3. THE EAST KIMBERLEY/VRD REGION – THE ORD-VICTORIA, WA/NT

Background

The aim in the East Kimberley/VRD region was to produce historical change maps over an extensive area, and to complement these with targeted ground data to provide summaries of condition and change in the region. Nine Landsat scenes covered the area in Western Australia and the Northern Territory (265 000km^2), and image sequences from 1987 to 1997 were assembled. For a ‘core area’ of four scenes, annual image data were acquired and processed, including Landsat TM data for 1998 (Fig. 13). The area analysed contains the most pastorally significant land types in the Victoria Bonaparte and Ord Victoria Plains IBRA regions (referred to herein as the Ord-Victoria region). This accounted for 53 percent or 66 550km^2 of the 126 000 km^2 within four mosaiced Landsat scenes.

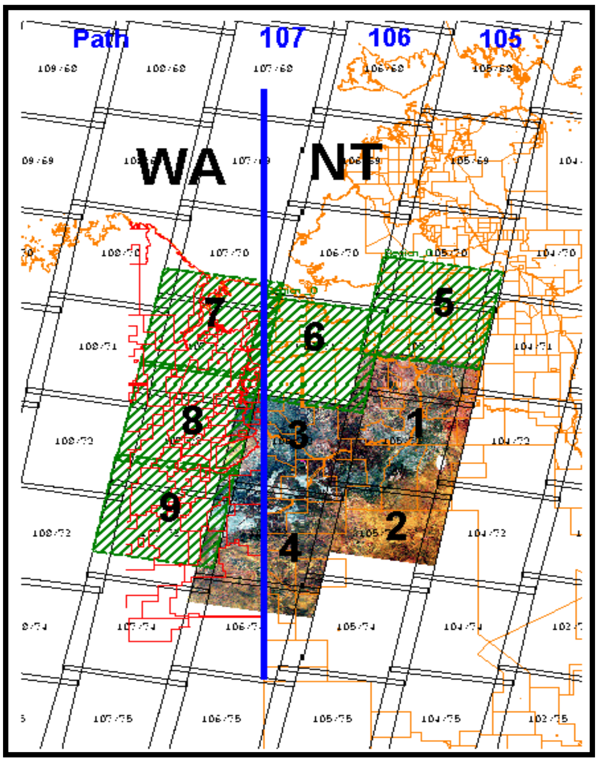


Figure 13 – Landsat satellite coverage in the East Kimberley/VRD region. The scenes numbered 1-4 indicate the core study area.

The region has a semi-arid monsoonal tropical climate with rainfall concentrated between November and March. Though rainfall can be highly variable, there is a distinct gradient of decreasing mean annual rainfall from 1000mm in the north to less than 400mm in southern areas (Williams, et al., 1997). Population is sparse between 6000 and 7000 (1996 Census) with a scattering of small towns and communities, of which Kununurra is largest with over 4000 residents.

This ‘last frontier’ of the Australian continent was opened to pastoralism in 1883, following the successful exploration expeditions of Gregory in 1855 and Forrest in 1879. Prior to 1960, property management was essentially a free range operation, with cattle ranging widely during the wet, but aggregating around large permanent waterholes along the major rivers towards the latter part of the dry. Substantial changes occurred in the pastoral industry during the 1960s, with investment into property infrastructure, construction of a beef road and use of road trains, which improved capacity to move large numbers of cattle quickly (Fig. 14). In the 1980s, the National Brucellosis and Tuberculosis Eradication program (BTEC) led to perhaps the greatest change to the pastoral industry. The BTEC program reduced the amount of wild cattle, led to improved animal husbandry, encouraged

Figure 14 - Roadtrain moving cattle in the VRD.

fencing away from river systems and led to changing herds from Shorthorn breeds to predominantly Brahman breeds.

Previous land condition information for the region has been mostly subjective assessments and although Tothill and Gillies (1992) concluded that most of landscapes in the region were intact, the location and extent of land condition classes were not known.

