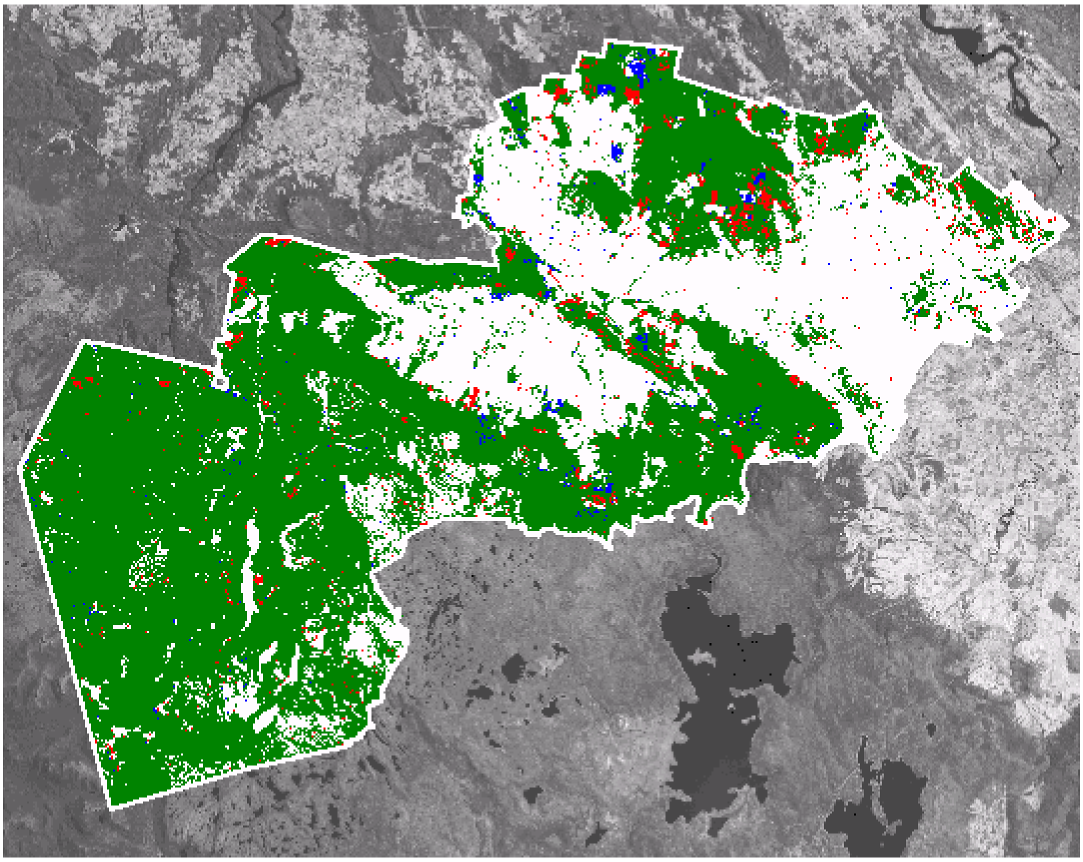
Appendix 2

Meander Valley Monitoring Study

Woody vegetation extent and change 1991-2000

Update of 91-99 masks with neighbourhood smoothing

Landsat scene (091/89)



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CSIRO Mathematical and Information Sciences

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Meander Valley Monitoring Study

Woody vegetation extent and change 1991-2000

Update to NOV 2000 of previous report and data

This report is an update of the previous report covering five dates from Feb1991 to November 1999. The November 2000 scene has been added and the processing repeated to produce a 6-date woody vegetation mask file. NOTE that these masks do not reflect clearing history as they include thin and disturbed vegetation at each date. Disturbance history can be investigated and summarised using the trend images within the masks describe in this report. The previous report has been edited to update the information relevant to the sixths date (23 November 2000).

This report describes the input data and processing to produce one of the information products for the Meander Valley Monitoring Study: the 'neighbourhood-smoothed' woody vegetation masks.

This product is a series of classifications of the extent of woody vegetation provided as a five-band raster file. Each band represents a date from 1991-2000. The bands can be displayed to produce maps of change in woody vegetation extent over time. An example hard-copy map has been produced to accompany the CD. The contents of the CD, and file details, are listed below.

The processing procedure is based on certain assumptions and a consistent numerical processing methodology. The accuracy is high overall but the final products do contain errors and a number of limitations which are described below.

1. The Area

The region considered is the Meander Valley Council (MVC) area illustrated in Figure 1. The region is covered by Landsat scene 091/89. The results are provided for the MVC region and are calibrated and corrected for terrain effects using the good-quality DEM for the area.

