INVESTIGATING MODIS RED BAND AS A TOOL FOR MONITORING LAND CONDITION IN THE ARID AND SEMI-ARID RANGELANDS OF THE NORTHERN TERRITORY.

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ABSTRACT
MODIS 'visible' red band imagery was used to develop a scaled index of vegetation cover to assist land condition monitoring programs of the pastoral lands of the semi-arid and arid Northern Territory. Statistics and visual representations were used to analyse cover change through time. Initial assessment of cover change was made through time-series plots and sequence image movies. Further investigation to assess variability across individual land types used histogram plots of percentages of pixels and change detection from one image to another. Comparisons of cover were made between pastoral properties, and across land types with differences presented in both map and graph form. Outputs should inform and enhance existing monitoring programs that assess land condition.

INTRODUCTION
The aim of this Natural Heritage Trust funded project was to provide a method to assist existing Northern Territory (NT) land condition monitoring programs by (1) providing an overview of cover at a given point in time, (2) to assist better targeting of ground-based activity, (3) early detection of potential land condition issues by identifying areas that are anomalous to trends. The project was undertaken from 2007 to mid 2008 and was also undertaken in the northern tropical savanna rangelands using a different methodology (Graham *et al.* in prep). It is crucial that the method be cost effective, repeatable at least annually and adopted within an ongoing framework that allows for continual refinement.

Developing a method presented some significant challenges. The extent and remoteness of the NT rangelands is logistically difficult and expensive to assess. The NT Government's Tier 1 monitoring program is a three year cyclic ground based method that aims to assess condition across all NT pastoral leases. An additional method based on remotely sensed data that can provide objective information at a broad scale and in a timely manner can assist the Tier 1 program. It would help target areas of concern and enable prioritisation of ground based programs.

Further challenges exist in analysing remotely sensed data for a landscape that receives low and infrequent rainfall. Measures of vegetation cover derived from satellite imagery have traditionally used responses to rainfall such as the 'greenness' index or Normalised Difference Vegetation Index (NDVI). The application of NDVI in arid landscapes is problematic when measuring cover over time as the interval between rainfall events that produce useful measurable flushes can be many years.

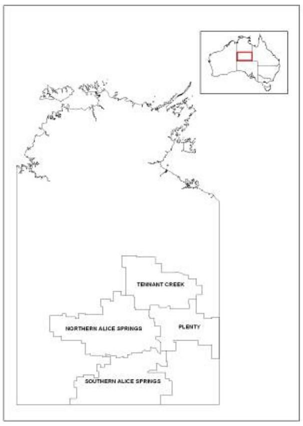

Figure 1. Study Area

To help overcome these difficulties the project examines the senescent trend of vegetation from a wetter period in 2000-2002 across a drier period ending in late 2007 when the latest data were collected. Minor flushes of limited intensity and extent occurred during the intervening years. The project has developed a method that uses the MODIS imagery base that is freely available as 16 day composites for the entire NT.

The use of the 'visible' red band, that is one of a number of available bands and indices, aims to overcome the climatic challenges of low rainfall. The project developed a number of different methods to explore both the spatial and temporal changes in vegetation cover with the aim of reporting on changes that may be associated with land condition.

METHODS

Satellite data

The MODIS 250m product data archive from July 2000 to December 2007 was acquired from both CSIRO Canberra and the NASA website http://modis.gsfc.nasa.gov/. Each image in the archive is a composite of the preceding 16 days to ensure cloud-free coverage. The 'visible' red band was selected to represent vegetation cover and image tiles stitched and clipped to a regional area of interest (AOI). The cover index was based on inverted values of the red band scaled between the minimum and maximum using methods similar to those applied by Bastin *et al* (2006) for the sheep-grazed rangelands of South Australia. Images were screened for erroneous cover values in the temporal sequence and those with seemingly false values removed from subsequent analysis. Erroneous cover values were mainly attributable to moist soil conditions and atmospheric haze or fine cloud.

Stratification / Scale (Areas of Interest)

Existing land system mapping was used to define broadly similar land types on the basis of landform and vegetation characteristics. Perry (*et al.* 1963) described land systems and grouped pasture types. The land system mapping required slight adjustment to align with the MODIS imagery.

