into the appropriate data base.

2. Fuel build-up and fuel load were estimated and shown in graphical form. The location and accuracy were estimated to be appropriate for operational use as per ground inspection.

3. Both 1) and 2) have shown the usefulness of satellite imagery as a monitoring tool as an aid in operational management decisions. This information can be made available on an annual basis.

4. NOAA-NDVI time traces from the Vegetation Watch Program were a useful aid to select the most suitable TM imagert.

5. The NDVI algorithm proved successful in showing locations of maximum and minimum biomass within the park.

Introduction

Satellite remote sensing offers the potential to provide quantitative information on large tracts of land, on a repetitive basis, that would be otherwise almost impossible to cover using traditional ground-based methods. The continuing research and development, that has guided this technology in areas of environmental monitoring, has provided methodologies that are applicable to vegetation monitoring requirements for CALM.

Location of fire occurrence boundaries and biomass status in areas such as Karijini National Park, are environmental questions for which satellite technology can provide regular information. By calculating the timing of the acquisition of satellite imagery, and applying known methods, it is possible to provide information promptly that should be used operationally in management.

Objectives

The objective of this study is to develop an annual monitoring system for CALM, using Landsat Thematic Mapper imagery, within Karijini National Park that can aid in the detection and mapping:

- of fuel load build-up of grasses and associated vegetation; and
- the extent of recent fire scars.

Method

To use satellite imagery to locate and map fuel load build-up and the extent of the recent fire scars within the National Park it is necessary:

- to establish which image dates, within the given time frame, would give the best possible result given the known seasonal impacts within the region;
- to accurately calibrate each image date to a reference image so that any change that had occurred between the dates is real;
- to establish spectral image enhancements, (from the Normalised Difference Vegetation Index (NDVI) for each image it is possible to interpret gross change associated with fire. These changes can then be highlighted into a colour display. The areas can be classified or boundaries can be manually digitised); and
- to produce NDVI over the selected sequential image dates for biomass interpretation, (by adding the annual maximum NDVI response from one year to another its possible to interpret locations within the park that have had successive increases in biomass or fuel load. Conversely by subtraction of the annual minimum NDVI from the annual maximum NDVI of any year it is possible to show locations of low biomass build-up or no increase in fuel load within that period).

Background to Remote Sensing Technology

Remote sensing is the acquisition of information about material objects from measurements made from a distance. The more common sensors include aerial and satellite cameras, multispectral cameras, scanners and radar systems designed to collect spectral data remotely and minimise collecting costly on-site ground data.

In all applications of remotely sensed data, it should be remembered that spectral, (wavelength or colour) spatial, (ground resolution) and temporal (changes caused by time) variations will influence the result.

Remote sensing is normally directed towards the surface of the earth and as such is designed to facilitate the managing of the earth's natural resources. Whether viewed on a local, regional, national or global basis, the human demand for earth resources (both renewable and non-renewable) is increasing at the very time when the supply of many of them is rapidly diminishing and the quality of others is deteriorating. Under such conditions, the careful management of these resources is vital. Wise management is greatly facilitated if timely, accurate inventories are periodically made available to the resource manager.

When dealing with natural resources, such as Karijini National Park, resource managers are likely to find that these resources are highly dynamic and not static, thus they will need to obtain periodic inventory - known as 'monitoring' or 'temporal assessment'.

Remotely sensed data can be used as a tool to detect, monitor and evaluate changes in ecosystems to develop management strategies for ecosystems resources. Satellite and airborne systems offer a plausible monitoring system for large-scale, earth surface viewing and provide a usable data base for change detection studies. Remote sensing data can be used to span temporal and spatial scales ranging from local systems to aggregated global systems (Graetz, 1990).

Recording land cover change over time is arguably one of the most important applications of digital remote sensing data, and aerial photography represents the most extensive archival remote sensing information set available. Unfortunately, aerial photography is in an analogue form and the manual handling of such an array of data for change detection using sequential photography is a formidable task (Adeniyi, 1980).

NOAA Time Trace

Green vegetation cover can be estimated from measurements of spectral reflectance made by the Advanced Very High Resolution Radiometer (AVHRR) on the National Oceanic and Atmosphere Administration's (NOAA) polar orbiting meteoritical satellite.

