Part B: TECHNICAL SUMMATION

Introduction

The National Land and Water Resources Audit's (The Audit) Rangeland Implementation Project has demonstrated methods for rangeland monitoring, using temporal Landsat data sequences over four biogeographical regions in northern Australia.

This section describes the application of methods over an 18-month time frame in three different areas where there were different levels of existing knowledge and data precision. The overall approach was to integrate land resource, infrastructure and ancillary data with map summaries of change derived from multi-date satellite data. This information, plus on-ground data, the use of existing datasets and incorporation of local knowledge was used to interpret land condition from temporal satellite sequences. Datasets produced in the project are an asset for research and may be interrogated for other purposes. An 11-year, time-series mosaic covering an area of 265 000km^2 in north west Australia is the first of its kind produced for Australian rangelands. Results from the project have been translated into information products, tailored for decision-makers at a range of scales from paddock to region.

Many jurisdictions across Australia now rely on temporal satellite data for providing information on land cover change. For example, Landsat data is used to determine the rate of tree clearing (Danaher et al. 1998; Barson et al. 2000), and NOAA-AVHRR data is used at regional scales for pasture growth modelling and climate forecasting (Hall et al. 1999) and identifying seasonality (ERIN 2000).

Assessment of the long-term effect of grazing on the landscape has traditionally required years of ground-based data collection and there has always been a problem of extrapolating point source data. A retrospective approach to range monitoring using historical Landsat data integrated with ground data, provides insight into landscape processes in response to grazing, fire and seasonal conditions. Landsat data is used as these satellites have recorded changes in the global environment over a period of almost three decades. No other satellite program has achieved such a continuous, complete and detailed record of Earth.

Two methods using Landsat data for extrapolating land condition over vast areas have recently been incorporated into range monitoring programs. In arid and semi-arid central Australia, the grazing gradient technology of Pickup and Chewings (1994) has been adopted into South Australia and Northern Territory range monitoring programs (Bastin et al. 1998a; Bastin et al. 1999). In the tropical savannas of northern Australia and shrubland of Western Australia, Wallace et al. (1994) demonstrated the application of statistical summaries of long-term sequences of Landsat data for mapping differing responses associated with land condition. This technique has been adopted in Western Australia and in tropical savannas of the Northern Territory (Wallace and Thomas 1999; Karfs in prep). The following describes the application of this technique in different biogeographical regions of northern Australia.

Wallace et al. (1994) describe an approach for processing and summarising historical image sequences to provide land condition information. Subsequent work in the VRD clearly indicated that on dark clay soils grassland dominated by annual and herbaceous species (poor condition), exhibited lower mean cover indices and far greater fluctuations over time than perennial grassland (good condition) (Karfs 1999; in prep).

Important steps for processing satellite data include selection of images from appropriate dates based on knowledge of the bioregion, calibration of the Landsat dataset, stratification of the landscape, and production of image summaries. These steps are summarised below in the context of the project.

- **Selection of image dates** - In northern Australia, a wet and dry season lasting approximately six months each dominate the regions' climate. Virtually no rainfall occurs in the dry season and although wet season rainfall is generally reliable, the timing and distribution of rainfall can be highly variable. Hence, vegetation response to rainfall in the wet season determines the amount of vegetative cover present in the dry season. The amount of cover is also affected by fire and grazing.

  All Landsat images in the project were selected in the late dry season, in or near the month of September for two main reasons: 1) the availability of cloud free data is optimal at this time of year, and 2) in most years the ground layer (ie. grasses, excluding evergreen species such as spinifex) is likely to be senescent. Thus, the contrast between ground cover and soil background is distinct and variability in greenness of the ground layer from year to year is minimised.

- **Image calibration** - Image calibration methods of Furby et al. (2000) were used for building Landsat MSS and TM time-series datasets in the East Kimberley/VRD and Dalrymple Shire. These image calibration methods or similar techniques are now widely accepted in the remote sensing community and used throughout Australia.

- **Stratification** - Satellite data were stratified into units of 'like' landscapes for all areas. Lithology type was the basis to partition the satellite data and to target key land types for analysis. Further stratification based on terrain and soil type was done where appropriate data existed.

