Mapping blackberry thickets in the Kosciuszko National Park using airborne video data

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Summary

High resolution, multi-spectral airborne video data were used successfully to map blackberry thickets (*Rubus fruticosis* spp. agg.) in the Kosciuszko National Park. The digital data with a spatial resolution of one metre and spectral resolution which includes channels of blue, green, red and NIR light were capable of detecting patches of blackberry as small 2 × 2 m. Five different mapping techniques were compared including manual interpretation, thresholding the NIR band, thresholding a ratio of NIR/red bands, unsupervised classification, and supervised classification.

Manual interpretation was able to successfully identify 97% of the known blackberry sites with no errors of commission. The two thresholding techniques were able to highlight the areas of known blackberry but were not able to clearly differentiate between blackberry and woodland areas. Similarly, the unsupervised technique showed good agreement with the regions of known blackberry thickets but was unable to adequately separate blackberry spectral response from woodland spectral response. Supervised classification was the best of the digital techniques for discriminating blackberry from surrounding land cover types, and achieved a 79% success rate for identifying known blackberry sites.

Introduction

Traditional methods of weed survey such as literature citation, herbarium records, questionnaires or field surveys cannot provide all the information necessary to accurately locate and monitor weed occurrence. Literature surveys and herbarium records are often incomplete, inconclusive or outdated. Questionnaires are limited by lack of response and large variation in estimate accuracy. Field surveys are restricted by high costs that affect the survey repeat time, area coverage and comprehensiveness (Pitt and Miller 1988). Remotely sensed data are comprehensive, synoptic, objective and repetitive (Johnston and Barson 1990). If these data can be linked to weed occurrence they provide an ideal means of supplementing the traditional weed survey techniques.

Remote sensing is a method of collecting data about earth phenomena without being in physical contact with the phenomena (Jensen 1996). Generally, a remote sensing device will detect variations in reflected electromagnetic radiation (EMR) as it interacts with the phenomena of interest. Common types of remotely sensed data used for weed survey include conventional aerial photography, infrared aerial photography, panchromatic satellite data, multi-spectral satellite data, airborne scanner data and airborne video data.

Aerial photography has been the most widely available and frequently used form of remotely sensed data for weed surveys (Pitt and Miller 1988). Digital remotely sensed data from satellite and airborne scanners and airborne video have been broadly available only for the last few decades. However considerable work has been conducted to assess the usefulness of these technologies for weed survey (Pitt and Miller 1988, Ullah *et al.* 1989, Everitt *et al.* 1991, Cofinas, Weir and Tupper 1992, Kastanis and Cranfield 1992, Everitt *et al.* 1993).

The successful use of remotely sensed data as a tool for surveying weeds depends upon the nature of the particular weed and spatial resolution of the data being used (Fitzpatrick *et al.* 1990). Weeds that grow in monospecific stands and have unique spectral characteristics for at least part of the year are likely to be detected.

The spatial resolution of remotely sensed data varies considerably from system to system. Historically, aerial photography has provided the highest resolution data with scales from 1:10 000 to 1:80 000 commonly being captured. The main limitations of aerial photography are its analogue format requiring manual interpretation and its poor spectral resolution.

Satellite remotely sensed data appropriate for weed survey have been available since the launch of the Landsat series in 1972. These digital data have greater spectral resolution than aerial photography and can be manipulated automatically using appropriate computer software and hardware. Coarse spatial resolution is the major limitation of the data. Because pixel sizes are generally in the order of hundreds of square metres, successful mapping is limited to very large stands of weeds. In the near future a number of high-resolution satellites will provide multi-spectral data with pixel sizes of 4 m and less. These new data may increase the ability of satellite systems to map weed infestations (Ridley *et al.* 1997).

Airborne scanning and video systems have the potential to combine the high spatial resolution of aerial photography with the spectral resolution and digital format of satellite data. Multi-spectral airborne scanning systems have been have been used successfully to detect weed infestations (Ullah *et al.* 1989), however high data acquisition costs have restricted their use (Pitt and Miller 1988). Airborne video data can provide a cheaper, multi-spectral, high-resolution dataset capable of successfully detecting weeds in a number of situations (Everitt *et al.* 1991, Everitt *et al.* 1993, Lamb 1996).

Background

In March 1997 a project was undertaken to assess the effectiveness of high-resolution airborne video data for mapping and monitoring the extent of blackberry (*Rubus fruticosis* spp. agg.) in the Blowering Dam foreshore area of the Kosciuszko National Park (Figure 1).