The AVHRR data is provided from the Western Australian Satellite Technology and Applications Consortium (WASTAC) in Perth and produced by the Western Australian Vegetation Watch Program, and made available by the Remote Sensing Services (RSS) of the Department of Land Administration (DOLA). The data are processed to provide a bi-monthly report on the green vegetation cover of the entire state at a ground resolution of 1 km (Smith, 1994).

The AVHRR data, were processed for Karijini National Park for a grid interval of 2min of latitude and longitude centred on 118.25E Latitude and 22.75S Longitude. A fortnightly trace of the NDVI values for the grid were then inspected to locate the seasonal periods of maximum and minimum NDVI for the Park for the period 1991 - 1996. Using the range of variation in vegetation, as measured by the coarser resolution AVHRR, three sequential Landsat Thematic Mapper (TM) images were chosen for the analysis to represent the extremes of greenness within the park.

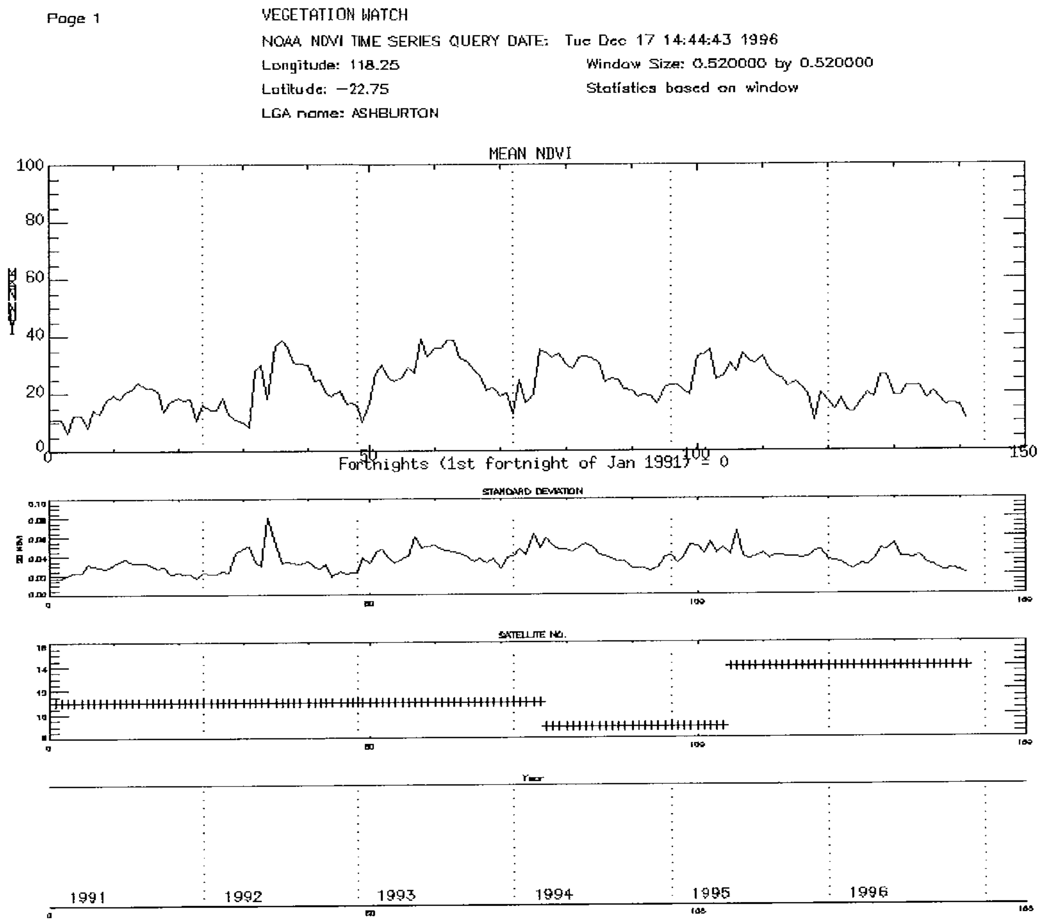


Figure One: The NDVI data derived from AVHRR from the DOLA Vegetation Watch Program. These data were processed for the Karijini National Park From inspection the maximum and minimum NDVI occurrences were used to locate the most appropriate Landsat Thematic Mapper Images.

