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CLASSIFICATION AND USE OF LANDFORM INFORMATION TO INCREASE THE ACCURACY OF LAND CONDITION MONITORING IN WESTERN AUSTRALIAN PASTORAL RANGELANDS.

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ABSTRACT

Historically landforms have been mapped from field-based surveys or using stereo aerial photographs. Information about landforms plays an integral role for landscape evaluations, suitability studies, erosion studies, hazard predictions and various fields of landscape and regional planning. First, techniques and software were explored to extract primary topographic attributes from a digital elevation model (DEM): elevation, slope, profile curvature and plan curvature. Second, LandSerf software was employed to classify the DEM into landform types through semi-automated feature extraction. Six landform classes were produced: pits, channels, passes, ridges, peaks and planar. Experimental methods established the most suitable sampling window scale and slope tolerance. Curvature was not used in the classification process therefore no differentiation was found between slope types: upper, mid, and lower slope. Object based image analysis was tested using Landsat TM imagery. The imagery was segmented into areas with similar shapes. The boundaries can be forced to replicate those of landscape variables including the landform data produced in LandSerf, land system boundaries and available land unit boundaries.

This research provides evidence that available software can be used to map landform elements at the land subsystem level where currently data only exists at a land system level. This research aims to increase the quality and quantity of available land condition data that can be used in monitoring conditions of pastoral leases. Greater ability to provide accurate results on pastoral conditions will enable the lessee to better manage their land and increase productivity.

1. INTRODUCTION

This research is a study into landform patterns and landform elements at the land subsystem level to areas where the land surface is currently only mapped at a land system level. A study area was chosen to explore land condition information. Geographic Information methods were investigated to use this information to develop data that could eventually be applied to other pastoral rangeland areas of Western Australia. The outcome of this research is to provide higher resolution data capturing a greater range of spatial variation that can be incorporated into land condition monitoring projects including Pastoral Lease Assessment using Geospatial Analysis (PLAGA) and field surveys.

Various plant species have a variety of effects on rangeland ecosystems. These effects are exemplified predominately through animal grazing, fires and the regeneration of plant species (McKenzie 2004). Traditionally information of these effects was acquired through field surveys by Department of Food and Agriculture, Western Australia (DAFWA) that are not always practical due to lack of accessibility in remote areas, cost and time considerations. Geographic information systems/science (GIS) enables these effects to be monitored through projects such as PLAGA using satellite imagery and remote sensing techniques. PLAGA monitors grazing land condition and other natural phenomena including fire (Robinson, pers. comm., 2010). To monitor vegetation the surrounding and underlying landscape also need to be considered. Particular plant species may thrive after a fire initiated by an increase in grassland caused by cattle feeding on woody plants in a certain area but also a plant will thrive dependent on soil condition and the terrain of the landscape.

2. BACKGROUND

The WA rangelands can be divided into five regions: Kimberley, Pilbara, Gascoyne, Murchison and Goldfields. The research reported here focuses in the East Kimberley regional district of the Kimberley (Figure 1). The Kimberley region covers a total area of approximately 422,000 km² occupying one sixth of the entire state (Department of Regional Development and the North West and Kimberley Regional Development Advisory Committee (WA) 1986). The East Kimberley is comprised of several river catchment areas. The Ord River Catchment was chosen due to availability of land condition information at the land system scale. The data covers three stations – Ivanhoe, Carlton Hill and Bow River Stations. Due to the extent of the Ord River Catchment initial studies have be conducted in the Bow River Station area that was chosen for the diversity in topography and its relative central location.