The project area is located on the eastern side of Blowering Dam, between the Snowy Mountains Highway and the lake foreshore. The topography of the region consists primarily of Low Undulating low hills to Low Rolling low hills (McDonald *et al.* 1990), with typical local relief in the order of 50 m. Although the pre-European settlement eucalypt woodland has been largely cleared there are still a number of remnant patches in the area.

Blackberry thickets occur throughout the study area generally in wetter areas and at the edge of woodlands. The thickets form monospecific stands ranging in area from less than a square metre to more than 100 m^2. Most patches are between 2 m^2 and 50 m^2 in size. Individual thickets stand approximately two to three metres above the ground. During late summer/early autumn, blackberry patches have vigorous crowns of green foliage (Ullah *et al.* 1989), whilst the vegetation of the background pasture and woodland is much less vigorous with duller green or brown foliage.

Airborne video data

The airborne video system owned and operated by Charles Sturt University consists of four high-resolution video cameras, along with camera controlling and image acquisition hardware, mounted in a Cessna 210 aircraft. Each video camera acquires an image in a preset spectral band, determined by an interchangeable filter. Typically these filters are set at blue (460 nm), green (550 nm), red (650 nm) and NIR (770 nm). A frame grabber is used to create a sequence of overlapping digital images that are 738 × 574 pixels in size. A global positioning system incorporated into the system automatically writes location co-ordinates to each image (Lamb *et al.* 1996).

The video data are usually acquired with pixel sizes of one or two metres depending on the flying height of the aircraft. These spatial resolutions offer potential mapping at scales between 1:2000 and 1:20 000. Because the system is mounted in a readily available aircraft it can be ready for operation within a couple of hours and data acquisition is limited only by poor weather conditions.

A run of airborne video data along the eastern foreshore of Blowering Dam was acquired at 11.00 am on 10 March 1997. A total of 44 images were captured producing a sequence running from Log Bridge Creek to south of Janeys Creek (Figure 1). The flying height of the plane was 1500 metres above the ground, producing a nominal pixel size of one metre and an effective maximum mapping resolution of approximately 1:2000.

For this project a single image in the sequence was analysed to see if the blackberries were discernible firstly on an enhanced hardcopy image and secondly using digital classification procedures. Figure 1 indicates the location of an image situated over a section of the foreshore approximately one km south of Log Bridge Creek, centred on Australian Map Grid co-ordinate (616400, 6078700). The image covered a ground area of approximately 740 × 570 m. This image was selected for analysis as it contained the major land cover types present in the full sequence of images (water, sandy or rocky shore, woodland, willow trees, pasture and blackberry).

Image analysis

All image processing was undertaken using ERMapper version 5.5.

Image preparation

To minimize bi-directional and vignetting effects on the data, marginal areas of the image were excised. Bi-directional effects result from the variation in pixel view angle and solar angle across an images field of view at the time of data capture, they cause increases in pixel brightness across the image as you move away from the sun. Camera aperture and lenses of the video system cause vignetting, resulting in a systematic decrease in image pixel values, radially out from the centre of the image. The remaining image was 404 pixels × 460 lines in size. Since the blackberry did not occur below the lake's high water level a mask was applied to remove the superfluous data below this level, reducing possible classification errors.

Image interrogation

The utility of the image as a tool to map blackberries was assessed initially by visually inspecting the data on the screen and interrogating the spectral characteristics of the major land cover types. This assessment indicated that blackberry thickets produced a distinctive spectral signature in comparison to the other major land cover types (Figure 2). The land cover class with the most similar spectral signature to the blackberries was the woodland class. Visual interpretation of a standard false colour image shows that the blackberries appear as bright red regions with little internal patterning. Woodland by contrast appeared as a duller red colour with large shadow regions associated with each tree. In terms of data brightness values, the blackberries have relatively low values of blue, green and red reflectance and very high NIR reflectance (Figure 2). The woodlands have similar blue and green reflectance, but slightly higher red reflectance and considerably lower NIR reflectance.

Training classes from sites of known blackberry patches and areas of woodland were selected to determine the statistical separability of these two classes in multidimensional space. Figure 3 indicates that there is clear separation between the blackberry and woodland training data. Canonical variate one (X-axis) shows that the blackberry training sites are clearly separable from the woodland training sites.

Based on this initial data interrogation it appeared likely that blackberry thickets would be able to be accurately mapped from airborne video data using both manual and digital techniques and that the NIR band was most important for separating blackberry from other land cover types.