From the NDVI time trace (Figure One) the three TM scenes were, March 1994 and April 1996, selected for maximum NDVI and December 1995, selected for minimum NDVI. Two scenes were purchased and made available by RSS and the other purchased by CALM.

Landsat TM Data

TM images provide regular broadscale coverage and are ideal for mapping and monitoring change. The ground picture element (pixel) size (30m) is practical for broad-area damage surveys as each pixel integrates the combined response of vegetation, soil and regolith for this area. Monitoring change also becomes possible with the ability to co-register and analyse imagery from various dates. Up to twenty two images per year of TM data are available for any area although in some areas cloud cover remains a problem for satellite monitoring.

Thematic Mapper imagery has seven bands - bands one, two and three in the visible parts of the spectrum, band four in the near infrared and bands five and seven in the short-wave infrared portions of the spectrum. Band six is located in the thermal infrared part of the spectrum (Table One).

Band No.	**Wavelength Interval (μm)**	**Spectral Response**	**Resolution (m)**
1	0.45 - 0.52	Blue-Green	30
2	0.52 - 0.60	Green	30
3	0.63 - 0.69	Red	30
4	0.76 - 0.90	Near IR	30
5	1.55 - 1.75	Mid IR	30
6	10.40 - 12.50	Thermal IR	120
7	2.08 - 2.35	Mid IR	30

Table One: Wavelength interval, spectral response and resolution of TM satellite imagery.

The three images used in this study were located, as described above, on the scene (path 112, row 076). Bands 3 and 4 were used for the NDVI analysis while bands 2, 3 and 4 were used for image enhancements and displays. The imagery, for all dates, had varying small portions of the western part of the National Park omitted, because of small shifts in the satellite's image orbital cycle, but this was considered not to be a significant enough problem to the study.

Calibration of TM Imagery

The image calibration approach followed procedures by Campbell and others, (1994) and selected 'invariant' targets (targets that are common or should remain constant and unchanged through time) including dense creek vegetation, shadow, cleared land, and rock outcrops. These targets were then used to calibrate the digital counts of the target imagery to digital counts of the reference imagery. The reference image being the 1996 spring image for calibrating both the March 1994 and April 1996 images. Calibration of the imagery is a vital requirement when gathering information about change. The variation or change in spectral responses of any object can only be measured and quantified if these procedures are carried out. Established robust regression techniques were used to estimate the gains and offsets to be applied to each image calibration.

The data values are used to define linear functions that transform each image to the reference image by assuming that changes in the digital counts are caused by to sensor and atmospheric effects and not changes to the target. Targets must be selected to cover a range of bright, mid-range, and dark data values.

Normalised Difference Vegetation Index (NDVI)

Indices, or mathematical combinations of spectral bands, are derived to express spectral anomalies that are diagnostic of specific target materials. The most commonly used is based on normalised ratios and can very effectively measure the amount of green vegetation cover over the soil. Using the visible red waveband (VIS), which corresponds to TM band 3, and the reflected near infrared waveband (NIR), which corresponds to TM band 4, an index described by Tucker (1979) relates to the proportion of photosynthetically absorbed radiation.

This index measures the differential reflection of green vegetation in the visible and infrared portions of the spectrum and provides a basis for monitoring vegetation. Satellite imagery is well suited for this monitoring with its spectral and spatial resolutions. The NDVI is commonly used in such applications. This index can be defined as:

$$NDVI = \frac{R_{nir} - R_{vis}}{R_{nir} + R_{vis}}$$

Where R_{vis} is the land surface reflectance in the visible waveband (0.58 - 0.68 μm) and R_{nir} is the land surface reflectance in the near infrared waveband (0.725 - 1.1 μm). The principle behind this is that the visible region is a part of the spectrum where there is considerable absorption on incoming solar radiation by chlorophyll, and the near infrared is a region where spongy mesophyll leaf structure leads increased reflectance (Tucker and Sellers, 1986).