- **Image summaries –** Image summaries of historical Landsat data are based on a spectral cover index. The cover index was derived from Landsat MSS band 2 (red band) or the average of MSS band 1 (green band) + MSS band 2, expressed as positive linear trend, negative linear trend and mean values. Slight variations of this base cover index were applied in the project and in the case where Landsat TM data was used, the corresponding wavelengths were analysed. Cover indices can be displayed as temporal map summaries or graphs of an area (eg. site, paddock, property or region). By examining the brightness and variation in cover indices over time in relation to distance from water and the location of fences, roads and land units a first indication of vegetation composition and condition may be interpreted. A schematic illustrating various cover index trends and mean values in relation to a regional cover index is shown in Fig. 6.

This statistically based image processing method was augmented with the collection of detailed ground data and evaluated using expert local knowledge in the project. The state of knowledge and existing datasets, and hence the questions which were addressed, varied across the three regions.

The areas described in this report include parts of the East Kimberley and VRD in north west Australia (WA and the NT); the adjacent Sturt Plateau of the NT; and the Dalrymple Shire in the Burdekin River Region of Queensland near Charters Towers (See Fig 1).

- In the Sturt Plateau, 'rapid land resource mapping' techniques using Landsat TM were applied to existing land system mapping, enhancing it to a scale more suited for property planning and monitoring.

- In the Dalrymple Shire, multi-date monitoring methods were applied within stratified regions and evaluated. The study relied on the use of datasets acquired from Queensland agencies and processed remotely with very little knowledge of local conditions.

- In the East Kimberley/VRD, expansion of multi-date monitoring techniques from a single Landsat scene to the regional scale across jurisdictions was undertaken (eg. nine Landsat scenes across WA and NT).

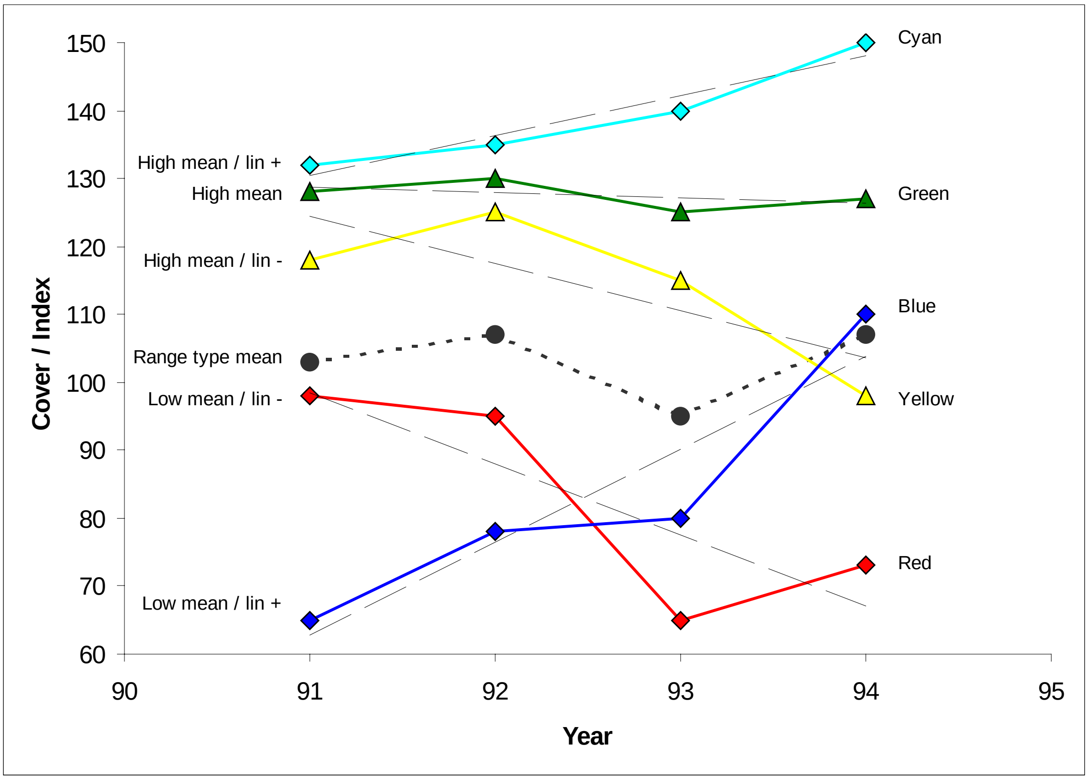

Figure 6 - Schematic diagram of different cover responses through time which may apply to a pixel, or larger area. Land type mean (black dashed line) is the regional spectral response from a stratified landscape. Summaries are listed on the left and the colour equivalents displayed on maps are listed on the right of the diagram. Linear trend lines as thin black dashed lines are represented for each summary.