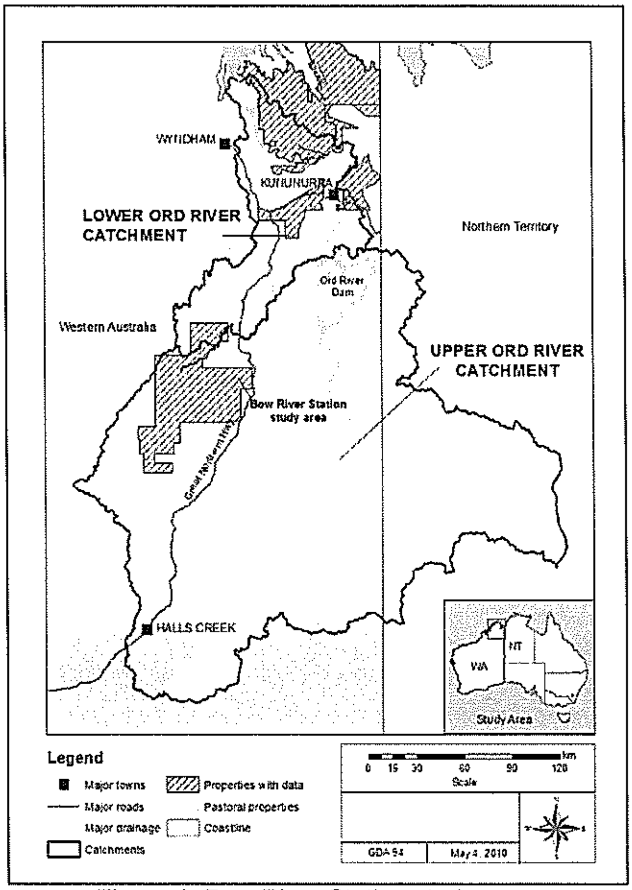

Figure 1: Bow River Station study area.

In general, the pastoral leases are extremely large with an average size of 1,850 km². A lease requires regular inspection although if a lease has no identified land condition problems then inspections are only performed once every six years. Around 75 leases are inspected annually by DAFWA at an estimated cost of $13,000 per lease. Lease reports produced by DAFWA are prepared for the WA Pastoral Lands Board (PLB), which administers pastoral lands under the WA Land Administration Act.

A large amount of research surrounds techniques and models that have been tried and tested for landform classification since the process of landform classification was first instigated by Gauss in 1828. There are two main spatial classification techniques used in GIS analysis; supervised and

unsupervised classification. These classification techniques require an input raster to analyse (e.g. Digital Elevation Model (DEM)) and the classes or clusters into which to group the data. The bases of class allocation for this analysis have been defined according to the *Australian Soil and Land Survey, Field Handbook*, where landform elements are classified as either: crest, ridge, flat, depressions and slopes (Speight 2009).
Attempts have been made to derive land unit information in the Ord River Catchment in the past. The main problem was that datasets were not at a high enough resolution to detect patterns in the land surface of an appropriate quality for precise land use classification. The model tested outside the "training data only predicted the correct land unit 3% of the time" (Schoknecht 2003).

3. METHODOLOGY

The methodology for this research can be divided into four steps that are as follows:

- Define landform features at a land subsystem level;
- Investigate techniques for extracting landform patterns and landform element from a digital elevation model;
- Investigate landscape models using other variables i.e. geology, land systems, drainage and land use data;
- Define a model to be used to extend landform features to other pastoral rangelands in WA

These steps can be represented as a structure chart that identifies the initial DEM and the process required to achieve data at a land subsystem level suitable for land condition monitoring techniques.