The NDVI is affected by the degree of absorption by chlorophyll in the red wavelengths, which is proportional to leaf chlorophyll density, and by the reflectance of near-infrared radiation, which is proportional to green leaf density. Therefore, NDVI is likely to correlate well with green leaf biomass, and can be related to healthy vegetation.

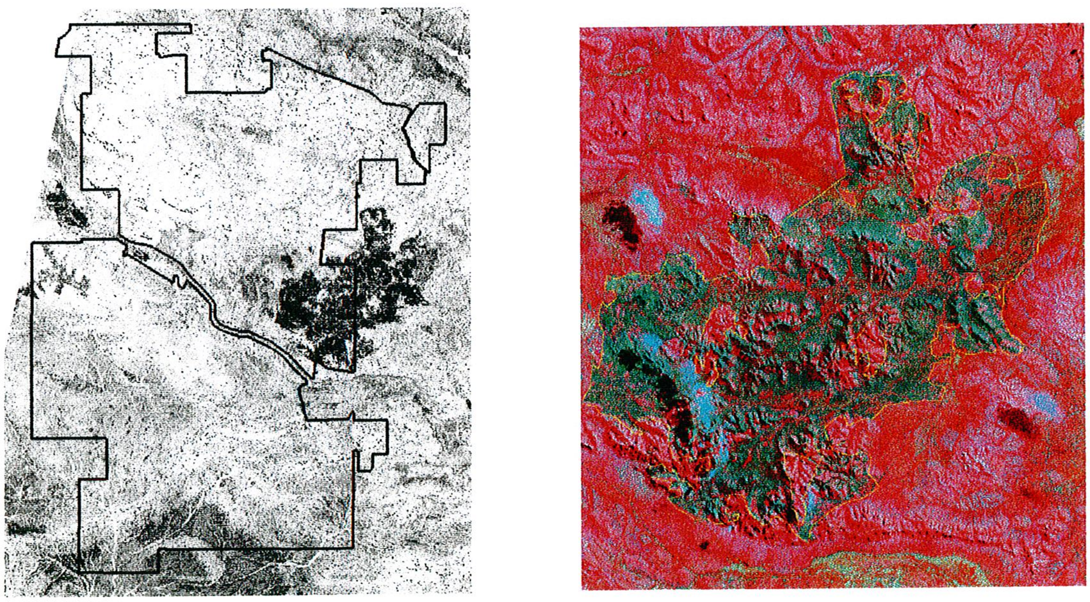
The NDVI is generally related to both green biomass and leaf area index of plants and is a very good measure of plant health and vigour. However, this relationship can vary with the structure of the vegetation type, and different relationships for major vegetation types are required to account for dry biomass (Bellairs and others, 1994). NDVI values are also affected by the colour and brightness of the soil.

If the NDVI is calculated from calibrated data it is repeatable between times of measurement. However, if it was calculated from raw counts without calibration to reflectances it will vary and will only create a meaningful image "once off". Therefore when an area is acquired at a later date, without calibration, the next set of NDVI values will not be comparable.

Results

Fire Scar Mapping

Figure Two shows the extent and detail that was extracted from the satellite images in relation to recent fire scars. The grey image (a) is the information extracted for peak NDVI for April 1996 and clearly shows fire scars as dark grey to black. Karijini National Park boundary is shown as a solid black line. The general rule in interpreting these data is that the darker the information the less vigorous green the vegetation. As recent fire scarring could still be described on the ground, as being areas of burnt, scorched, and ashen, the expected reflectance values for the NDVI enhancement would be low. These low values are the dark pixels within the image. The coloured image (b) is an enlargement of the fire scar area of image (a). The colours are made from the 1996 maximum NDVI, TM visible band 3 and TM visible band 2 displayed in the red, green and blue guns respectively. This enhancement shows the discrimination between areas that are green and healthy (indicated by red tones) to that of burnt areas (dark and black).



(a) **(b)**

Figure Two: The fire scars in image (a) are shown as black areas within the NDVI 1996 image. The coloured image (b) shows a coloured enhancement that clearly identifies the variability within the burnt area.

The coloured image (b) from Figure Two was used to manually digitise the extent of the fire scar and the digitised boundary captured for this scar is displayed in yellow. The captured data is then transferred to the required GIS data base.

