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ANALYSIS OF VEGETATION INDICES FOR ASSESSING AND MONITORING VEGETATION COVER IN AN ARID ENVIRONMENT IN SOUTH AUSTRALIA

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ABSTRACT
This study reviewed and evaluated different groups of satellite image-based vegetation indices for estimating vegetation cover in southern arid rangelands of South Australia. Slope-based, distance-based, orthogonal transformation, and plant-water sensitive vegetation indices were calculated from Landsat Thematic Mapper (TM) sensor data. These indices were compared with vegetation cover data collected by the SA Pastoral Management Branch (PMB) as part of the Pastoral Lease Assessment program. Relationships between vegetation cover and various vegetation indices were compared using linear regression at two different scales: landscape scale involving a range of land types present within an entire Landsat scene, and within selected land systems. Among the different vegetation indices, Stress Related Vegetation indices from the group of plant-water sensitive vegetation indices showed the most significant relationships with vegetation cover at the 95% confidence level at both landscape and land system scale. It was generally observed that the estimation of vegetation cover within land systems was more accurate than across land systems.

INTRODUCTION
One of the widest applications of remote sensing is vegetation monitoring and assessment via vegetation indices (Bannari et al., 1995). However, most of the commonly used vegetation indices have been shown to be inappropriate in arid and semi-arid land of Australia (O' Neill, 1996). The aim of this study was to evaluate the suitability of vegetation indices derived from Landsat Thematic Mapper (TM) imagery as an adjunct to field methods for assessing and monitoring vegetation cover in southern rangelands of South Australia. Using these image-based methods may overcome some of the limitations of field methods as a means of documenting and monitoring land condition; the time and cost of data collection, the potential error in observations and the difficulty of extrapolating beyond sample points.

METHODS
Study area
The study area was located in the Kingoonya Soil Conservation District in the southern rangelands of South Australia (figure 1). The region lies within latitudes 29° 30′ S and 31° 30′ S and within longitudes 133° 00′ E and 136° 00′ E. The Kingoonya District covers an area of 65, 815 km^2. The climate in this area includes hot summers and cold mild winters. Rainfall is variable from year to year, with an average annual rainfall varying from less than 150 mm in the northeast to around 200 mm in the southwest and is among the lowest in Australia (Kingoonya Soil Conservation Board, 1996). The Kingoonya District includes many different land systems, vegetation communities and some salt lakes. The study area comprised 10 different land systems falling within the 34, 000 km^2 covered by a full Landsat scene. Buckshot and Gina land systems that were studied in more detail are described in Table 1.

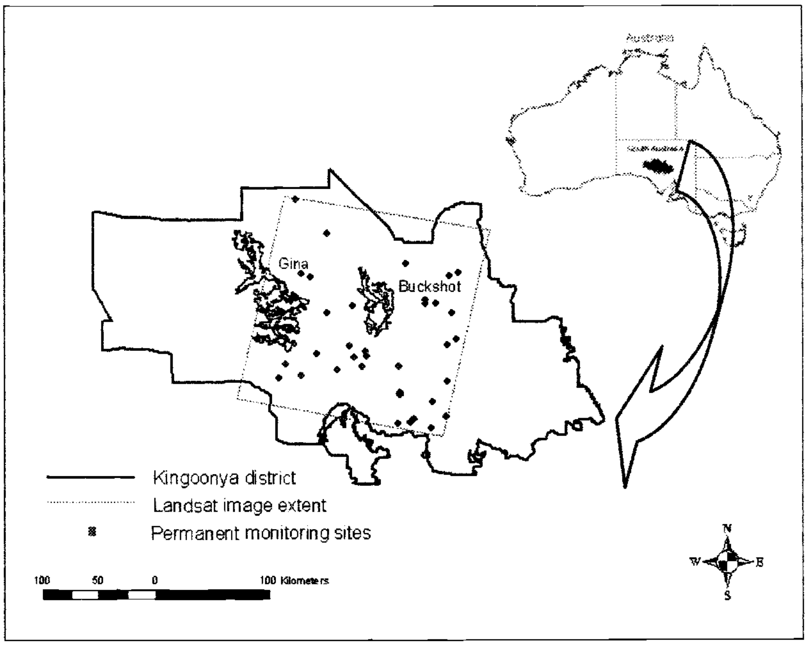

Figure 1: Location of study area within Kingoonya Soil Conservation District

Table 1: Summary description of Buckshot and Gina land system
(Department of Water, Land Biodiversity and Conservation, 1991)

Land system	Description
Buckshot	Mt Eba buckshot gravel plains. Plains of mulga low open woodland with dead finish, emubush and low bluebush; gilgai plains of cottonbush with Mitchell grass, neverfail, some saltbush and bluebush; mulga woodland watercourses with dead finish and emubushes.
Gina	Extensive sandy calcareous plains. Calcareous plains of pearl bluebush low shrubland with hopbush and cassia; sand spreads of mulga open woodland over cassia and grasses; run-on flats of mulga and dead finish over grasses.

Field and satellite data

The vegetation cover data used in this study was collected by the Pastoral Management Branch (PMB) as part of the first land condition assessment at permanent monitoring sites throughout the District in 1991. The vegetation cover was recorded using the step-point technique with minimum 500 points or hits. In order to coincide satellite data with the collection of vegetation cover data, a full scene of Landsat Thematic Mapper (TM) (path 100 row 81) from 20 October 1991 was acquired, radiometrically corrected and geometrically rectified to Australian Map Grid coordinates.