1. STURT PLATEAU REGION, NORTHERN TERRITORY

Background

The Sturt Plateau, in the Northern Territory, is a biogeographic region of significant agricultural production/economic potential (Fig. 7). Land use development and management strategy of the Sturt Plateau Region has recently been undertaken as part of a three-year Natural Heritage Trust project. To help formulate this strategy, there was a need for accurate land resource information to assess production potential, infrastructure development and conservation values and assist in property management planning.

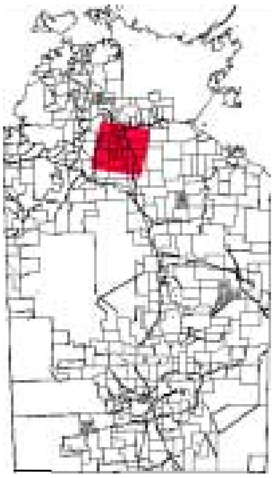

Figure 7 - Location of the Sturt Plateau in the NT.

Reconnaissance land system mapping of the area was completed by Day et al. (1985), and has since provided the basis for assessing subdivision proposals and carrying capacities for the region. Whilst this information has been valuable, limitations in its use at the property or paddock level were evident. To address this deficiency, 'rapid land resource mapping' using satellite imagery was undertaken. This mapping should provide a base for stratification for monitoring work in the future.

The Sturt Plateau is predominantly a flat erosional plain, dominated by savanna woodlands of mixed eucalyptus with a perennial grass understory and open woodlands on clay soil floodplains. Average rainfall is 640mm with nearly all the rainfall occurring in the months between November and March.

Historically, the Sturt Plateau region has seen minimal settlement and development, this began to change during the 1980s when a number of subdivisions increased the number of pastoral properties from nine to twenty-three. Some properties now produce hay to supplement production on native pastures. With this increase in development, detailed mapping of productive land types and areas of high conservation value was a priority.

Methods and Results

Image Stratification and Classification

Multispectral Landsat TM data combined with existing datasets were considered the best option to define land types at 1:100 000 scale. This was done by classifying the Landsat data within land system boundaries and using multiple datasets integrated in a GIS to identify distinct land types in a sequential classification framework (Bastin et al. 1998b).

Issues which had to be addressed included the transient effects of fire and the uncertainty of labels on existing mapping. Fire scars were readily identified using PCA analysis; classification from an alternative date was used for burnt areas. The existing land system vectors had first to be corrected to the more accurate TM base. The Landsat data was then stratified prior to classification to minimise amalgamation of 'component units' of different land systems that had similarities in spectral response. Training areas were identified using ancillary land resource data and a supervised classification was then applied. At the 25m-pixel size, image texture was observed within classes; accordingly, a neighbourhood classifier was applied using a 7x7 window.

Groundtruthing and Results

The initial groundtruthing of the classified satellite data was postponed until May 2000 due poor accessibility resulting from heavy late wet season rainfall. Land type classes were visually inspected along route and notes made on:

- landform;
- the nature of the soil surface;
- vegetation type, structure and density; and
- evidence of fire.

Classified maps were also shown to several pastoralists and details regarding the location of specific land types and their physical characteristics were discussed.

Preliminary results clearly identified inherently different land types very well. For example, in the Banjo land system (8000km^2), gravelly lateritic and spinifex rises with low productive potential were delineated from red earth soil landscapes with high production value (Fig. 8). This information has value in developing management plans and assessing subdivision proposals.