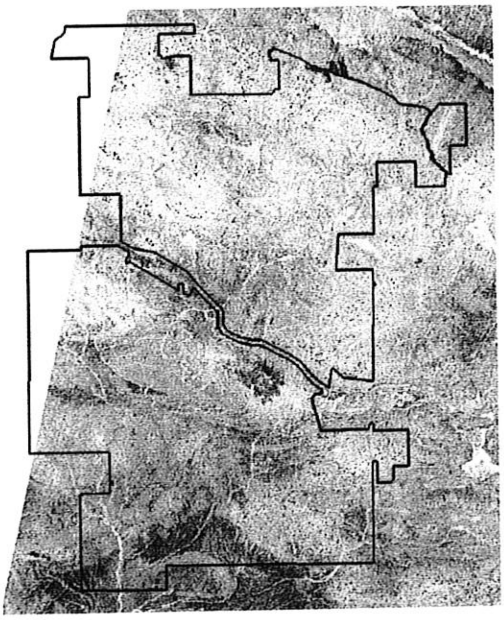
Fuel Load Build-up

From the three black and white NDVI images in Figure Three, it can be shown that there has been biomass increases and decreases within the National Park over the two year period from March 1994 to April 1996. These fluctuations in biomass have many causes some of which are explained below. It must be remembered that the variation within a season plays a significant role in determining change in NDVI. The National Park boundary has been overlaid as an aid in identifying locations.

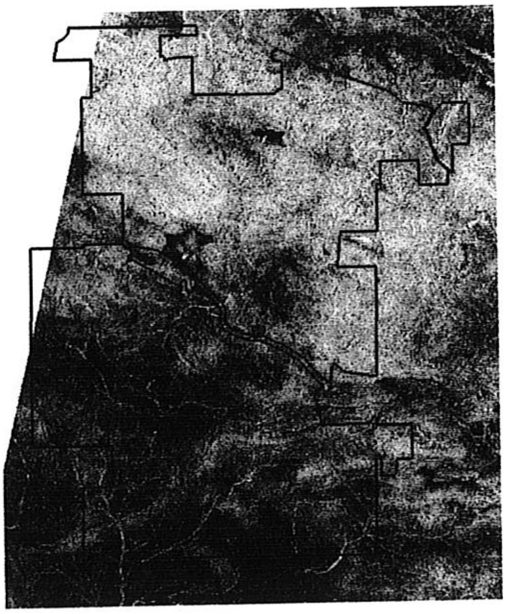
Figure 3(a) is the maximum NDVI as determined from the AVHRR time trace for 1994, where lighter areas are related to relative high occurrences of greenness due to seasonal flush and the darker areas are related to areas of low or no greenness. The dark areas may include previous burnt locations or areas of little to no vegetation.

Figure 3(b) is the minimum NDVI as determined from the AVHRR time trace for 1995 and shows extensive areas of black. These black areas have little to no associated greenness and may be caused by bare soil or dry vegetation. Bright areas are green vegetation associated creek lines and Mulga vegetation. Typically this result is what may be expected within the park after prolonged periods of dry weather.

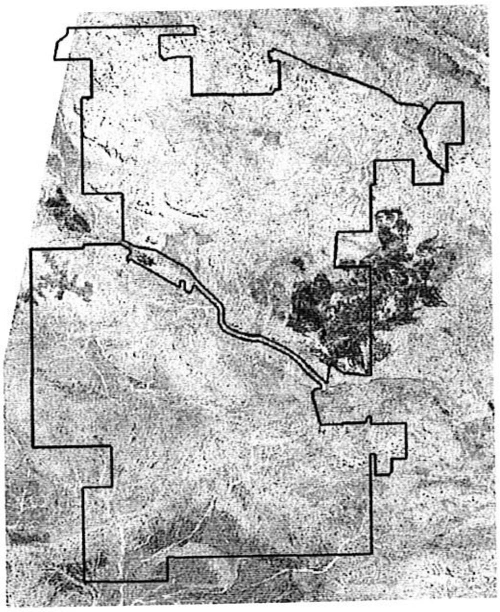
Figure 3(c) is the maximum NDVI as determined from the AVHRR time trace for 1996 and shows dark or black areas that are fire scars that have occurred between 1994 and 1996. Other darker areas are areas that are less vigorous while the lighter areas are again associated with increased green vegetation.



