MULTI-TEMPORAL ANALYSIS OF LAND COVER CONDITIONS IN MITCHELL GRASSLANDS, AUSTRALIA, USING MODIS SATELLITE IMAGERY

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ABSTRACT

Natural grasslands provide primary feeding source for cattle farms. Due to its important role in natural environment and economy, regular monitoring and analysis of its various aspects are essential. This study focused on analysing land cover changes in Mitchell Grasslands, the most extensive tussock grasslands in Northeast Queensland, Australia. The approach was to detect the relationship between the greenness and rainfall based on appropriate fluctuations of Vegetation Indices. After gathering multi-temporal imagery from MODIS at 250m resolution, image processing was conducted using ENVI 4.4 software and MODIS Conversion Toolkit. The average of Vegetation Indices of study area was calculated for the respective time. The data analysis showed a positive relationship between greenness of the grasslands and fluctuations of the rainfall. Results of the study pointed out the highest NDVI value (0.53) in April related to the highest precipitation event in the year. The mean NDVI value is lowest (0.16) in November as the end of the dry season. However the study found the significant rainfall in the dry season is not strong enough to produce any significant progress in greenness. Both random horizontal profiles over NDVI images also showed high and very low deviation of NDVI values in April and November, respectively. The usefulness in regular monitoring and analysing land cover changes using freely available MODIS data were also highlighted in this study.

1. INTRODUCTION

The Moderate Resolution Imaging Spectroradiometer (MODIS) data outputs have been widely used in research community since 2002. MODIS system has a number of advantages including free and easy access data, daily images, large swath width, and data in multi-spectral bands with medium spatial resolution. MODIS also provides plentiful products for monitoring and predicting about atmosphere, land, ocean and calibration. A number of studies about various aspects of earth surface using multi-temporal MODIS imagery have been conducted including land cover mapping, crop area estimates and analysing biomass fluctuations (Zhan et al. 2002; Perera et al. 2009; Perera et al. 2010).

Normalized Difference Vegetation Index (NDVI) value is most sensitive to fluctuations in the amount of green biomass and chlorophyll content. The NDVI approach has been used for many years to measure and monitor plant growth, vegetation cover, biomass production and assessing the relationship between crop yield and seasonal variability. Furthermore, NDVI is an appropriate approach to conduct image analysis to extract biomass characters in Mitchell

Grasslands (Perera et al. 2009). The present study was conducted to assess the changes of greenness in the Mitchell Grasslands of Queensland, Australia, due to the difference in rainfall amounts in the wet season and dry season. The aim of the study was to analyse the fluctuation of NDVI values affected by rainfall to show the relationship between greenness and precipitation. The study also determined the usefulness of MODIS satellite imagery in this research field.

2. METHODOLOGY

Figure 1 illustrates main steps of methodology used in the study. Multi-temporal MODIS imagery in 250m resolution was gathered for every month from January to December 2011 from NASA website using MRT Web tool. Image data were selected during the period of low cloud cover and other disturbances.

Daily rainfall records in 2011 were collected from the Bureau of Meteorology website. The selected weather observation station is located close to the study area. Each land cover type was identified using high resolution images available in Google Earth data. These identified land cover classes were pure grassland, forest, mixed grass land, bare soil and water. Selected land cover samples are small areas respective of these land cover and cloud-free areas on MODIS imagery.