Physical Characteristics

The geology of the Ord-Victoria region is complex, but may be divided into three broad structural units. The stable Kimberley and the Victoria River Basins in the western and eastern parts of the region respectively, are separated by the Halls Creek Province which extends north east to the Pine Creek Geosyncline (Plumb et al. 1990). The oldest rocks are about 1.8 billion years old of mostly sedimentary origin, though granitic and metamorphic rocks are common. Cambrian basalt is prominent in the Victoria River catchment giving rise to productive grasslands; discrete areas of limestone and mudstone lithologies of similar age are also present. Eroded remnants of Mesozoic and Cainozoic sandstone, shale and laterite are widespread, formed when the region was covered by an ancient sea some 90 Myr, followed by a period of intense lateritisation (Bolton et al. 1990). Broad alluvial plains were formed along river systems in the Quaternary, about 1.8Myr to 10 000 years ago as erosion of older lithologies occurred.

Most of the Ord-Victoria region is less than 300m above sea level with few areas attaining elevations more than 600m. About 50 percent the area is rugged country with considerable outcrop and shallow stony soils (Stewart et al. 1970). The remaining land consists of gently undulating lateritic surfaces, erosional plains formed by the weathering of underlying rock, alluvial plains associated with major stream valleys and coastal environments. The Ord and Victoria River are the main catchments of the region, emptying into the Joseph Bonaparte Gulf to the north. Other coastal draining catchments are associated with the Chamberlain, Keep and Fitzmaurice Rivers. The remaining catchment is an internal system emptying southwards into the inland deserts. Most of the coastal flowing rivers maintain perennial waterholes with the duration of intermittent waterholes largely dependent on wet season rainfall.

Stewart et al. (1970) reported that on erosional and alluvial plains clear relationships exist between soils, and the parent material, drainage and climate. He added that the well-drained steep hilly country with rock outcrops normally had shallow skeletal soils, while deeper soils were largely confined to poorly drained flatter country. Subsequent authors have reported these observations.

Perry (1970) described the vegetation in the Ord-Victoria region as “structurally and floristically…similar to that of a great belt stretching from east to west across the continent in similar latitudes”. Perry and successive authors working in the region identified lithology and rainfall as major factors influencing vegetation patterns. Wilson et al. (1990) noted that seasonal and longer-term climatic variations and fire have had a profound influence on the temporal variability of much of the vegetation covering the Victoria River region. Structurally, woodlands with grassy understoreys typify the vegetation, except the lowest rainfall areas in the south. Trees are generally low, less than 10m, with tree density decreasing to the south from woodlands to open woodlands in distinct climatic zones (Perry 1970).

In the VRD, Stockwell and Andison (1996) suggested that more than 60 percent of land was suitable for grazing given improvements in infrastructure, breed type, technology and markets. Based on land systems of Stewart et al. (1970), Stockwell and Andison calculated that 47 percent of the VRD was categorised as plains. Plains country is normally highly resilient, supporting various perennial grass communities with grasslands developed on basalt, alluvium and residual clay lithologies generally regarded as the most productive (Tothill and Gillies 1992).

Methods and Results

Due to previous work by CMIS and NTDLPE, there was some understanding of how landscapes had changed and how changes translated into spectral response over recent seasons. Further, digital land resource and infrastructure data were largely available within NTDLPE, saving delays in data acquisition. The challenge in this region was to go beyond the interpretation of individual Landsat scenes to a regional level of multiple scenes. The major steps in assembling the data are as follows.