(a)



(b)



(c)

Figure Three: NDVI display of the three image dates of Karijini National Park. In all three images the lighter the area means the greener the vegetation, the darker the areas indicate less vigorous the vegetation. The images show the seasonal and annual fluctuations in the vegetation growth. Image (a) is NDVI for March 1994, (b) NDVI for December 1995, and (c) NDVI for April 1996.

By adding all three dates of the NDVI into a single image

NDVI (1996) +NDVI (1995) + NDVI (1994) (1)

its is possible to determine trends in biomass from the March 1994 to April 1996 image. From Figure Four (a), the brighter or whiter areas are locations of increased biomass over that period. These increases are associated with vegetation areas of Mulga that have had little to no recent fire history and contain seasonal flushes.

Figure Four (b) is the combined image using the equation

(NDVI (1995) +NDVI (1994)) - (NDVI (1996) - NDVI (1995)), (2)

which shows the dark areas that are associated with areas of biomass loss, and the bright areas have remained relatively constant. The obvious dark area is a recent fire scar and the other lighter shades of grey within the image area associated with previous fire scarring where the locations are either still bare or has some small degree of vegetation recovery.

(a) **(b)**

Figure Four: The lighter areas in (a) are associated with increased green biomass while the darker areas have had little to no change, and in (b) the lighter areas are locations of decreased green biomass while the dark areas are recent fire scars.

By combining both the images in Figure Four into a single image it was possible to produce an unsupervised classification that separated areas of positive biomass from that of areas of negative biomass. Figure Five below show this combination with the areas of increase biomass depicted in green and areas of decline in biomass are shown in red. Areas un-coloured or grey are areas of little to no change. The National Park boundary in black and the manually digitised fire scar boundary in yellow, are overlaid as an aid to assist location.

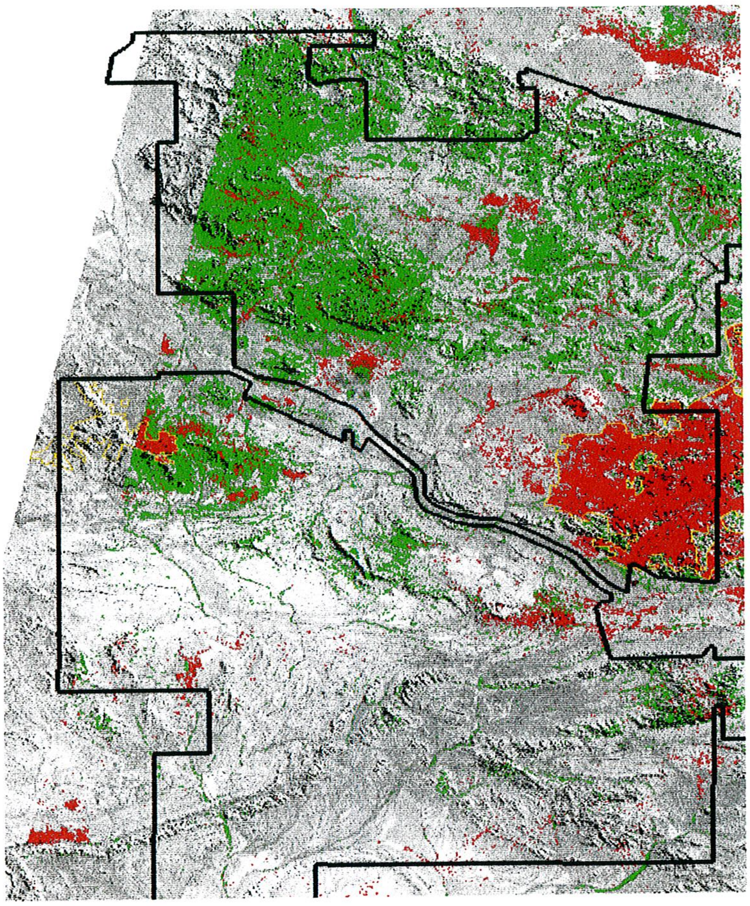


Figure Five: Areas shown as green are locations of increased biomass as compared to areas with a decrease in biomass, shown as red. The National Park boundary is shown in black and the recent fire scar in yellow.