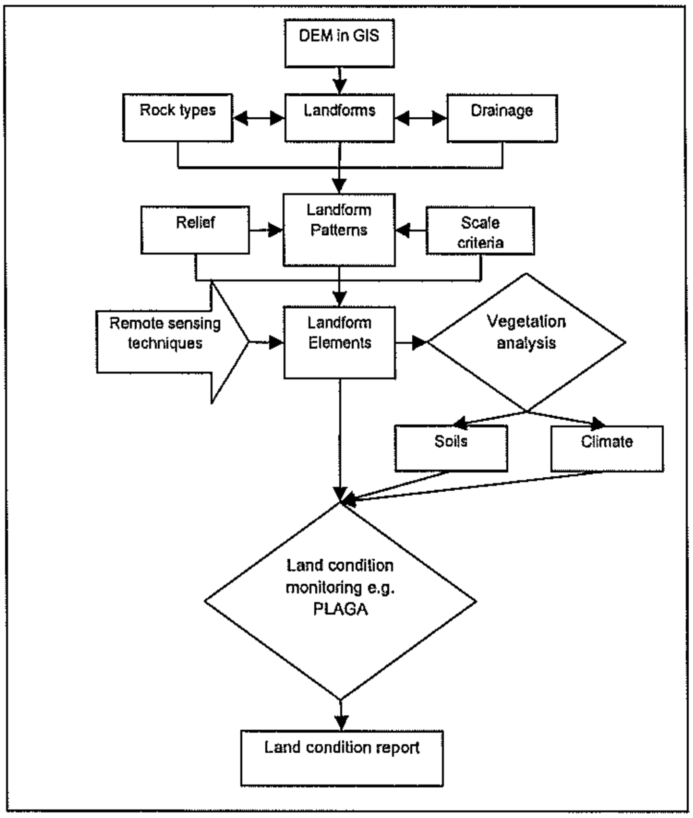

Figure 2: Methodology structure chart.

Initial research investigated the capabilities of GRASS, ArcGIS and LandSerf software to perform semi-automated landform feature extraction using unsupervised classification techniques. GRASS was found to have limited geomorphological processing capabilities in comparison with LandSerf and was rejected from further spatial analysis. LandSerf offers a feature extraction tool suite that allows user specification of window scale, slope tolerance and curvature tolerance (Wood 2009). LandSerf semi-automatically classifies a digital elevation model (DEM) into six classes – peaks, channels, plains, passes, pits and ridges. These classes can then be exported as shapefiles, rasters and various other data formats suitable for a variety of software. To find the ideal tolerance levels for landform classification, LandSerf offers a set of query tools. Using the query tools LandSerf parameters for the Bow River Station DEM were defined suitably. Due to the complexity of ridges and passes it was decided to simplify classification by classifying primary landforms channels and peaks first and to then extract and define more complex landforms with slope and curvature individually. A single landform raster was created in LandSerf. This landform raster was then imported into ArcGIS software.

ArcGIS was used for individual feature extraction of raster data, subset data analysis, preparation and presentation of findings and results as maps. Landform data was imported into ArcMap as a single raster that was broken into separate landform element rasters to be used in a comparative study. The study involved visual analysis of individual landform rasters with a variety of data and imagery to determine similarities and differences. Comparisons were made with Landsat 2002 imagery, geology, land system and land unit shapefile data both in ArcMap and ArcScene for two and three dimension perspectives respectively.

Due to arising limitations found during post-processing of LandSerf data to acquire acceptable accuracy for landform element class boundaries an investigation was made into Object Based Image Analysis (OBIA). The advantage of OBIA is the use of many different image layers in the analysis and classification processes. Data were loaded as image layers and thematic data into eCognition. The image layers included individual and combined landform rasters, slope and curvature rasters, a mosaic and clipped DEM for Bow River Station and Landsat 2002 imagery. The thematic data included land system, land unit, drainage and geology shapefiles. The Landsat 2002 image, as provided, did not provide enough spectral information (only Bands 1, 2, 3) so Landsat 5 TM imagery was downloaded from the US Geological Survey (United States Geological Survey. 2011) website for the Bow River Station area. The first step in eCognition was to segment the data using one or many of the image layers. First, segmentation was explored using the 30 m resolution DEM. The scale parameter was chosen by trial and error with an acceptable scale found to be 25. The newly created segmented layer was named "DEM", defined by elevation only. Land units were then used to segment the land surface to aid classification of the landforms. For classification to begin a class hierarchy was devised to define – channels, peaks, passes, pits, plains and ridges chosen to match those produced by LandSerf. Supervised classification techniques were used to classify the segmented data in eCognition. Pixel samples were selected that represented each landform element class. The classes were defined with threshold values of any or all of the image layers and/or of the thematic data. Conditions were also set for the classes that defined that individual landform (e.g. Channels: slope < 0). Once the threshold and conditions were defined a process was written that allowed the software to select every feature of that class. The eCognition classification process allows all classes to be classified together or using single class classification. The class layers can then be exported as shapefiles or rasters.

4. RESULTS

Classifications of landform information at a scale suitable to increasing land condition monitoring in Western Australian pastoral rangelands requires the results to be accurate and precise. The pastoral rangelands cover a large area that poses many problems within itself. The Kimberley pastoral rangelands are extensive and the topography is greatly diverse. Since it was not possible to classify the area as a single entity, small study sites were used for landform classification analysis. The study sites were chosen within pastoral leases where previous studies had produced land unit and land condition data.