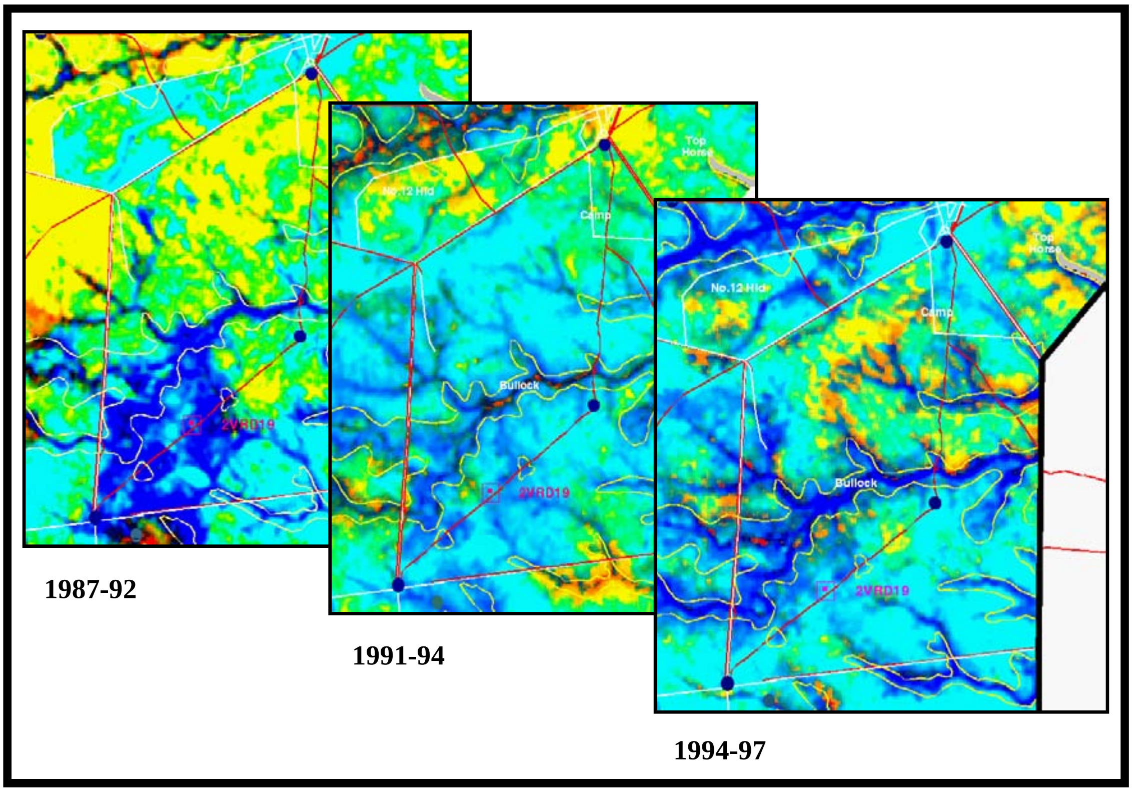
- Rectification, registration and calibration of Landsat MSS data was contracted to CMIS in Perth. Cross-calibration routines developed by CMIS were applied to nine scenes, forming a single time-series mosaic spanning the period 1987-97 and covering an area of 265 000km^2 (see Fig. 1). Landsat MSS data was resampled to 100m. Further details of image processing are included in Appendix 4 and 5.
- Land system mapping at 1:1 000 000 scale (Stewart et al. 1970) and land unit mapping at 1:100 000 scale (van Cuylenburg et al. in prep) were integrated in a GIS. Land system mapping covering 230 000 km^2 was manually registered to a satellite base map.
- ‘Rugged’ and riparian areas identified from land unit and drainage data were extracted from the satellite datasets. For areas covered by land system data, only extremely rugged systems were extracted. Other land systems with a mix of rugged and undulating landforms were classed as rugged within the stratification process.
- The satellite data was stratified based on lithology for three important pastoral land types (Table 2).
- Burnt areas were identified on the time-series data and integrated with NOAA-AVHRR fire history mapping.

Table 2 – Summary of stratified land types analysed in the Ord-Victoria region.