Application

This example demonstrates the use of satellite imagery to define a broad stratification base for use in range monitoring. The Sturt Plateau region was suitable for this form of land resource mapping due to its relatively uniform relief. By combining image data with covers derived from airphoto interpretation and field survey, it was possible to enhance original data in a consistent manner without expending resources on traditional soil and vegetation survey. Spectral discrimination of inherently different landscapes also provides a basis for stratifying multi temporal satellite data into ‘like’ units.

Refinement of this form of land resource data is expected as new information is captured from landholders and field staff. By making the process inclusive, stakeholders will understand the potential of this mapping and hopefully become pro-active in improving the quality of the data. A primer explaining basic remote sensing principles is presented in Appendix 3.

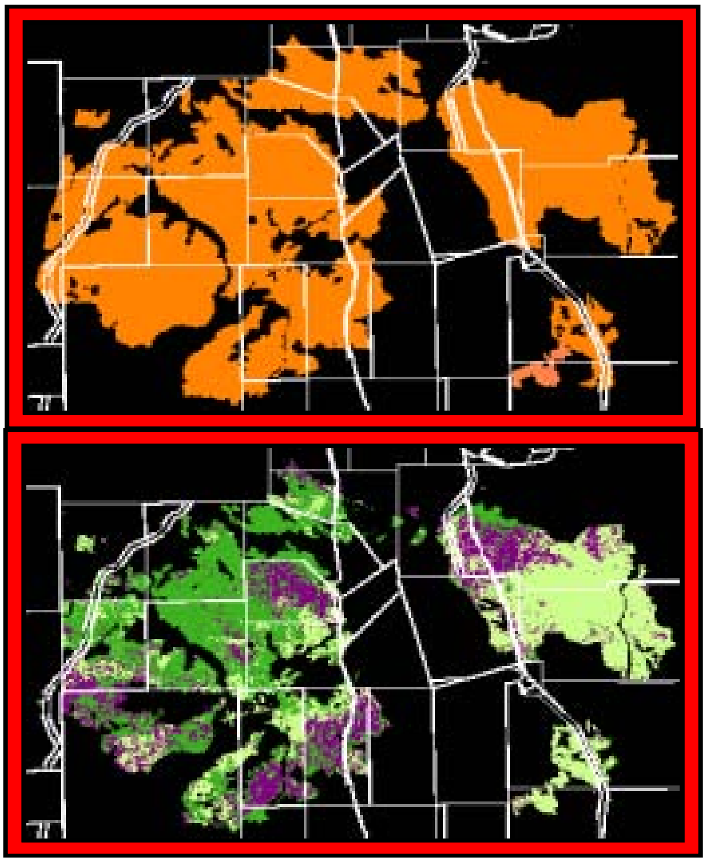

Figure 8 - Example of Landsat TM classification on the Sturt Plateau. The Banjo land system (top) is classed into three distinct land types (below).

2. BURDEKIN RIVER REGION – DALRYMPLE SHIRE, QUEENSLAND

Background

The Dalrymple Shire is located in the upper Burdekin River Region of North Queensland, an area approximately 6.8 million hectares (see Fig. 1). The region was opened to pastoral settlement in 1861, with the first pastoral properties being large expanses of land located on river frontage. Within ten years of pastoral settlement, gold was discovered at Cape River in the north east of the Shire. The subsequent influx of population ultimately resulted in large pastoral properties divided into smaller holdings, leading to closer settlement of the region. Currently the population of the Dalrymple Shire is nearly 9000 (ABS 1998), down from 30 000 experienced during the gold rush of the late nineteenth century.

Annual rainfall for the Dalrymple Shire is highly variable, ranging from 500mm in the southwest and up to 1600mm in coastal ranges located in the north east. The area recently experienced six consecutive years of drought from late 1991 to 1996.

Several land cover studies using Landsat data have been conducted in the region. The Queensland Statewide Land Cover and Trees Study (SLATS) project (Danaher et al. 1998) used Landsat TM data to determine the extent of tree clearing between 1991 and 1995, and provide information on vegetation resources. Taube (1999) investigated the use of single-date Landsat TM for detecting ground cover as a surrogate of land condition. Preliminary results suggested that stratification by soil type was necessary to interpret spectral indices. Wallace and Meston (1998) conducted land condition analysis over the Townsville Field Training Area (TFTA), using historical Landsat MSS band 2 and Landsat TM band 3. Detailed stratification by land type was recommended for improved analysis of trend and condition.