The analysis used a hierarchal approach to examine cover change for the various scales or 'areas of interest':

- the Pastoral District (Figure 1) consisting of many properties extending over a large geographic area;
- the sub district level that consists of a number properties that exhibit similar or connecting land types; and
- individual properties and the paddocks within them.

Cover Images and time-traces

Each scaled image was masked to the land type of interest. Pixel cover values were then grouped into cover classes, particularly focussing on areas of low cover. Finally each image was placed in time-sequential order and an animation created. Changes through both space and time could then be visualised. Also a time-trace plot was created for each land type based upon the mean cover value for the area of interest for each point in time.

Histograms

The 'movie' of cover images enhanced variability across individual areas of interest that could not be summarised in a time-trace. More objective comparisons were made by selecting one image from the dry period each year and comparing histograms of the frequency of pixel cover values (Jeff Milne, Qld Dept. Natural Resources and Water, pers comm.,2008). Comparisons between areas of interest were made as well as comparisons with the entire district. Frequency distributions for levels of 'critically low' cover were determined and compared.

Change detection

The 'dry' images were also grouped into five cover classes and compared for degrees of change in broad cover categories. This was reported as a positive and negative scaled classification and shown in map form.

RESULTS
Preliminary results are presented to illustrate development of the method to date.

Scaling of the red band was tested using a number of parameters to determine appropriate maximum and minimum thresholds. A number of percentile 'cut off' points were tested. The most functional is yet to be determined however it was found that separate scaling was required for each land type due to their broadly different cover levels (e.g. woody cover) and associated data ranges.

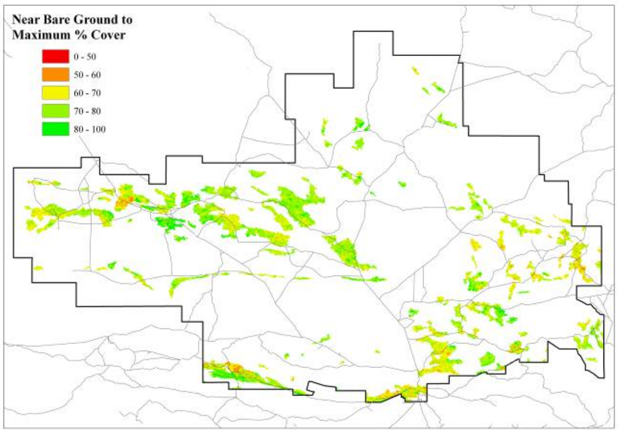

Figure 2. Land Type Cover Image

Development of the method was undertaken with the ability to readily adjust future inputs. This allows for future more detailed land stratification to be used and new outputs readily generated.

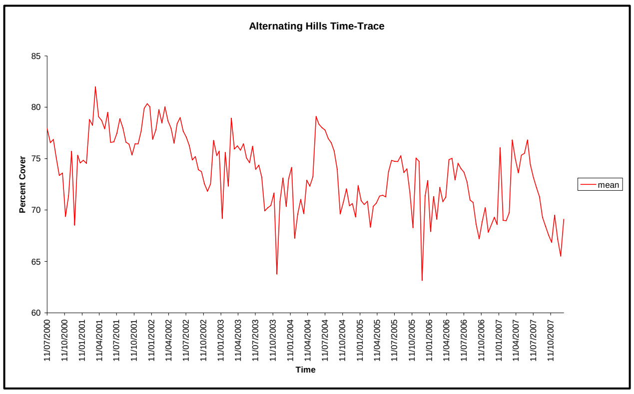

Figure 3. Land Type Time-Trace

The 'movie' of cover images has proven valuable for examining spatial patterning of sequential changes in cover. Changes in areas of low cover were further enhanced by manipulating the colour table to highlight these areas. It was apparent that from earlier dates to the most recent, extensive areas of low cover have developed across most land types. Figure 2 shows low cover areas of the 'Alternating Hills' land type coloured as yellow to red. Time-traces of average cover were also created for each land type and area of interest. Figure 3 shows an example of the 'Alternating Hills' land type. This result indicates the general high cover trend for the first three years and lower cover for the remaining four years, in the areas of interest. This was mostly attributed to three years (2000-2002) of above – average rainfall across the study area.