LITHOLOGY	LANDFORM	SOIL TYPE	VEGETATION
Undulating Basalt	Level plains to undulating rises	Black cracking clay soils	Grassland - Mitchell and other mid-height grasses
Rugged Basalt	Hilly country with gently undulating plains	Skeletal red and brown earths with a stony surface	Low open woodland with sorghum and spinifex understory
Residual Clay & Sediments	Level plains	Grey and black cracking clay soils	Grassland - Mitchell and other mid-height grasses
Limestone & Calcareous Sediments	Gently undulating plains to steep low hills	Brown clay loam to red sandy loam soils with limestone outcrop	Low woodland to low open woodland to desert shrubland

Cover indices were used to produce trend summary images. Initially Landsat MSS band 2 was used as this band had been successfully used in basaltic land types of the VRD and was expected to be 'robust' for application across a range of land types. An example of these results for a paddock 100km^2 over three time sequences from 1987–97 is shown in Fig. 15. A tabular summary of the colours shown in Fig 15 is presented in Table 3. This table also relates to the schematic cover index responses shown in Fig 6.

Several time sequences were examined in the Ord-Victoria region, with recent dates from the poor season of 1992 through good seasons to 1997 considered most appropriate. Trend summary imagery incorporating 1992, 93, 94, 95, 96 and 97 were produced. Vector covers of infrastructure, fire history, etc. were overlain on trend summary image maps and saved as geo-referenced tiff files, for use with a global positioning satellite (GPS) and laptop computer for groundtruthing. Subsequently, an average of Landsat MSS bands 1 and 2 was assessed based on the work by Wallace and Thomas (1999). This combination improved overall correlation with ground observations and was consequently used for comparing groundtruth data with trend summary imagery.



1987-92

1991-94

1994-97

Figure 15 – An example of trend summary imagery at paddock scale (100km^2) over three time sequences. Colours cyan and green indicate-good vegetative cover; yellow-good cover with decreasing trend; blue and red-poor cover. Watering points are shown as solid blue circles, fencelines in white and roads in red. Continuous high cover indices detected over the 10-year period indicate good condition grassland dominated by perennials, which groundtruthing confirmed. Drainage lines having a dense tree canopy display low cover indices (blue and red), due to absorption in Landsat MSS band 2. This response is similar to exposed, dark coloured soil on the adjacent plains, requiring stratification of these systems. Recovery is evident in pastures near the bore in the lower left, following grazing impact in 1987.

Table 3 – Trend Summary Colour Summation

Mean Brightness over period (displayed in intensity of green) RELATIVE to regional annual response.	**Slope**- linear trend over time RELATIVE to regional mean trend (positive trend in Blue negative trend in red).	Combined map colour using additive colour scheme – **Interpretation** based on an assumption of uniform soil colour.
GREEN: High +	**BLUE**: Positive =	**CYAN**: High cover, increasing trend over period
GREEN: High +	**BLACK**: Steady =	**GREEN**: High cover, trend close to regional average
GREEN: High +	**RED**: Negative =	**YELLOW**: High cover, trend decline over period
BLACK: Low +	**BLUE**: Positive =	**BLUE**: Low initial cover, increasing trend over period
BLACK: Low +	**BLACK**: Steady =	**BLACK**: Low cover relative to regional average, steady
BLACK: Low +	**RED**: Negative =	**RED**: Low cover, trend decline over period

Differences in condition, and annual/perennial composition, can be associated with expected changes in cover levels over time (Wallace et al. 1994). Trend summary maps identify areas where different changes have occurred, and these may be associated tentatively with condition differences. As well as maps, time trend plots can be produced for particular sites, or scaled up to represent management units or regions. One aim of the ground data was to examine links between ground conditions and Landsat-derived changes at sites. Based on this information, site-based knowledge can be extrapolated to the wider landscape. The trend summary maps were used to locate a range of sites which represented changes in the region. Without this information, it would have been impossible to locate an adequate set of fixed sites for ground sampling.

Groundtruthing was conducted at two levels of detail largely based on the NTDLPE Tier 2 monitoring program (Karfs in prep). The aim was to test if detailed ground techniques for measuring landscape function could be made simpler and less time consuming and still relate to trend summary images. Groundtruthing data were collected from July to November 1999. At rapid assessment 1 sites (RA1) three transects running downslope 100m long and 50m apart were assessed producing a site area of 100m^2 (1ha). Total cover estimated along each transect was subdivided into perennials, annuals, litter and tree canopy. The number of obstructions (eg. perennial plants) along transects were counted and dominant species noted. Attributes along each transect were then aggregated and an averaged cover value calculated. Soil colour and surface nature including degree of stoniness and presence of silty or sandy veneers were also documented. Finally, a condition class of good, fair or poor was assigned and a photograph taken. With two people, data collection required about 20-30 minutes per site. Once assessors gained familiarity with vegetation communities and local variation within the landscape, estimates of cover and soil surface nature were made from the vehicle and logged into the laptop computer as rapid assessment 2 sites (RA2).

