Satellite remote sensing as a tool to quantify the area of lucerne at a paddock scale in the Fitzgerald River catchment of Western Australia

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Abstract

Extensive livestock production systems in southern Australia are changing in response to climatic and economical challenges. These changes are occurring at regional, catchment, property and paddock levels. In order to understand changes in the feed base and implications to industry, accurate and timely quantification of pasture composition and condition is required. This is essential to assess the impacts of threats from salinity and climate change and to evaluate the adoption of new systems and technologies to maximize livestock production. In this project, medium resolution remotely sensed data sets (Landsat Thematic Mapper) pertinent to Fitzgerald River catchment, Western Australia were used. Using non-conventional digital image processing techniques, emphasis was given to identify and map annual and perennial pastures distribution at paddock level. Area of lucerne was the major focus. Validation of the mapping results was checked against the paddock level information (e.g type of pasture sown in 2007) provided by interviews with a selected group of farmers. Overall, 92 percent mapping accuracy was achieved. Due to the pixel level classification technique, it was possible to enumerate the total area coverage for lucerne at paddock, property and catchment levels.

Key Words

Farming systems, digital image classification, pastures mapping, raster & vector data integration, mapping accuracy.

Introduction

The Fitzgerald River catchment is located on the South coast of Western Australia, 20 km east of Jerramungup and 440 km south-east of Perth. Only 35% of the catchment has been cleared for agriculture with the majority of the catchment area located within Fitzgerald River National Park. Covering an area of over 329 000 ha, the National Park is one the largest in Australia and is recognised as one of the most diverse botanical regions on earth with around 1,800 species of flowering plants (nearly 20 per cent of Western Australia's flora species). According to hydrological zone mapping carried out by the South Coast Natural Resource Management group (SCNRM), about 10 per cent of the cleared land on the South Coast is thought to be affected by salinity to some extent. This area of salinity is expected to increase to about 17 per cent in the next 15 to 25 years before stabilising at almost 24 per cent, unless high water use farming systems, such as lucerne production, are adopted (http://www.southcoastnrm.com.au).

Lucerne (*Medicago sativa* L.) is a perennial legume that is widely sown in Australia because of its superior nutritional value for livestock. This value is most apparent at times when annual pastures are establishing or have senesced. Further benefits from lucerne include nitrogen fixation in soil, reduction in the leakage of rainwater into groundwater systems (reducing the risk of dryland salinity) and opportunities to reduce herbicide resistant weeds in cropping systems (Robertson, 2006). It has been estimated that lucerne is grown on 3.2 Mha in Australia, with a further 27 Mha of land identified as having potential for lucerne production (Robertson, 2006).

A tool to quantify the area of agricultural land planted to lucerne (or other species) will have multiple uses. Firstly, it allows Government and Catchment Management Authorities (such as SCNRM) to gain a better understanding of water use and thus dryland salinity risks within catchments. This may have implications for targeted investment in perennial plant systems and other salinity prevention measures. Secondly it may help the livestock industry achieve better forecasts for seasonal outputs such as prime lamb or lucerne fodder in a particular region. Finally it may be useful in understanding the adoption patterns of new plant species. Nichols et al (2007) have reported that 58 new annual and short-lived perennial pasture legumes have been released in Australia in the past 15 years. To date the only way to monitor success of these releases is to examine seed sales and data from farmer surveys. Development of an accurate satellite-based tool could lead to mapping of temporal adoption patterns of new species.

In recent years, there is increasing pressure from the fodder and livestock industry for a system that could map and monitor pastures with an acceptable accuracy level. Existing ground survey based techniques to map and quantify annual and perennial pastures are time consuming, labour intensive and costly. These techniques are largely impractical especially when dealing with catchment scale monitoring on a regular basis. Spatial technologies such as satellite based remotely sensed imagery provide substantial opportunities to strengthen pasture management programs and protect the environment via scientifically controlled grazing activities. The objectives of this project are to evaluate the use of digital image processing techniques for analysing medium resolution Landsat Thematic Mapper data sets for the identification and mapping of lucerne at paddock level and to quantitatively assess the validity of mapping results

Methods

A cloud free Landsat 5 satellite scene containing 4 spectral bands and recorded on 6th September 2007 was chosen for this study. The visible green (band 2) was selected for information on green reflectance by healthy vegetation mapping using the green reflectance peak as a result of chlorophyll pigment. The visible red (band 3) was used for information on vegetation mapping and biomass estimation using the chlorophyll absorption part of the spectrum. The near-infrared (band 4) was used for information on vegetation status, since NIR radiation is strongly reflected by photosynthetically active plants and to define boundaries of surface water bodies. Finally, the middle infra-red (band 5) was selected because of its use in estimating moisture content of vegetation.

Image processing was carried out using the ERDAS Imagine system. The key image pre-processing steps include data cleaning, image enhancement, atmospheric path correction, geo-registration of the input imageries to a base map and integration of the vector layers highlighting paddock and farm boundaries. Prior to three tier image classification, all areas outside the paddock and farm boundaries were masked out.

