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Appendix 1. Delineating woody vegetation in the Boorowa Shire on the South West Slopes of New South Wales by using satellite imagery

Rectification of SPOT imagery

The main remote sensing dataset used for mapping woody vegetation in this study was SPOT 4 Panchromatic data. A SPOT 4 Panchromatic scene covering the Boorowa Shire and surrounding area flown on 2 January 2001 (Nadir angle: 3.8 degrees) was acquired from The Australian Centre for Remote Sensing (ACRES). Initial visual inspection indicated horizontal displacement errors in excess of 100 m for some locations within the study area. This was beyond the acceptable tolerance for the project. Hence, a rectification was performed by using 22 ground control points (GCPs) captured in the field with a Garmin handheld GPS unit. A first order rectification generated the best overall result by using ENVI IDL Version 3.5 (2003) image processing software.

After rectification, the root mean square error (RMS value) for the GCPs was 3.1 m. This value was well within the accepted threshold of one pixel size of the source imagery (10 m for the SPOT Panchromatic image). Horizontal accuracy for the 22 control points averaged approximately 15–25 m, and represented a significant improvement over the original horizontal displacement in the source imagery. Horizontal positioning of the Landsat TM data appeared adequate for integration with the SPOT panchromatic image and therefore required no further rectification.

Delineation of woody vegetation

The rectified high resolution SPOT 4 image was used to ‘sharpen’ the lower resolution (25 m) multi-spectral Landsat TM image (Cootamundra scene, Path/Row 91/84 captured on 9 February 2000). This was done by the application of a colour normalised (Bovey) panchromatic sharpening algorithm (Vrabel 1996), with Landsat TM bands 2 (visible green), 3 (visible red) and 4 (near infrared).

Image classification—identification of water

The spectral range of SPOT 4 Panchromatic data is limited, making it difficult to differentiate woody vegetation from other features, particularly water. To overcome this problem, a preliminary supervised classification to delineate water features in the Landsat TM imagery was conducted. This resulted in the creation of a water mask, which was used to remove water features (e.g. farm dams, lakes, reservoirs, rivers and creeks) in the final classification.

Image classification—mapping woody vegetation

The pan-sharpened satellite image was used to perform an unsupervised classification in combination with a class-clumping procedure to delineate woody vegetation by using the Isodata algorithm (ENVI 2003). The classification resulted in 12 pixel classes, which were then clumped to delineate woody vegetation on the basis of a visual comparison with the SPOT Panchromatic data. Water bodies delineated earlier were consequently masked from this final classification.

One undesired outcome from the use of a water mask was the inclusion of shadows in this class in the more rugged southern and eastern regions of the study area. To overcome this, slope was used in the analysis on the basis of the assumption that water bodies have a slope approximating zero and that shadows occur in relatively high relief areas. A 25-m resolution digital elevation model (DEM) was used to derive an estimation of slope. Slopes above eight degrees were removed from the water mask, in effect allowing these areas to be classified as woody vegetation.

Validation of the woody vegetation layer

Preliminary visual inspection of the final woody-egetation map indicated that the classification was an improvement on previously available woody vegetation layers, with the layer we derived having higher positional accuracy and finer resolution. However, there appeared to be some areas of misclassification, particularly in low-lying pastures, which in some cases were mapped as woody vegetation in the layer we derived. This occurred primarily as a result of the limited spectral resolution of the SPOT 4 Panchromatic data, combined with the confounding influence of various agricultural land-use practices. To quantify the accuracy of the final woody-vegetation map, a method developed for binary mapping (Fielding and Bell 1997) was adopted for this study. The method relies on the calculation of confusion matrices, which compare the accuracy of the predictions against an estimate of the truth (derived from *in situ* methods or expert interpretation of source satellite imagery).

An estimate of the truth was obtained by interpreting the 'true' presence or absence of woody vegetation at randomly selected sites by using expert interpretation of the SPOT Panchromatic image. Three 25-km^2 test areas were randomly selected within the Boorowa Shire to ensure a variety of land uses were represented in the validation. Within each test area, 100 randomly generated points were assessed and allocated to one of the following four validation classes:

- (a) true positives—sites predicted to be woody vegetation and classified as this by the expert;
- (b) false positives—sites predicted to be woody vegetation but not classified as this by the expert;

- (c) false negatives—sites predicted to be non-woody vegetation but not classified as this by the expert; and
- (d) true negatives—sites predicted to be non-woody vegetation and classified as this by the expert.

From the above criteria we calculated a range of accuracy metrics after Fielding and Bell (1997) (Table 4). The classification was generally good with a misclassification rate of between 0.15 and 0.25; however, of particular interest in this study was the false positive rate. False positives were the major concern and indicate the image classification algorithm appeared to over-predict the presence of woody vegetation, which was confounded by such features as pine plantations and some agricultural land uses, including occasional miss-classification of low-lying pastures. The false positive rate ranged from 0.15 and 0.27, whereas the false negative rate was lower, ranging from 0.11 to 0.17 (Table 4). This is reflected in the considerably higher negative predictive power (0.96) than positive predictive power (0.5) (Table 4).

Table 4. Classification accuracy measures for the woody-vegetation mapping of the Boorowa Shire

Woody-vegetation mapping was derived from classification of SPOT 4 Panchromatic sharpened Landsat TM satellite imagery. Values are based on 100 random points from each of three 25-km^2 test areas within the Shire. See the text in Appendix 1 for explanations of the variables in each calculation

Parameter	Calculation	Region 1	Region 2	Region 3	Mean (± s.e.)
Misclassification rate	(b+c)/N	0.15	0.2	0.25	0.2 (0.03)
False positive rate	b/(b+d)	0.15	0.21	0.27	0.21 (0.03)
False negative rate	c/(a+c)	0.11	0.17	0.12	0.13 (0.02)
Positive predictive power	a/(a+b)	0.55	0.55	0.40	0.50 (0.05)
Negative predictive power	d/(c+d)	0.97	0.94	0.96	0.96 (0.01)
Kappa (*K*)	See Fielding and Bell (1997)	0.59	0.53	0.40	0.51 (0.06)

We have also calculated values for Cohen's Kappa statistic (*K*), which can range from 0 to 1.0, with a higher value implying a higher reliability. Landis and Koch (1977) noted the following ranges for use of the *K* statistic: poor $K < 0.4$; good $0.4 < K < 0.75$ and excellent $K > 0.75$. Our results for *K* ranged from 0.40 to 0.59, indicating acceptable levels of agreement between the predicted and the actual presence of woody vegetation (Table 4).

The technique developed in this study to define a high resolution woody vegetation layer was limited by the satellite imagery available to the project. Much higher classification accuracy would be gained if similar techniques were employed with high-resolution multi-spectral data such as SPOT 5 multi-spectral imagery. The availability and affordability of this imagery is improving rapidly and is now being used by natural-resource management agencies across broad areas of New South Wales.