Arid Land Condition Assessment and Monitoring Using Multispectral and Hyperspectral Imagery

By

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ABSTRACT

Arid lands cover approximately 30% of the earth's surface. Due to the broadness, remoteness, and harsh condition of these lands, land condition assessment and monitoring using ground-based techniques appear to be limited. Remote sensing imagery with its broad areal coverage, repeatability, cost and time-effectiveness has been suggested and used as an alternative approach for more than three decades. This thesis evaluated the potential of different remote sensing techniques for assessing and monitoring land condition of southern arid lands of South Australia. There were four specific objectives: 1) to evaluate vegetation indices derived from multispectral satellite imagery for prediction of vegetation cover; 2) to compare vegetation indices and field measurements for detecting vegetation changes and assessing land condition; 3) to examine the potential of hyperspectral imagery for discriminating vegetation components that are important in land management using unmixing techniques; and 4) to test whether spatial heterogeneity in land surface reflectance can provide additional information about land condition and effects of management on land condition.

The study focused on Kingoonya and Gawler Soil Conservation Districts that were dominated by chenopod shrublands and low open woodlands over sand plains and dunes. The area has been grazed predominately by sheep for more than 100 years and land degradation or desertification due to overgrazing is evident in some parts of the region, especially around stock watering points. Grazing is the most important factor that influences land condition. Four full scenes of Landsat TM and ETM+ multispectral and Hyperion hyperspectral data were acquired over the study area. The imagery was acquired in dry seasons to highlight perennial vegetation cover that has an important role in land condition assessment and monitoring.

Slope-based, distance-based, orthogonal transformation and plant-water sensitive vegetation indices were compared with vegetation cover estimates at monitoring points made by state government agency staff during the first Pastoral Lease assessments in 1991. To examine the performance of vegetation indices, they were tested at two scales: within two contrasting land systems and across broader regional landscapes. Of the vegetation indices evaluated, selected Stress Related Vegetation Indices using red, near-infrared and mid-infrared bands consistently showed significant relationships with vegetation cover at both land system and landscape scales. Estimation of vegetation

cover was more accurate within land systems than across broader regions. Total perennial and ephemeral plant cover was predicted best within land systems (R^2=0.88), while combined vegetation, plant litter and soil cryptogam crust cover was predicted best at landscape scale (R^2=0.39).

The results of applying one of the stress related vegetation indices (STVI-4) to 1991 TM and 2002 ETM+ Landsat imagery to detect vegetation changes and to 2005 Landsat TM imagery to discriminate Land Condition Index (LCI) classes showed that it is an appropriate vegetation index for both identifying trends in vegetation cover and assessing land condition. STVI-4 highlighted increases and decreases in vegetation in different parts of the study area. The vegetation change image provided useful information about changes in vegetation cover resulting from variations in climate and alterations in land management. STVI-4 was able to differentiate all three LCI classes (poor, fair and good condition) in low open woodlands with 95% confidence level. In chenopod shrubland and Mount Eba country only poor and good conditions were separable spectrally.

The application of spectral mixture analysis to Hyperion hyperspectral imagery yielded five distinct end-members: two associated with vegetation cover and the remaining three associated with different soils, surface gravel and stone. The specific identity of the image end-members was determined by comparing their mean spectra with field reflectance spectra collected with an Analytical Spectral Devices (ASD) Field Spec Pro spectrometer. One vegetation end-member correlated significantly with cottonbush vegetation cover (R^2=0.89), distributed as patches throughout the study area. The second vegetation end-member appeared to map green and grey-green perennial shrubs (e.g. Mulga) and correlated significantly with total vegetation cover (R^2=0.68). The soil and surface gravel and stone end-members that mapped sand plains, sand dunes, and surface gravel and stone did not show significant correlations with the field estimates of these soil surface components.

I examined the potential of a spatial heterogeneity index, the Moving Standard Deviation Index (MSDI), around stock watering points and nearby ungrazed reference sites. One of the major indirect effects of watering points in a grazed landscape is the development around them of a zone of extreme degradation called a piosphere. MSDI was applied to Landsat red band for detection and assessment of these zones. Results showed watering points had significantly higher MSDI values than non-degraded reference areas. Comparison of two vegetation indices, the Normalized Difference Vegetation Index (NDVI) and Perpendicular Distance vegetation index (PD54), which were used as reference indices, showed that the PD54 was more sensitive than NDVI for assessing land condition in this perennial-dominated arid environment. Piospheres were found to be more spatially heterogeneous in land surface reflectance. They had higher MSDI values compared to non-degraded areas, and spatial heterogeneity decreased with increasing distance from water points.

The study has demonstrated overall that image-based indices derived from Landsat multispectral and Hyperion hyperspectral imagery can be used with field methods to assess and monitor vegetation cover (and consequently land condition) of southern arid lands of South Australia in a quick and efficient way. Relationships between vegetation indices, end-members and field measurements can be used to estimate vegetation cover and monitor its variation with time in broad areas where field-based methods are not effective. Multispectral vegetation indices can be used to assess and discriminate ground-based land condition classes. The sandy-loam end-member extracted from Hyperion imagery has high potential for monitoring sand dunes and their movement over time. The MSDI showed that spatial heterogeneity in land surface reflectance can be used as a good indicator of land degradation. It differentiated degraded from non-degraded areas successfully and detected grazing gradients slightly better than widely used vegetation indices. Results suggest further research using these remote sensing techniques is warranted for arid land condition assessment and monitoring in South Australia.

DECLARATION

This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

I give consent to this copy of my thesis being available for loan and photocopying.

Signed:……………………. Date:……………………..

Reza Jafari

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PUBLICATIONS ARISING FROM THIS THESIS

Refereed Publications

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Jafari, R., Lewis, M.M. and Ostendorf, B., 2007. An image-based diversity index for assessing land degradation in an arid environment in South Australia. *Journal of Arid Environments* (submitted January 2007, under review).

Other Publications

Jafari, R., Lewis, M.M. and Ostendorf, B., 2006. Analysis of vegetation indices for assessing and monitoring vegetation cover in an arid environment in South Australia, Proceedings of the 14th Biennial Australian Rangeland Society Conference, Renmark, South Australia, , September 2006, pp. 229-232.

Jafari, R., Lewis, M.M. and Ostendorf, B., 2006. An image-based diversity index for assessing land degradation in an arid environment in South Australia, Proceedings of the 13th Australian Remote Sensing and Photogrammetry Conference (ARSPC), The Photogrammetry Association of Australia, CD publication, November 2006, Canberra, Australia.

Jafari, R., Lewis, M.M. and Ostendorf, B., 2006. Use of EO-1 hyperspectral imagery for discriminating arid vegetation, Proceedings of the 13th Australian Remote Sensing and Photogrammetry Conference (ARSPC), The Photogrammetry Association of Australia, CD publication, November 2006, Canberra, Australia.