RA1 sites selected represented a range of cover (low, high), type (grassland, open woodland), and species composition (perennial, annual), whilst RA2 sites were continually recorded as significant changes in the landscape were encountered. During groundtruthing, land managers were shown trend summary products. Discussion about the effect of seasons, fire, stock movement and infrastructure modifications helped staff relate on-ground factors to land condition interpreted from the satellite data. Photopoints from NT and WA monitoring programs were also used to verify land condition interpreted from the trend summary data.

To summarise rapid assessment data into condition classes (good, fair and poor), a condition ranking was applied by multiplying perennial cover by the number of obstructions, then adding annual and litter cover estimates. Sites were then plotted along a continuum of landscape function for each lithology type (Karfs 1999). This correlated well with trend summary imagery. Since number of obstructions is not recorded in RA2 sites, a perenniality index was substituted based on the percentage perennial cover to total cover. This allowed classification of all RA sites into condition classes. A continuum of function for 167 residual clay and sediments lithology RA sites is shown in Fig. 16, thresholds determined by 'breaks' along the trendline.

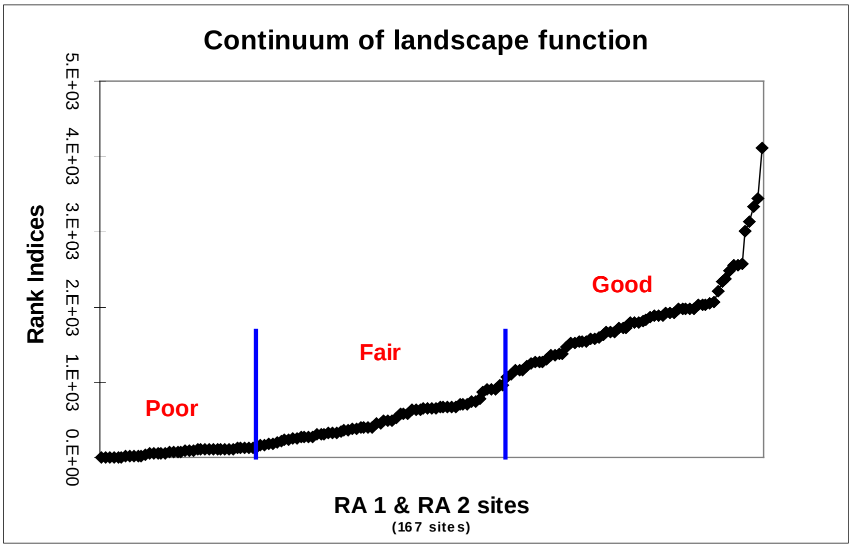


Figure 16 - Condition ranking into good, fair and poor classes along a continuum of landscape function for 167 rapid assessment sites in the residual clay and sediments land type. Thresholds determined by breaks along trendline.

'Temporal signatures' were then derived from the time-series dataset for the measured sites. Cover indices were extracted using GPS coordinates for all sites within each condition class, and the mean value for each year determined. Marked differences were apparent over time for each class shown in Fig. 17, where vegetative cover is associated with cover indices.

In Fig. 17, the good condition class had the highest indices throughout the period followed by the fair and poor classes respectively. Interestingly, all classes had similar low indices in 1988 and 1992, when very low rainfall was recorded. A distinct separation between the poor and fair classes occurred after 1992, indicating different levels of recovery. After successive good seasons during the mid 1990s, all classes had a similar cover index in 1997. In the case of the poor class, this indicates an increase in ephemeral plants and litter, which was observed at poor sites mostly located close to waters in 1999.