Conclusion

From the study, locations of recent fire scars were successfully located, mapped and digitised. The areas and extent of fuel-load build-up and fuel-load decline were identified within the National Park.

The fire scar mapping has shown that given the appropriate selection of satellite imagery, acquisition times and selected processing techniques, it is possible to locate and map the fire scar boundaries within the National Park on an annual basis. There is a necessity to correctly register and calibrate the image dates before processing can commence. The results of the fire mapping using TM imagery can quickly be verified from the coarser resolution NOAA Fire Scar Mapping Programme, at any time. The results clearly show that TM satellite imagery can locate and discriminate recent fire scars with a level of accuracy that can used in an operational situation. Other relevant ecological management information, found from this study, is the accurate location of 'unburnt islands' of vegetation within fire scars can be accurately mapped. The need for good ground information both prior to and after the analysis is critical to the success of the project. The ground information aids in determining which time of the year best supports data purchase, and as a monitoring tool to aid in assessing vegetation recovery after the fire. This information may include, knowing when fires occur within the park, and the establishment of ground monitoring sites for data on vegetation regeneration.

The ground fuel load or biomass mapping represented a qualitative approach to assess the usefulness of TM satellite data to provide information that could be regularly extracted for additional fire management intelligence within the park. The detail that was extracted from the data, using NDVI processing, provided a map of biomass build-up and decline within the park for the two year period. From field validation this detail represented known areas of general biomass increase and decline.

The information supplied from time traces of NOAA satellite has proved successful. This information together with expert ground knowledge is vital for the success of the project.

Cost

1. It is recommended that TM satellite imagery that covers the dates of minimum and maximum NDVI, as recorded by Vegetation Watch, be purchased @ $2080 for the 4 band image data. The total cost of imagery for the fire scar mapping for 1997 is **$4160**.
2. The continuation of the biomass analysis is recommended, given the data required are the same as for the fire scar mapping.
3. Additional funds may be required if the project is to be extended into neighbouring parks. The results are transferrable to other regions and not exclusive to Karijini.
4. The cost of field validation and inspection to be paid for by the regional offices.
5. The cost of image analysis and production, needs to be included for any continuation of the project. Given the positive results of this study and the development of successful methodologies for future work, it is estimated that any on-going work, that covered Karijini National Park, would take minimal time (estimate 6-7 man days plus equipment = **$1500**). Included is the digitising and forwarding of fire scars boundaries in MapInfo format.

6. The cost of NOAA time traces from RSS (DOLA) is **$50**.
7. **Total** costs of **$5710** for continuation.

References

Adenyi, P.O., 1980. Land-use change analysis using sequential aerial photography and computer technique. *Photogrammetric Engineering and Remote Sensing*, Vol. 46, pp. 1447-1464.

Bellairs, S.M., Turner, N.C., Hick, P.T. and Smith, R.C.G. (1994). Plant and soil influences on estimating biomass of wheat in plant breeding plots using field spectral radiometers. *Australian Journal of Agricultural Research* (in press).

Campbell, N.A., Furby, S., and Fergusson, B., 1994b. Calibrating images from different dates. Report to LWRRDC. Project CMD1. CSIRO Division of Mathematics and Statistics, Perth.

Graetz, R., 1990. Remote sensing of terrestial ecosystem structure: An Ecologist's Pragmatic View. In: *Remote Sensing of Biosphere Functioning*, R. Hobbs and H. Mooney, eds. Spring-Verlag, New York, pp. 5-30.

Smith, R.C.G. (1994). *Vegetation Watch.* Report to the Rural Industries Research and Development Corporation. Available from Remote Sensing Services, Department of Land Administration, Leeuwin Centre of Earth Sensing Technologies, 65 Brockway Road, Floreat, WA.

Tucker, C.J. (1979). Red and photographic infrared combinations for monitoring vegetation. *Remote Sensing of the Environment,* 8, 127-150.

Tucker, C.J. and Sellers, P.J. (1986). Satellite remote sensing of primary production. *International Journal of Remote Sensing*, 7, 1395 - 1416.