The aim of this project in the Dalrymple Shire was to process historical Landsat data to produce maps showing changes through time, and to evaluate these summary products against the considerable body of knowledge for the area. It was also undertaken to strengthen ties between States/NT and test the 'workings' of data exchange through different jurisdictions.

Methods and Results

All satellite data for the Dalrymple Shire were selected and processed by NTDLPE in Darwin, using a standard SLATS scene to maintain consistency with that project. Imagery was selected and evaluations conducted in collaboration with partner agencies QDPI in Charters Towers, CTAG in Townsville and the TS-CRC Executive in Darwin. Image dates were acquired immediately before, during and after the drought period. Six Landsat TM scenes were purchased for the time-series dataset over the years 1991-98. Late dry season imagery was acquired in each year.

For stratification, interpretation and map production, the project relied upon the provision of digital data by Queensland agencies and national data sets from the Australian Surveying and Land Information Group (AUSLIG). Spatial data used in the project included: land resources (Rogers et al. in press), cadastral boundaries, roads, fencing, watering points and drainage.

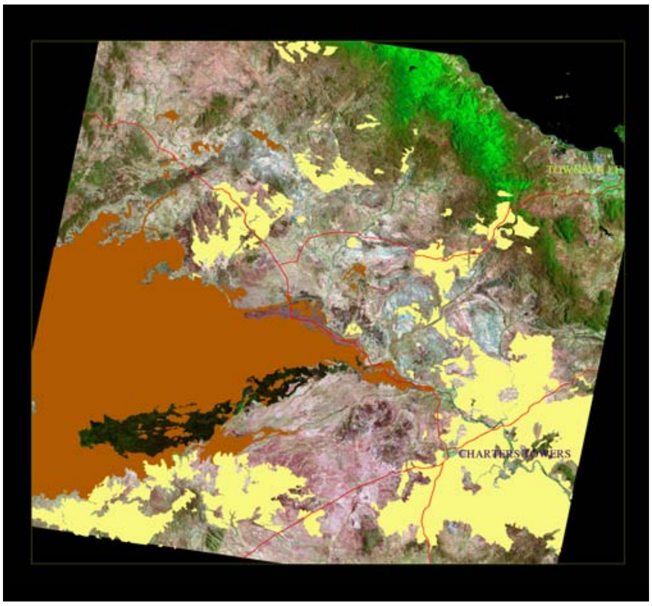

Figure 9 - Land resource stratification in the Dalrymple Shire; basaltic landscape in brown and Goldfields land system in yellow.

Prior to the multi-date processing, the area was stratified into two important pastoral land types based on lithology. These were landscapes formed on basalt parent material and the "Goldfields" land system, formed primarily on Granodiorite (Fig. 9). The stratification was based initially on the assumption that dark coloured soils were associated with the basalt country and lighter coloured soils were associated with the Goldfields system. This proved effective, and demonstrated the ability to produce a rapid initial stratification framework.

To provide a clearer understanding of land condition, further data stratification was performed.

- Basaltic lithology was divided into ferrosols and vertosols (Isbell 1996), recognising vegetation and landscape differences associated with these soil classes.
- ‘Rugged’ landscapes with slopes greater than 10% and relief greater than 90m were cut from the satellite data, as normally cattle do not heavily use these areas.
- Rivers and creeks were removed. In riparian areas, the mix of tree density, sand, outcrop and water generally show different reflectance change than the broader landscape, and these are difficult to interpret. Buffers of 200m and 300m were applied to the creeks and rivers respectively.

Trend summary image maps for the time sequence 1991, 93, 95, 96, 97 and 98 were produced, using TM band 3 as a surrogate cover index. Maps were produced which highlighted areas of different change over time. Overlays identified these with management boundaries to provide a basis for initial interpretation.

Ground truthing was conducted in October 1999. Field checking proved successful in correlating fence effects with areas of contrasting cattle activity, despite a thick cover of Indian couch (*Bothriochloa pertusa*) resulting from good wet seasons in 1997/98 and 1998/99. In many cases anecdotal evidence such as presence of erosion features, weed species, and soil conservation works provided insight into historical land condition as indicated by the summary maps. Discussion with QDPI officers was also encouraging in that much of what was interpreted from the satellite data matched their knowledge of land condition in the region. The extent of areas of similar responses was identified. Groundtruthing routes are shown in Fig. 10.