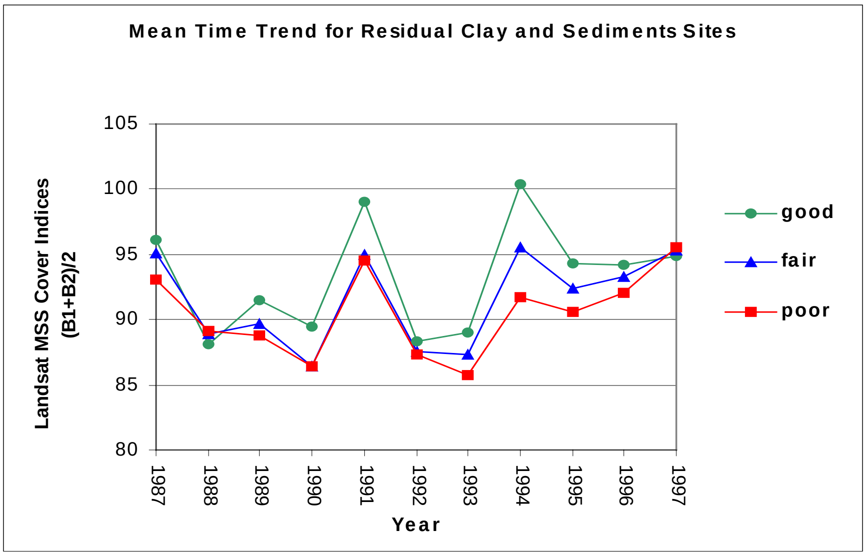


Figure 17 - 'Temporal signatures' of good, fair and poor condition sites (see Fig 6) from 1987-97. The average of Landsat MSS band 1 + band 2 was used to calculate cover indices. Highest indices represent greater vegetative cover. Differences in response to rainfall are evident, particularly following poor seasons in 1988 and 1992.

A regional trend product for the Ord-Victoria region from 1992-1997 (Fig. 18), was created using statistical techniques of Wallace and Thomas (1999) for each of the three lithology types, then combined into a contiguous coverage. Light green represents areas where cover increased and dark green areas with stable cover over the period. Areas shown in red represent a decreasing trend in cover. In this example, fire scars have not been removed and much of the red is attributed to burnt country. Fire history vectors overlain on this image would aid in identifying areas affected by fire. Clearly these data show that over most of the Ord-Victoria region cover has increased. This trend can be directly attributed to an exceptional run of good seasons from 1993-97. It is also consistent with Tier 2 site monitoring data collected in the VRD over the same period.