Hardcopy image production for manual interpretation

A simple three band colour composite with green, red and NIR displayed as blue, green and red respectively (standard false colour image) was used for the hardcopy production. A standard histogram equalization stretch was applied to each band and hardcopy output was produced using the Hewlett Packard Design Jet 650 A0 plotter.

The hardcopy plot was manually mapped by an experienced aerial photograph interpreter. The interpreter was given the following set of guidelines to identify blackberries:

- The blackberry thickets form uniform patches of bright red above the high water level with little or no associated shadow.
- The blackberry thickets grow mainly at the fringes of the woodlands.
- The blackberry thickets tend to follow gullies or wet areas.

Digital image classification

Four methods of digital classification were attempted: thresholding of the NIR band; thresholding a ratio of NIR/Red; isodata-unsupervised classification; and supervised maximum likelihood classification.

For the NIR band, a simple threshold was created such that all values above it were assumed to be blackberry and all values below it were assumed not to be blackberry. If the blackberry NIR response was clearly higher than that of the woodland then this simple threshold should be sufficient to map the blackberry.

In a similar way to the first technique a threshold value was applied to the ratio of NIR/red, with all values above assumed to be blackberry and all values below assumed not to be blackberry. Data interrogation revealed that the blackberry had a relatively higher NIR and a lower red reflectance than the woodland. A ratio of these two bands should give higher values for blackberry and lower values for woodland.

Isodata unsupervised classification is the standard unsupervised classification procedure available in the ERMapper software. It involves using the isodata algorithm to partition the data into classes based on spectral characteristics. Default parameters were used with the exception that the maximum number of classes required was reduced to 20. The classification required 321 iterations to stabilize and produced 19 output classes.

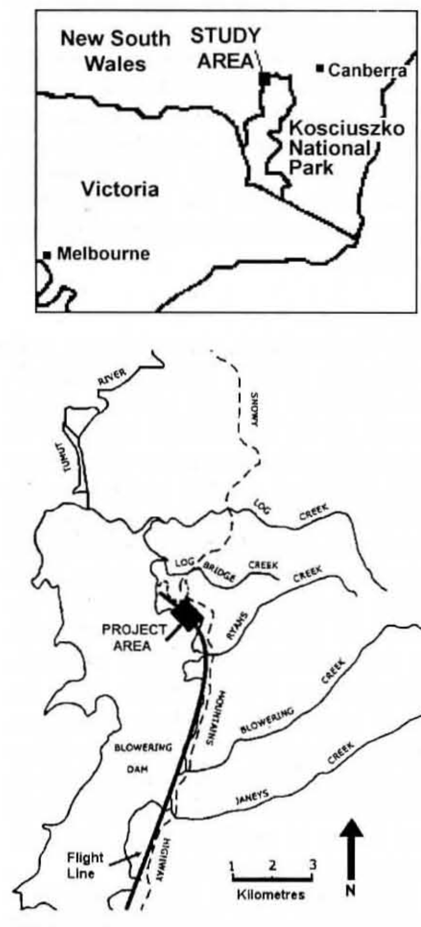

Figure 1. Location of the project area on the Blowering Dam foreshore.