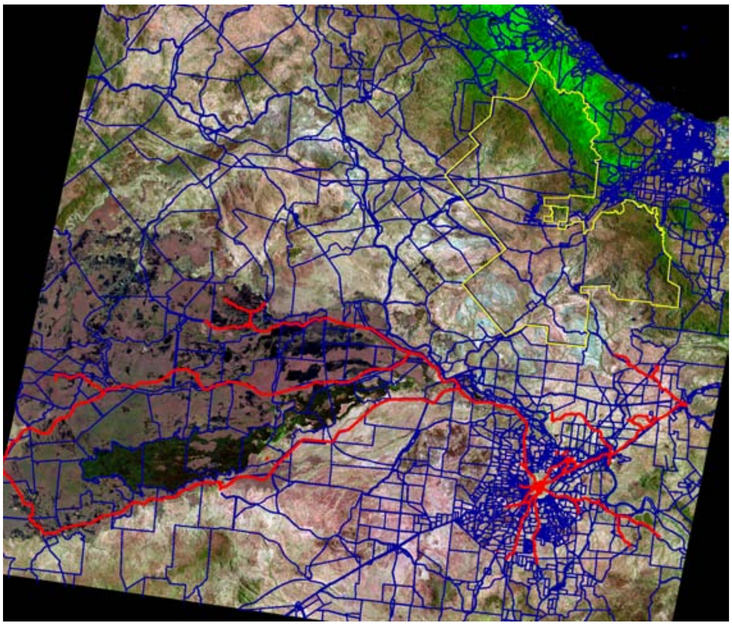

Figure 10 – Groundtruthing routes taken over 5 days in the Dalrymple Shire shown in red. Infrastructure shown as blue lines.

Tracking the regional cover response of different land types with different soil colour through time is a useful monitoring tool for understanding landscape behaviour with respect to seasons. In Fig. 11, the overall responses of the stratified land types described above are shown. The Goldfields land system has high index values in the drought years from 1993–96 resulting from losses in cover and exposure of light coloured soils. The downward slope on the time trace from 1996 to 1998 represents an *increase* in cover. Conversely, on the dark coloured basaltic soils, low cover indices through 1993–96 represent less cover and more exposed soil. Stratification is essential for understanding these changes and for simplifying summaries.

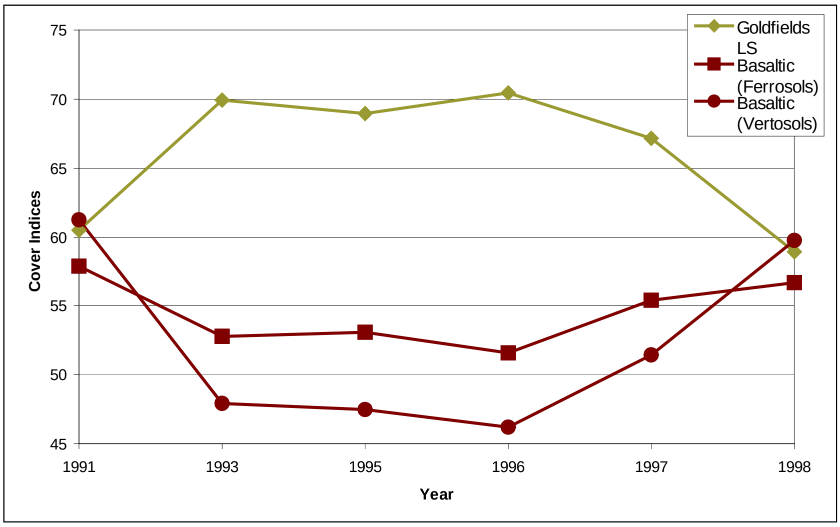

Figure 11 – Regional time traces of three land types examined in the Dalrymple Shire from 1991–98. High cover index values in the Goldfields land system represent low vegetative cover, in basaltic land types it is the opposite; low indices represent low cover. In 1998, vegetative cover appears to have recovered to 1991 levels in all land types following drought from 1993–96.