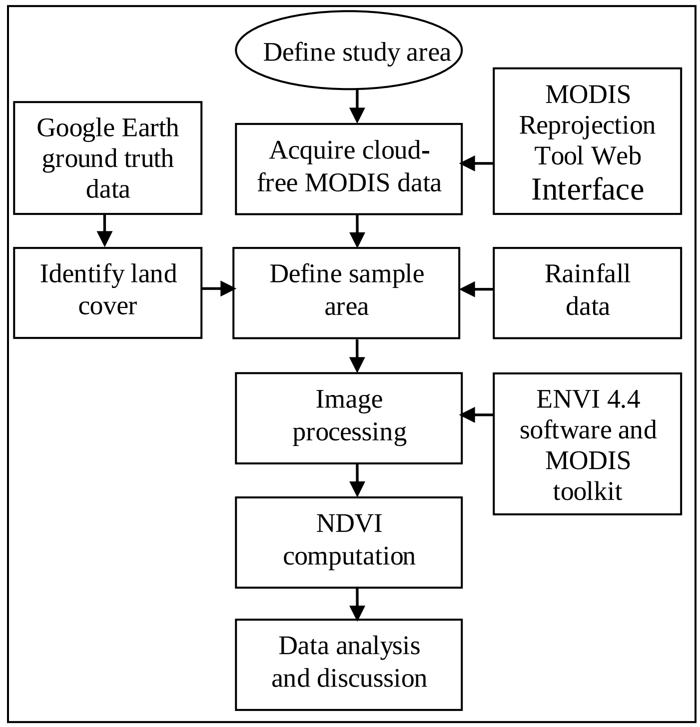

Figure 1. Research methodology

MODIS Conversion Toolkit was used to convert MODIS HDF file format into the required format before an image processing conducted to produce the classification using ENVI 4.4 software. NDVI was computed using MODIS band 01 (red) and band 02 (near infrared) data as the following formulation [1]:

$$NDVI = \frac{\rho_{NIR} - \rho_{Red}}{\rho_{NIR} + \rho_{Red}} \quad (1)$$

where ρRed (600-680 nm) and ρNIR (846-885 nm) are the bidirectional surface reflectance for the MODIS band 01 and band 02 respectively.

3. DATA ACQUISITION AND PROCESSING

3.1 Study Area

The Mitchell grasslands covers a large area (540,000 km^2), which occupies about 15% of Australia's land area, stretching from northwest New South Wales to north and northeast Australia (Figure 2 and 3). This grassland area has supported a population of over 15,000 people. It is also an important pastoral recourse for breeding farm as well (Figure 4). About 72% of this grassland area falls within Queensland where extensive cattle and sheep farming are taking place. It is a primary feeding source for about 12 million cattle in the state (Perera et al. 2009). Based on previous studies, the study area was selected with the size of 400 pixels by 200 pixels (5,000 square kilometers) close to the Richmond weather observation station. Most of the study area is dominated by Mitchell grasses but the upper central area has a region of riparian forest and savanna where some soil patches are also available.

Figure 2. Mitchell Grasslands, Australia

Figure 3. A typical view of Mitchell grasses, 24 Sep 2010

3.2 Data Acquisition

MODIS Terra/Aqua Surface Reflectance Bands 1-2 8-Day 250m (MOD09Q1&MYD09Q1) provides spectral images including the red light (Band 1) and near-infrared light (Band 2) at 250-meter resolution in an 8-day gridded level-3 product. These products have projected in the Sinusoidal projection. Each pixel comprises the best possible L2G observation during an 8-day period such as low view angle, the absence of clouds or cloud shadow, and aerosol loading. Data was projected on the geographic projection with WGS84 datum. The bounds of the study area were also limited to suit research scope respectively using USGS Reprojection Tool Web Interface (MRTWeb). MODIS dataset was collected in free-cloud condition for every month in 2011.

Figure 4. Cattle grazing in Mitchell Grasslands, April 2012

3.3 Data Processing

Collected data including 12 MODIS images corresponding to each month of 2011 were converted from HDF format into ENVI format with band 1 and band 2 using MODIS Conversion Toolkit. Then, these images were resized to select the interesting region before calculating the NDVI value using NDVI function that is available in the ENVI 4.4 software. The statistics of NDVI images were computed to gather the Min, Max, and Mean values of the NDVI. The histogram of NDVI values was plotted with the range values selected from -1 to 1. The Mean values were matched to rainfall data to represent the relationship between the greenness and precipitation events. From NDVI images of April and November, two profiles were randomly selected to analyse. The statistics of these two profiles were gathered and represented together using Microsoft Excel software.