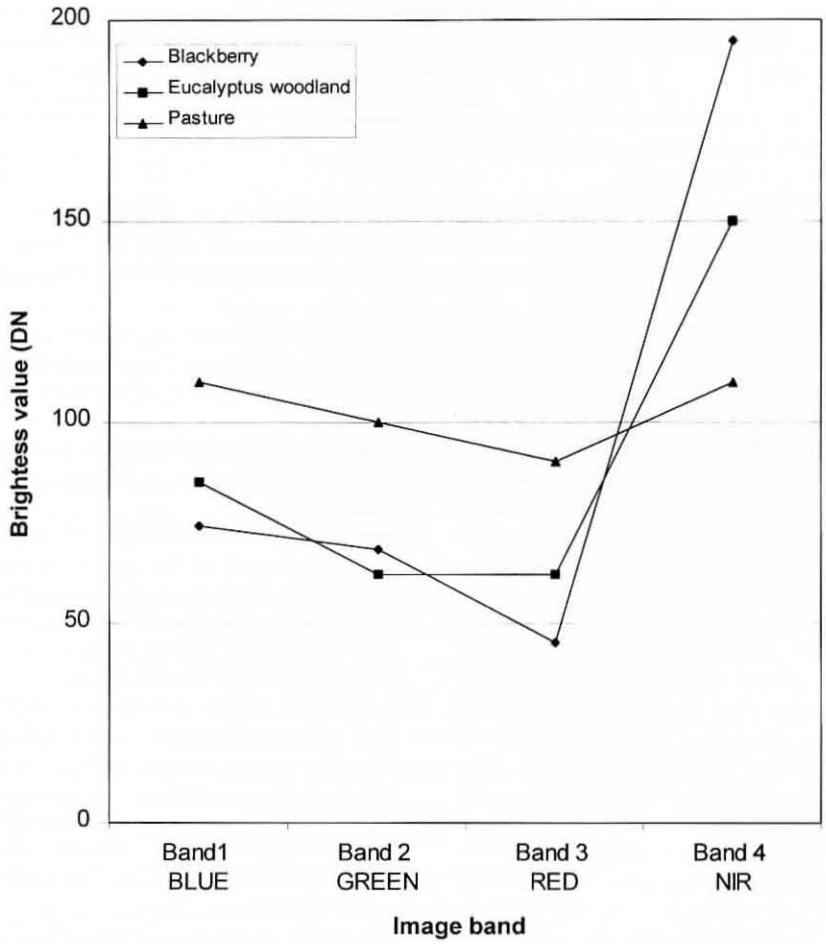

Figure 2. Spectral signatures of the major landcover categories.

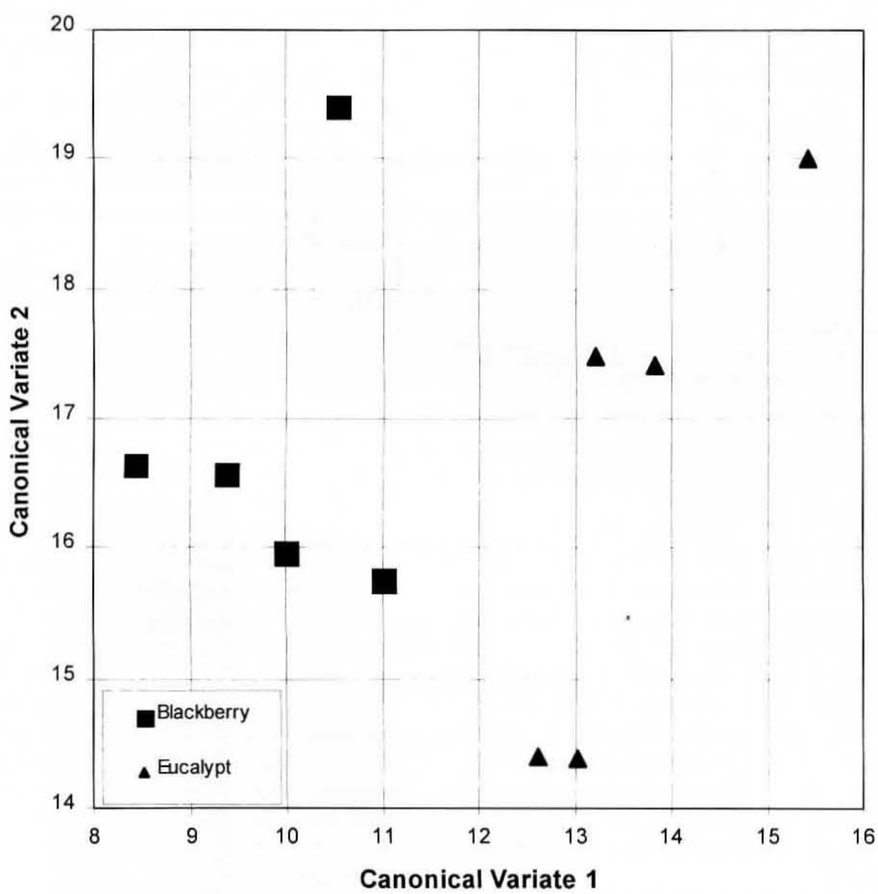

Figure 3. Canonical variate means of blackberry training sites vs. woodland training sites.

Supervised maximum likelihood classification was undertaken using training sites on the actual image. Fourteen training sites, well distributed across the image, were selected from known blackberry patches to represent the blackberry class. Similarly, eight training sites were selected for the woodland class. This training data was then processed using the enhanced maximum likelihood classification algorithm (standard on ERMapper). The resulting blackberry class was then refined by eliminating pixels with typicality values of less than 5%.