Vegetation indices

Vegetation indices are combination of spectral bands from remote sensing instruments that provide information about vegetation cover on the ground. Actively growing photosynthetic vegetation displays strong absorption in red visible wavelengths and high reflectance in the near-infrared part of the electromagnetic spectrum. This strong contrast in red and near infrared of the electromagnetic spectrum has been the basis for developing many different vegetation indices. The first vegetation index was produced using the near-infrared/red ratio for separating green vegetation from soil background. Since then, different vegetation indices have been produced, modified, analysed, compared and classified (Bannari et al., 1995). In this study we have grouped vegetation indices into four groups: group one which is based on the contrast between red and near-infrared (slope-based), group two which is based on perpendicular distance from soil line in multispectral space (distance-based), group three which involves orthogonal transformations of a number of multispectral image bands (orthogonal transformations), and group four which include visible red, near-infrared, mid-infrared and short-wave bands which are thought to be sensitive to plant water content (plant-water sensitive). Definitions of the different vegetation indices that were evaluated are given in table 2. Data from 40 monitoring sites was used to assess relationships across the extent of the entire Landsat scene, while 8 and 19 sites were used in Buckshot and Gina land systems, respectively. Each of the monitoring sites was located on the rectified vegetation index image and then we extracted average pixel values for each of the vegetation indices within a 150 m buffer around the sites. To examine the relationships between vegetation indices and vegetation cover simple linear regression was used.

Table 2: Vegetation indices applied to 1991 Landsat scene

Vegetation index group	Vegetation Index	Acronym	Formula	Landsat TM bands
Group 1	Simple	SVI	NIR/R	4/3
(Slope-based)	Normalised Difference	NDVI	(NIR-R)/(NIR+R)	(4-3)/(4+3)
	Soil Adjusted-A	SAVI-A	[(NIR-R)/(NIR+R+L)] × (L+1) L= Soil adjusted factor	[(4-3)/(4+3+0.25)] ×1.25
Group 2 (Distance-based)	Perpendicular Vegetation Index-3	PVI-3	A×NIR– B×R A= the intercept of soil line B= the slope of soil line	A×4-B×3
	Perpendicular Distance	PD54	Perpendicular distance from soil line toward vegetation line	2 v 3
	Soil Stability Index	SSI	Perpendicular distance from soil line toward vegetation line	2/4 v 3/4
Group 3 (Orthogonal transformations)	Soil Brightness Index	SBI	Orthogonal Transformation	All bands except band 6
	Green Vegetation Index	GVI	Orthogonal Transformation	All bands except band 6
Group 4 (Plant-water sensitive)	Stress Related-1	STVI-1	(MIR×R)/NIR	(5×3)/4
	Stress Related-3	STVI-3	NIR/(R+MIR)	4/(3+5)
	Stress Related-4	STVI-4	NIR-(RED×MIR)/NIR+MIR	4-(3×5)/4+5
	Mid-infrared-1	MSVI-1	NIR/MIR	4/5
	Mid-infrared-2	MSVI-2	NIR/SWIR	4/7
	Mid-infrared-3	MSVI-3	NIR/(MIR+SWIR)	4/(5+7)

RESULTS

Across land systems, all the slope-based vegetation indices were significantly correlated with vegetation cover ($p<0.05$). Among distance-based and orthogonal vegetation indices, the Soil Stability Index had no significant relationships with vegetation cover. Plant-water sensitive vegetation indices showed varying strengths of relationships with plant cover. The Stress Related Vegetation Indices (STRV-1 and 4) were significantly correlated with vegetation cover data.

Within land systems, there were stronger relationships between vegetation indices and vegetation cover than across land systems. This may result from low spectral variations within land systems. In Buckshot land system, the STVI-1 showed significant correlation ($r^2>0.88$) with vegetation cover, followed by the Soil Brightness Index (SBI) ($r^2>0.82$) and STVI-4 ($r^2>0.78$). In Gina land system, the Green Vegetation Index (GVI) correlated best with vegetation cover ($r^2>0.74$), followed by STVI-4 ($r^2>0.66$).

DISCUSSION

It was generally observed that the estimation of vegetation cover at land system scale was more accurate than at broader landscape scale. Although distance-based and orthogonal vegetation indices have been designed for use in sparsely vegetated areas, they appear to be less applicable than slope-based indices in areas with high spectral variations (across land systems). Another difficulty with distance-based vegetation indices is that selecting appropriate soil and vegetation pixels for determining the slope and intercept of a soil line makes this group more subjective than other vegetation indices. In contrast with other vegetation indices, the Stress Related Vegetation Indices (STVI-1 and 4) showed relatively high to very high correlations with vegetation cover at both landscape and land system scale.

CONCLUSION

This study reviewed and tested the different groups of the vegetation indices and found that the STVI-1 and STVI-4 performed better than other indices in this arid environment of South Australia. They appear to be less sensitive than other vegetation indices to different soil and vegetation types in various land systems. Thus, this study proposes these vegetation indices as an appropriate adjunct to field methods in assessing and monitoring of vegetation condition. These indices can be applied to images from different times to detect changes in vegetation cover over time.

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