4. RESULTS AND DISCUSSION

Precise measurements in analysing changes in greenness (plant biomass production) are important to estimate the increase in Mitchell grass growth after the rainy season. This investigation is essential for grazing activities of local communities and for the sustainable ecosystem management of the region. Figure 5 indicates the relationship between rainfall and mean NDVI of each month calculated for the study area in the year of 2011. NDVI value covers a range from -1 to 1 in which values closer to 1 are greener. Based on the graph, it is clear that the fluctuation of rainfall has a significant effect on NDVI values (greenness). As the effect of a strong La Niña event occurred by the end of last year (2010), a heavy precipitation season has resulted in the high NDVI value (0.45) found in January of 2011. The NDVI value was slightly reduced and can be associated with the decrease of rainfall in the following month. However, the figure increases then and reaches the highest value (0.53) in April (A) as a result of the highest precipitation event in the year before gradually declining during the dry season. The mean NDVI value is lowest (0.16) at the end of the dry season (C). The figure also shows that the mean NDVI in July and August is still low although there is a significant rain before (B). This demonstrates that a significant rainfall in the dry season is not strong enough to produce enough greenness. Additionally, the timing of rainfall is also an important factor that has a remarkable influence on the greenness.

To assess precisely the direct effect of rainfall on NDVI values, data of April and November was selected to analyse the difference since they represent the highest and lowest mean NDVI. In figure 6, bright white to gray areas present higher NDVI or greener pixels. All NDVI values were less than 0.321 in November while the April image recorded values as high as 0.797. In April, riparian forest along the rivers is clearly visible, especially the area around the lower right corner of the image. However, during the dry season, the bright color of this area has changed to gray representing the low NDVI. Through changes of NDVI values, it indicates that changes of greenness are directly associated to the precipitation. Significant difference in biomass related to extreme precipitation events showed in these images has given valuable evidence to demonstrate the quantitative relationship between precipitation and greenness.