Stage one of image classification included the application of unsupervised classification using ISODATA image classifier technique (Mather, 2004). This resulted in a great deal of spectral overlap between a number of land cover classes. A non conventional image classification procedure (Ahmad and Hickey, 2008) was applied to generate a set of unique spectral classes representing the dominant land cover classes observed in the area. For this purpose, three large polygons encircling different land cover types spread over different parts of the image were defined from the paddock level information i.e. type of crop or pasture sown in 2007 (figure 1) provided by the participating farmers in the Fitzgerald River catchment,. These polygons were independently classified in an unsupervised classification mode using minimum distance to the mean classifier and the resultant spectral classes were pooled together. Identical spectral classes were then deleted and spectrally similar classes were merged using Euclidean distance (Mather, 2004) and transformed divergence algorithm (Erdas Imagine, 2010). Spectral separability and spatial contiguity of these classes was checked by mapping it on the classified image that was linked to the corresponding raw image and the classes with the lowest separable value were merged. Spectral classes were only aggregated if they were spectrally similar and intermixed spatially when displayed on the screen. The resultant classes were then used as an input for the supervised classification of the full input image of the study area. The final classification stage involved overlaying paddock and farm boundaries onto the classified image to evaluate the mapping exercise at paddock level.

Figure 1: Image showing paddock boundaries and corresponding crops and pastures. This information was provided by participating farmers.

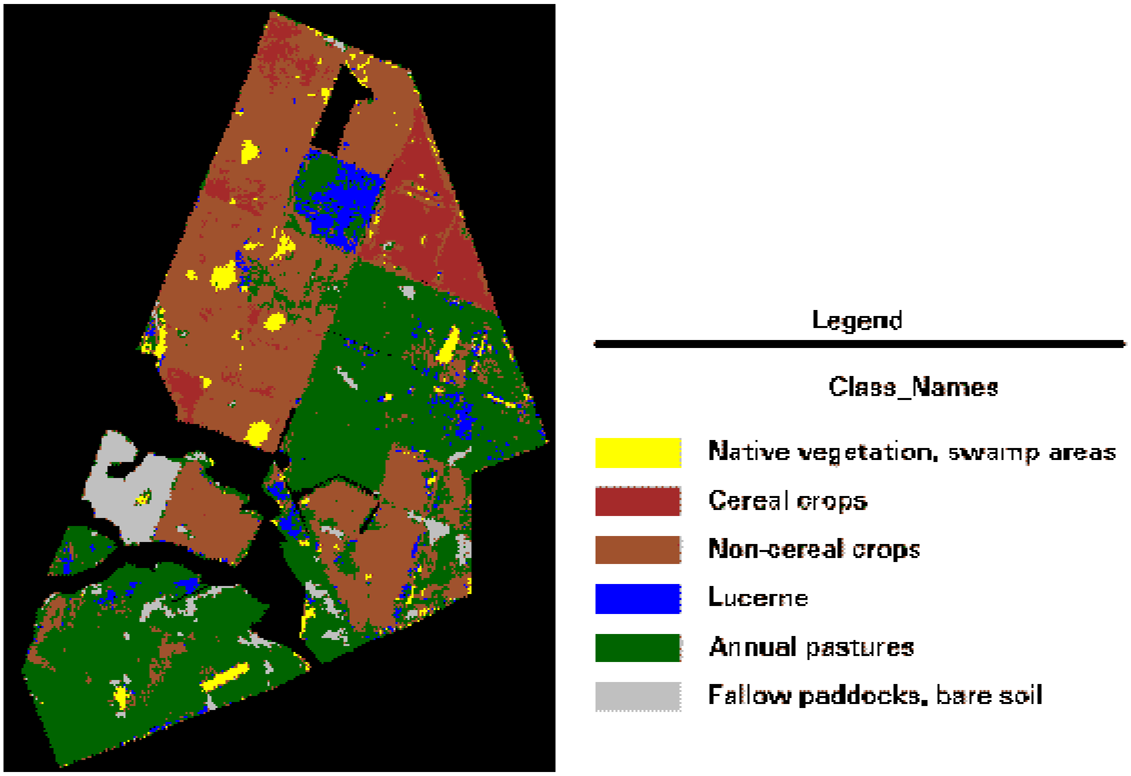

Figure 2: Landsat TM classified mage showing the distribution of Lucerne and other land cover types.

Results and assessment of accuracy

The classification procedure and the geo-linking of the landsat TM classified image with the actual land cover information provided by the participating farmers (figure 1) resulted in the reduction of 40 spectral classes into six super classes (figure 2). It is important to recognise that the conventional computer based classifiers do not recognise spatial patterns in the same way as the human interpreter does. The classifiers perform class assignments based only on the spectral signatures of specific paddock pixels. The geographic locations of those pixels nor the spectral characteristics of surrounding pixels are taken into account. Prior to the amalgamation process, every single spectral class was designated a distinct colour and its spectral similarity and spatial contiguity was assessed with the help of the field data highlighted in figure 1.

In this study we focussed on the identification and mapping of the 46 hectare lucerne paddock highlighted in blue colour in figure 2. The classification process generated two spectral classes for this cover type. The dominant lucerne class accurately mapped most of the healthy lush green and fully ground covered part of the targeted paddock. However, in the north western part of the targeted area where the lucerne germination was poor there was a spectral class overlap with sparse annual perennial pastures. This can be visualised by the overspill of the blue colour into the annual pasture areas.

A range of qualitative and quantitative techniques are generally used to assess the accuracy of remotely sensed data based classification maps. In this project an error matrix analysis (Lillesand et al. 2008) was used to determine the overall mapping accuracy of the six super classes mapped in this project. The actual land cover information at paddock level provided by the participating farmers and highlighted in figure 1 was used as an input to evaluate the paddock level mapping accuracy. Overall, ninety two percent mapping accuracy was achieved.

Conclusions

The results of this project reveal that to evaluate the impact of changing climatic and economic conditions at individual farms and paddock level, the medium resolution remotely sensed imageries along with digital image classification techniques can be successfully used. Such timely, cost effective and accurate information has the potential to be used as an alternative tool to evaluate the impacts of threats such as salinity and climate change and to evaluate the adoption of new systems and technologies to maximize livestock and agricultural production.

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