In Fig. 11, vegetative cover relative to each land type increased from 1996 to 1998 as the drought broke. The lowest cover indices in the sequence are associated with 'black soil' vertosols, which are distinct from the response of the red-brown coloured ferrosols. Cover levels in all land types in 1998 appear to have recovered to 1991 levels.

Comparing the cover response of management units against the regional mean is also a useful information product. In Fig 12, the time trace of the vertosol land type from 1991-98 is compared for 5 pastoral properties. A regional value for each year was subtracted from the cover indices recorded within each of the 5 pastoral properties. The heavy dashed line with cover indices of '0' represents the regional mean. The portion of vertosol land type occurring within each of the 5 properties ranged from 2-14 percent of the regional vertosol land type. The time traces show distinct differences, where properties A and B are generally lower than the regional mean compared to properties C, D & E. This information raises questions regarding management histories in relation to seasonal response.

The TFTA is in the north east of Dalrymple Shire, and ranges from forested, highland ranges to undulating open eucalypt woodlands of sedimentary, igneous and metamorphic

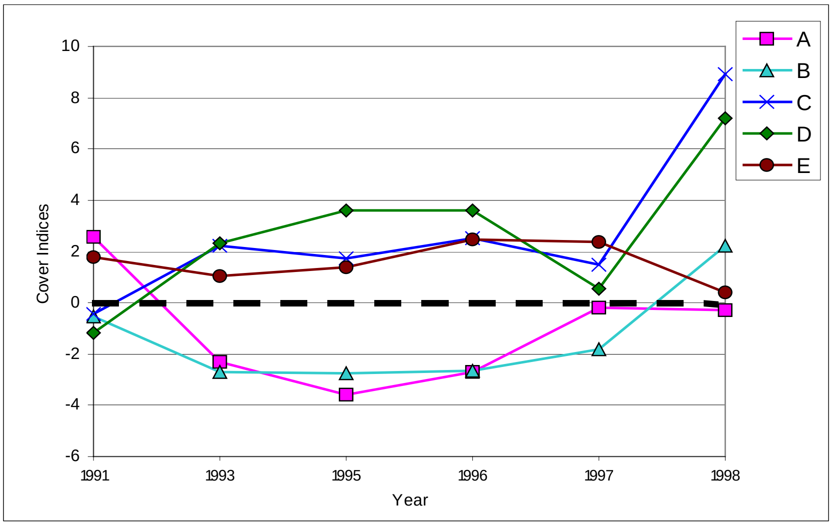

Figure 12 – Time trace analysis from 1991-98 comparing the vertosol land type on 5 pastoral properties. The heavy dashed line with cover indices of '0' represents the regional mean. The time traces show distinct differences, raising questions regarding management histories in relation to seasonal response.

lithologies. It serves as a training area for Australian Defence Force personnel. To compliment earlier work of Wallace and Meston (1998), time-series satellite data over the TFTA was stratified using detailed soil mapping by CTAG at 1:50 000 scale. As with the Goldfields and basaltic landscapes, rugged and riparian areas were excluded.

Trend summary products were provided to CTAG, for comparison with land condition data collected on the TFTA in 1991 and 1996. Of 18 sites compared, ground data confirmed the condition interpretation from trend imagery, though at a few sites rubber vine *(Cryptostegia grandiflora*) infestation was confused with increasing trend and condition (see Table 1).

Table 1 – Summary of land condition site data collected on the TFTA in 1991 & 1996 compared with trend summary image data.

CTAG SITES	NUMBER	COMMENTS
Correlated	16	Trend summary analysis consistent with 1991 and 1996 ground data.
Poorly correlated	2	Rubber vine in the area had increased over the period 1991–96.

Application

Trend analysis conducted in the Dalrymple Shire provided encouraging results. Differences in the cover responses indicated by fenceline effects, small acreage boundaries and watering points were clearly shown. The high intensity of tenure and variety of land development in the Dalrymple Shire highlighted the need for a substantial level of local knowledge to produce an informed interpretation of trend and condition.

Time constraints of the project did not allow for the full utilisation of TRAPS and QGRAZE site data. If methods were implemented in this region, TRAPS and QGRAZE data would provide a strong foundation for interpreting the time-series satellite data.