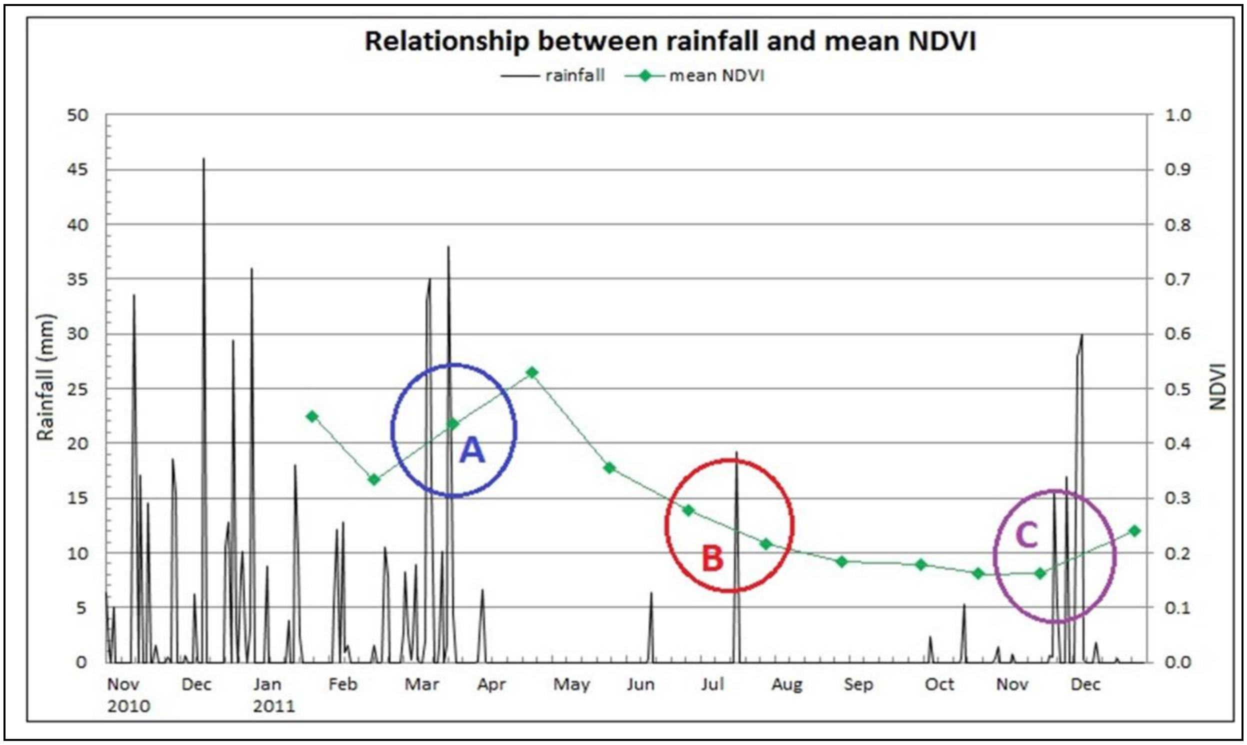

Figure 5. Relationship between rainfalls and mean NDVI in 2011

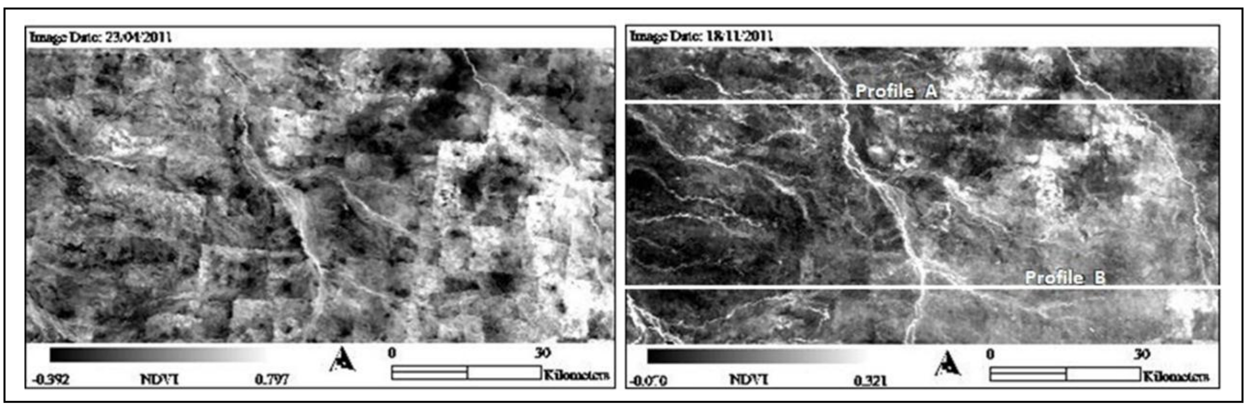

Figure 6. NDVI products calculated for April and November 2011 using MODIS band 1 and band 2 data