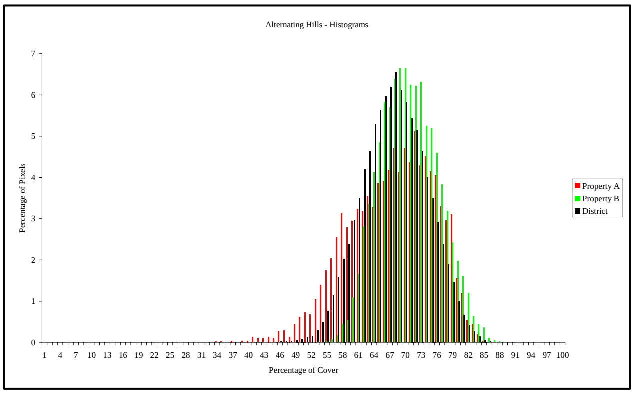

Figure 4. Land Type Histograms

The histograms of percentage of pixels for each land type gave a greater understanding of the cover variability throughout the areas of interest. A cover threshold level was tested to determine at which point cover was deemed to be in a low category. The threshold is still to be confirmed however thresholds are likely to be different for each land type. Figure 4 illustrates cover histograms for two pastoral properties and the overall district. Property 'A' (red) can be seen to have a higher proportion of pixels to the left of the histogram than both the district (black) and property B (green). This suggests a higher proportion of pixels in a low cover state.

DISCUSSION
Vegetation cover is considered to be vital to the condition of arid and semi arid landscapes, Tongway and Ludwig (1997 cited in Ludwig *et al* 2002) noted that landscapes with a high cover of vegetation

patches that act as obstructions have a high potential for capturing any resources. Consequently cover is used as a surrogate indicator of condition; however there are limitations such as fire and landscape variability that need to be considered to determine the effects of grazing. A process of removing or at least identifying these affects should form part of any 'further investigation' process. Preliminary project results indicate measurable changes in cover at both the broad pastoral district and at the individual property scale. These changes were presented and discussed with a small group of local experts and Departmental personnel during the project's development. This resulted in refinements to the methodology based on the experience of others who have used MODIS imagery in similar landscapes. Their detailed ecological and historical knowledge was used to test the outputs and this provided a degree of confirmation of the result.

Three main difficulties experienced during the project and that may have implications for adoption of the method are (1) the spatial and attribute limitations of existing landscape stratifications, (2) greater capacity to ground truth the scaled cover and to validate the outputs and (3) a longer time scale in the data set to compare long term seasonal changes.

The main recommendations are therefore to confer with local experts about the method and outputs, to utilise future land resource mapping, to test and validate the outputs and scaled imagery and to investigate use of longer term AVHRR imagery. There is also the need to establish some of form of benchmarking or referencing using landscapes under different management regimes where the land condition is known and understood.

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REFERENCES

Bastin, G., James, C., Chewings, V., & Brook, A. (2006), Wool Producers with remote control: New tools for whole of property management, Final report for Land, Water and Wool Funded Project, CSIRO Sustainable Ecosystems, Alice Springs, NT.

Graham, K., Trueman, M., & Yates, C. (in prep), Monitoring land condition in tropical savannah rangelands using MODIS imagery in the Northern Territory, NT Department of Natural Resources, Environment and The Arts, Darwin, NT.

Ludwig, J.A., Eager, R.W., Bastin, G.N., Chewings, V.H & Liedloff, A.C. (2002), A leakiness index for assessing landscape function using remote sensing, Landscape Ecology **17,** 157-171.

Perry, R.A., Mabbutt, J.A., Litchfield, W.H., Quinlan, T., Lazarides, M., Jones, N.O., Slatyer, R.O., Stewart, G.A., Bateman, W and Ryan, G.R. (1963), General Report on Land of the Alice Springs Area, Northern Territory, Compiled by Perry, R.A. Land Research Series No.6, Commonwealth Scientific and Industrial Research Organisation, CSIRO printing, Melbourne.

Tongway D.J. and Ludwig J.A. (1997). The nature of landscape dysfunction in rangelands, Chapter 5. In: Ludwig J., Tongway D., Freudenberger D., Noble J. and Hodgkinson K. (eds), Landscape Ecology, Function and Management: Principles from Australia's Rangelands. CSIRO Publishing, Melbourne, Australia, pp. 49–61.