Initially this research investigated the quality of the digital elevation model (DEM). The DEM available for this research consists of 30 m resolution Shuttle Radar Topographic Mission (SRTM) Level 2 Elevation Data. The main issue of classification with a DEM of this resolution is that some features will be compromised by the scale of the elevation data. Depending on the classifying software a

sampling window needs to be chosen that is small enough to identify small landform features otherwise landform results would be estimated. This classifying effect has little influence on larger landform features classified at a larger or smaller scale. It was decided following analysis into other available elevation data that the 30 m SRTM DEM was the best source for topography in the study area.
The results from software analysis found strength and weakness for ArcGIS, LandSerf and eCognition. In each case, the DEM was input as the main data source. The DEM was then analysed using query tools and methods used to extract landform classes. It was found through an iterative process that LandSerf and eCognition were the best choice for landform classification for this research.

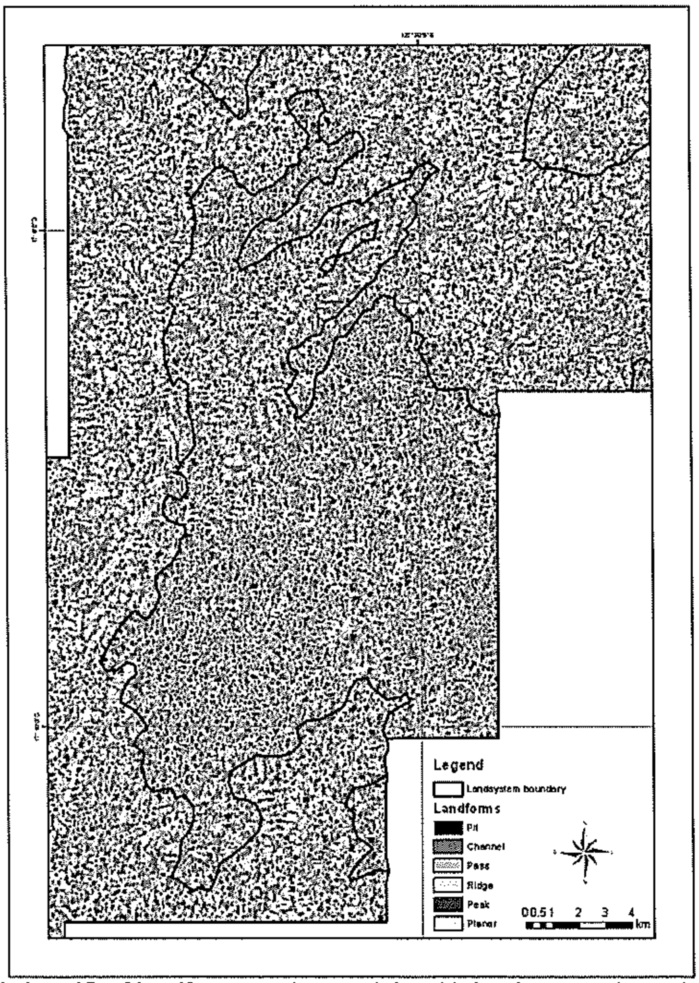

Figure 3: LandSerf landform results overlain with land system boundary data.

LandSerf produced results that divided the land surface into very small landform features (Figure 3). Most features appeared to correlate well with the DEM topography however some features appeared improperly grouped and incorrectly placed. Examples were channel features found to be discontinuous in landform classification. This discontinuity is likely due to errors or imperfections with the DEM and/or abrupt changes in elevation. These issues and abrupt changes in elevation then led to other classification errors including peaks allocated to low lying isolated points. According to Speight, (Speight 2009) peaks relate to hill tops defined by greater than 300 m elevation. The main cause of these problems was that only the DEM was used in the feature extraction process and more complex algorithms in the process were not possible. All LandSerf results were converted to ArcGIS GRID raster and added to ArcMap. The results were compared with land unit and land system data (Figure 3). Preliminary results using LandSerf identified that post-processing manipulation of the landform raster was required to achieve data that relates to other land condition information. Results found there were limitations with LandSerf unsupervised classification techniques.