Ground truth assessment

To assess the accuracy of the five mapping techniques a ground survey was conducted over the image area. A hardcopy plot of the image was taken into the field and a number of areas of blackberry and woodland were mapped directly onto the plot. This information was then digitized and converted into a single band image allowing per pixel accuracy assessment to be conducted. Due to the relatively small area of blackberry on the image there was some overlap between blackberry patches used for training the supervised classification and those patches used for accuracy assessment.

Results

Table 1 shows a summary of the resulting accuracy of each of the methods undertaken. Manual interpretation of blackberry patches is clearly the most successful of the methods achieving an agreement of 97% with the blackberry patches identified by ground truth, whilst not including any of the woodland as blackberry. The distinctive high values in the NIR band and the monospecific nature of the blackberry thickets, lead to it being represented as solid bright red patches on the standard false colour display. When this distinctive bright red colour is added to other features such small shadow area, tendency to wetter areas, and absence below the lake high water level the blackberry patches are reasonably easy to map manually.

Of the digital classification techniques, supervised maximum likelihood classification was the most successful. Although the percentage agreement between the classified blackberry areas and the ground truth blackberry areas was lowest of all techniques (79%) (Table 1), it is acceptable, and included much less of the woodland area as blackberry (9%), than any of the other digital techniques. Supervised maximum likelihood classification was clearly the best of the digital methods at separating the blackberry information from the woodland information. The technique was able to successfully map most of the brighter regions of blackberry with the main omission being the less vigorous thickets and parts of thickets.

The thresholding techniques achieved high rates of accuracy in identifying the known blackberry patches; 88% for the NIR threshold and 86% for the ratio threshold. However, to achieve this accuracy both techniques resulted in large regions of woodland being classified as blackberry, (47% and 17% respectively). These large errors of commission arise from the low threshold values used. In order to include most of the blackberry areas this value had to be reduced well into the range of values occupied by the brighter woodland pixels. This resulted in the inclusion of large areas of woodland being mapped as blackberry. The NIR/red ratio threshold was successful in substantially reducing the confusion between woodland and blackberry classes, however, the error of 17% is still too high for practical use.

Similarly the unsupervised classification identified known blackberry sites well achieving an accuracy of 90%, but classified too much woodland as blackberry. Three classes out of the final 19 were found to contain regions of blackberry, however, two of these classes also contained substantial amounts of woodland. This confusion within these classes creating substantial errors of commission with 43% of the known woodland area being classified as blackberry.

Table 1. Comparative accuracy of blackberry mapping procedures.

Classification Procedure	Blackberry mapped as blackberry	Eucalypt woodland shown as blackberry
Supervised classification	79%	9%
Unsupervised classification	90%	43%
NIR threshold	88%	47%
NIR/red ratio threshold	86%	17%
Manual interpretation	97%	0%

Discussion

High-resolution airborne video data have proved capable of successfully mapping blackberry thickets in the Kosciuszko National Park. The fine spatial resolution of the data and the capture of NIR as well as visible light allowed the mapping of small thickets down to 4 m^2 in size. Manual interpretation of standard false colour composites was the most successful of the techniques attempted. Digital classification techniques were not as successful as the manual method but still achieved good levels of accuracy for identifying blackberry sites. All of the digital techniques produced errors of commission to varying degrees where the separation of blackberry pixels from woodland pixels proved impossible. The simpler techniques of thresholding and unsupervised classification were particularly prone to map woodland areas as blackberry.

The problems encountered with the large errors of commission with the simpler techniques of digital image classification were caused by high variability of the NIR reflectance within blackberry 'and woodland patches. This variability creates an overlapping region of spectral response in the NIR band for these two land cover types. This overlap essentially means that simple attempts at threshold classification must over estimate blackberries in order to represent every known blackberry patch. Similarly the isodata-unsupervised classification was affected by the high level of data variability in this band and was not capable of accurately discriminating between the blackberry and woodland regions. The more sophisticated method of maximum likelihood classification was better able to cope with this problem and reduce the confusion between the two classes.

A major problem encountered by all techniques was an inability to successfully determine the extent of blackberry under areas of shadow. Shadow effectively reduces the amount of reflectance received by the sensor from these regions. The dampening of spectral response across all bands significantly lowers the digital numbers in the image. For digital classification the shadow regions over blackberry area are not separable from the shadow regions over pasture or woodland. Similarly, in the false colour composite shadow regions show up as dark brown to almost black patches for all shadow types again making mapping of the blackberry boundary impossible.

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