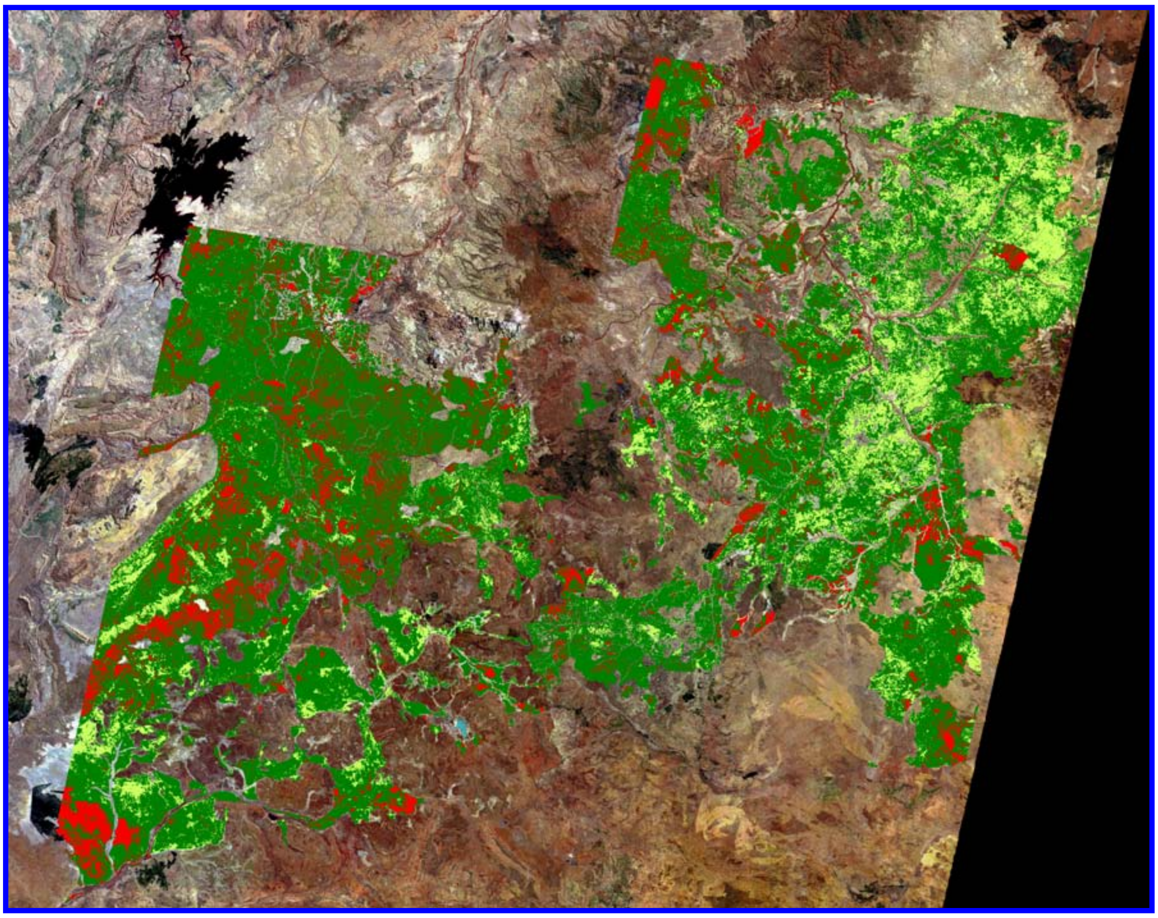


Figure 18 – Regional trend product for the Ord-Victoria region from 1992-97 using the average of Landsat MSS band 1 + band 2. The area analysed is 66,550km^2 of the 126,000 km^2 within four mosaiced Landsat scenes. Light green represents areas where vegetative cover has increased; areas in red a decrease in cover and dark green represents stable cover. Many of the red areas are associated with fires occurring over this period. The regional outlook of increasing cover and stability is apparent.

Discussion

The effect of fire and grazing combined with variable rainfall complicate the interpretation of landscape change and condition in rangelands. In teasing out the underlying trend in land condition, Pickup et al. (1998) have argued that consistent patterns of change over long periods (e.g. a decade) in response to rainfall are more indicative of the true condition of the landscape than its response after major rainfall events. Watson et al. (1996) echo this view, pointing out that land managers need to manage continuous vegetation change occurring yearly to ‘prepare’ the land to counter long-term affects caused by catastrophic events with return times measured in decades.

In tropical savannas, variable rainfall from year to year results in the expansion and contraction of perennial vegetation patches, and the episodic infilling by annual species between patches. Long-term trend and cover responses recorded by satellites can provide information on these fluctuations. By comparing ground information from sites in a range of conditions, satellite derived ‘temporal signatures’ may be created to help understand complex ecological processes in relation to seasons and the impact of fire and grazing.

This project has demonstrated the application of time-series Landsat data for use in monitoring tropical savannas. The development of products that compare watering points, paddocks and properties in the context of regional averages, provides information for managers to develop options with respect to economic capability. The identification of under- and over-utilised pastures and their spatial extents is baseline information to undertake this task.

Time-series information products are also beneficial to statutory agencies to report on regional differences within their jurisdiction. They aid in preventing alarm caused over land degradation that may be the lasting result of a previous management regime, combined with contemporary poor rainfall. In this regard, there is considerable potential for comparing current and past management practices to assist in establishing appropriate benchmarks for sustainable rangeland use.

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