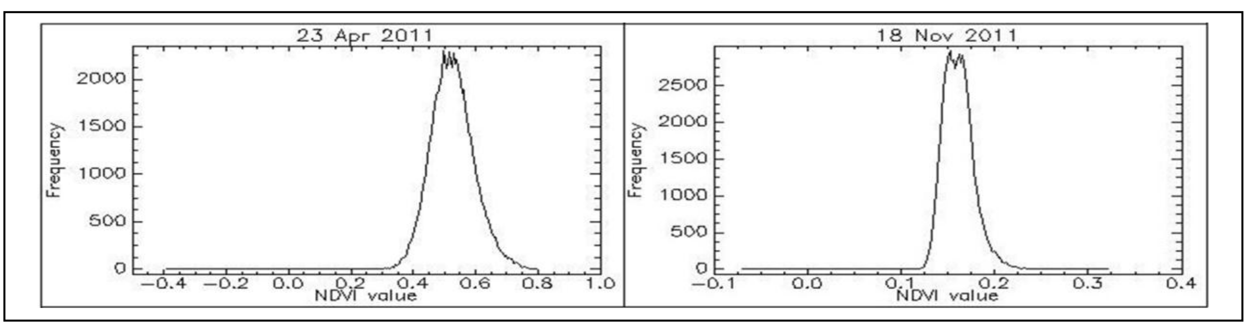

Figure 7. Histograms of NDVI values of April and November 2011

Figure 7 presents histograms of NDVI at lowest precipitation event (after dry months) and highest precipitation (after rainy months). The representation of NDVI values indicates that the mostly study area is covered by a large homogeneous Mitchell grasses. The values of NDVI image shows only 1.9% of study area has 0.2 NDVI or higher values in November compared to 97.6% of area has 0.4 NDVI or higher values in April. Heavy rainfall in the wet season has effected on the increase of greenness represented through the active photosynthesis conditions in the Mitchell grassland. The effect of rainfall on the fluctuation of greenness presented through NDVI values was further analysed using NDVI profile transects as showed in figure 6. Profile A and B was defined as the random horizontal profiles over NDVI images of April and November in 2011. The NDVI values along these two profile lines are plotted in the figure 8. Both profiles defined in the November image present very low deviation of NDVI values showed by the mean just 0.160 for both A and B. Profiles of April show much higher values, 0.533 and 0.524 for A and B, respectively.

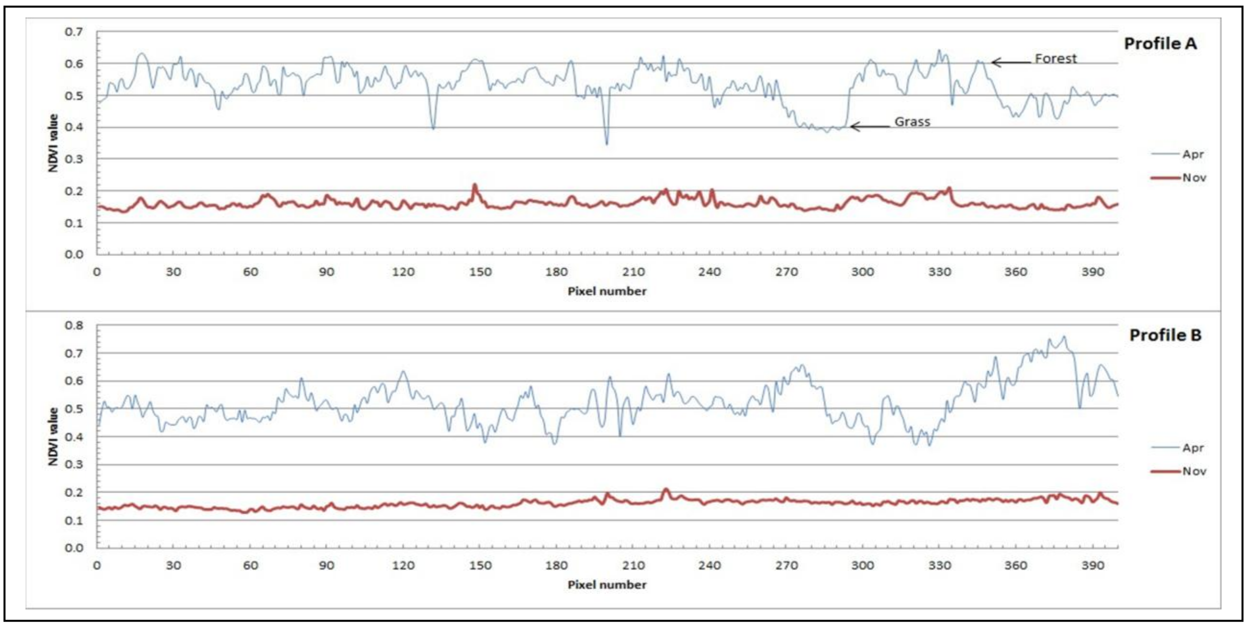

Figure 8. NDVI profile transects of April and November images in 2011

5. CONCLUSION

MODIS system has more advantages for widespread grassland mapping and detecting surface changes at very low cost. Results achieved in this study were able to determine the positive relationship between rain fall and greenness through very high NDVI values in rainy months and conversely in dry months. The rainfall duration also has a distinct effect on the health of plants. However, a heavy rain in a short time duration occurring in the dry season is not strong enough to increase greenness of the Mitchell Grasslands. Annual changes of this vast grassland due to rainfall fluctuations can be evaluated and monitored using MODIS data to support planning pastoralism and avoiding overgrazing. This can contribute in maintaining the persistence of this unique natural ecosystem and agricultural industry in Queensland and Northern Territory of Australia.

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