Limitation of LandSerf initiated research into other software and techniques that might allow more input layers in the classification process. It was identified that slope, curvature and geology could aid classification of the Bow River Station area. If the classification process was forced to include such variables then better results might be found. ECognition is remote sensing software that allows input of various data types and provides a variety of classification techniques. Segmentation and supervised classification are the main functions of eCognition and results found using these techniques produced more precise channel and peak data (Figure 4).

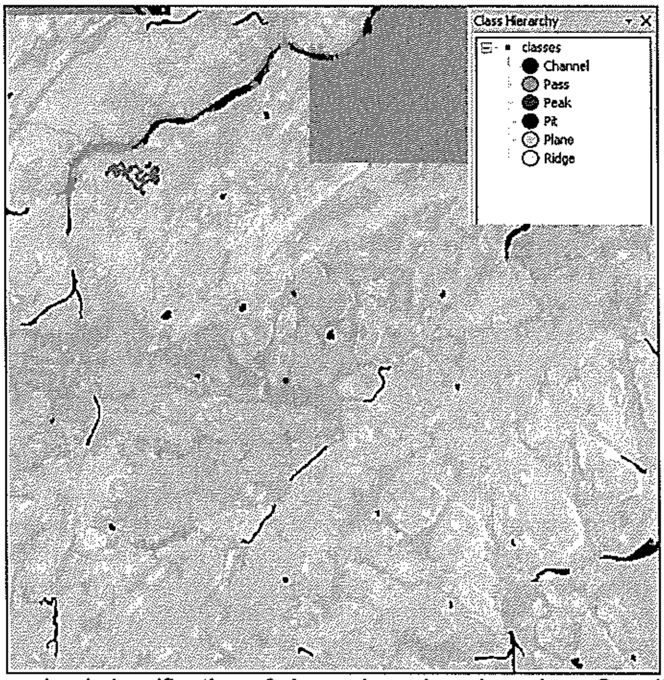

Figure 4: Supervised classification of channels and peaks using eCognition software.

5. DISCUSSION

The objective of the work reported here is to provide evidence that software exists that is capable of mapping landform patterns and landform elements at the land subsystem level in areas where the land surface is currently only mapped at a land system level. This research aims to significantly increase available land condition data in the Ord River Catchment and to devise a method that can be expanded to other areas of the pastoral rangelands.

Providing land subsystem level data for the PLAGA project will increase the quality and quantity of data for land condition assessment. Early warnings of land degradation especially at higher resolution could be used to trigger land management response, such as lowering stock numbers or complete de-stocking, to avoid long-term damage to the pastoral rangelands (Robinson, pers. comm., 2010). Increased quality and quantity of data incorporated into PLAGA will also improve the identification of areas that have recovered from previously 'poor' states that can be used, for example, to gauge the outcomes of such land management responses (Robinson, pers. comm., 2010).

The results have shown that LandSerf provides a good basis classification however limitations of LandSerf were discovered in that the user is unable to alter curvature and slope tolerances or change the processing model. These limitations not only prompt further investigations into other techniques and software types but also identify likely sources of error.

Object-based image analysis methods allow integration of existing remote sensing techniques and allow incorporation of classification practices that increase the power of semi-automated classification (Lang 2008). ECognition is powerful OBIA software that produced results that are promising for landform element classification in this research. Error and uncertainties are still factors that will need to be addressed with further application of this software.

6. CONCLUSION

This ongoing research will continue in order to refine suitable techniques and results for landform classification within the Western Australian pastoral rangelands. Accuracy was a problem in the past that inhibited the use of semi-automated to automated feature extraction from digital information to be used in land condition monitoring programs. This has led to continual challenges in monitoring remote areas to a high degree of certainty to support policy, planning and management for sustainability.

Both LandSerf and eCognition have proved capable of producing landform data. The challenge now is to perfect this data and simplify the methods so that they can be applied to other pastoral rangelands with varied terrain. By achieving landform classification in remote areas it would then be possible to extrapolate this information to soil types and vegetation types.

Understanding the landforms, soils and vegetation ultimately will lead to better monitoring of pasture degradation with more feasible results relying less on field-based surveys.

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