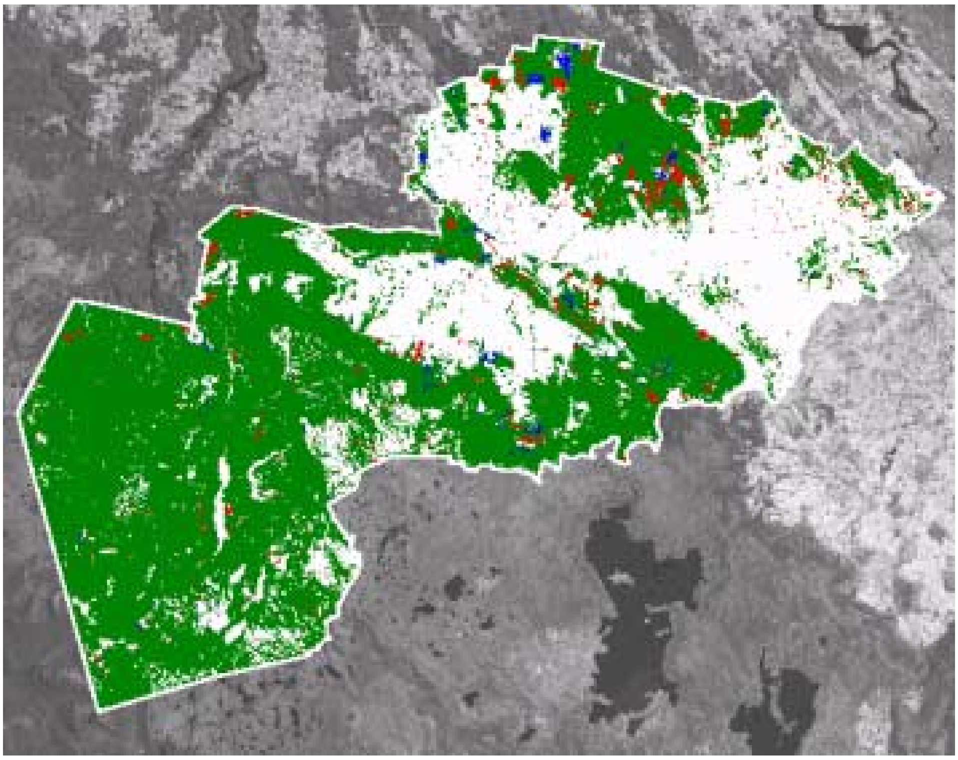

Figure 1. The MVC region: display of the vegetation change data from 1991 to 1999. Areas of woody vegetation loss over the period are mapped as red, and revegetation as blue.

2. The Satellite Image Data and Basic Processing

Landsat data from the following dates were used to derive the maps.

Landsat Scene 091/89
24 February 1991
4 December 1995
23 November 1997
26 January 1998
29 November 1999
23 November 2000

All data were rectified (AMG Zone 55, Projection AGD66) and calibrated prior to processing. Four of these images contained some cloud over the MVC area. The effects of cloud on the results are discussed in sections 3 and 4 below.

The data were also subjected to a terrain illumination correction (McDonald et al 2000) prior to the analysis and processing described below. The effect is to produce an apparent ‘flattened’ image in which the numerical values for consistent land cover are approximately the same, independent of the terrain. This correction was applied to the MVC area only, as this was the area of interest, and also the only area for which a digital elevation model (DEM) of sufficient quality was available. The high-quality DEM for the MVC was gridded and provided by Mark Brown of Tasmania’s DPIWE.

3. Processing Methodology

The steps used to produce the series of vegetation maps are listed below. The methodology follows that being used for Vegetation Change in Western Australia's Land Monitor Project (Caccetta et al 2000) and the national AGO Landcover Change Project (Furby 2001), with adaptation for terrain illumination effects. In addition, neighbourhood smoothing was applied at the multi-date CPN stage (6 below). The steps are :

1. Co-register the images to a common map base. This allows ground sites to be traced through time and the satellite data to be compared with ancillary map data. Ortho-rectification was applied.

2. Calibrate the images to a common radiometric base. This step incorporates a physically based correction for solar position and a bi-directional reflectance distribution function (BRDF) correction as adopted in the AGO methodology (Wu et al 2001, Furby 2001).

3. Apply terrain correction based on DEM derivatives; parameters were estimated from cloud-free vegetated areas in the MVC region, using the method described in McDonald et al 2000.

4. Produce individual 'vegetation probability' maps from each date of TM imagery using the CMIS index-threshold approach which produces measures of confidence of 'perennial' and 'non-perennial' vegetation at each date. Following analysis a common set of two indices were used for each date. Thresholds were adjusted for each date after visual comparison. Data values falling between the thresholds are given a probability (0-100%), scaled linearly with distance relative to the thresholds. The analysis and thresholding steps are described more fully in the appendix.

5. Mask out cloud & cloud shadow areas for each date. Cloud-affected areas within the MVC were digitised using image display and manual interpretation. Data within these areas was set to null prior to the Condition Probability Network (CPN) processing (below). The CPN processing replaces the null values with 'most-likely' cover class determined from the other dates.

6. Process the sequence of cover class probabilities from all dates using a conditional probability network (CPN) approach (Caccetta 1997, Kiiveri and Caccetta 1998). This uses the probabilities from neighbouring dates to modify the probabilities of each pixel. The effect is to 'smooth out' sudden changes (e.g. from cultivation) and to reduce uncertainty and errors in the individual dates. The usual CPN output contained a large number of small spots within the farming area, erroneously mapped as woody vegetation. In this version, neighbourhood smoothing was also applied in the CPN processing, with three iterations. The effect of this is to provide a spatial smoothing based on woody/nonwoody probabilities of the neighbouring pixels. The effect is to 'smooth out' isolated pixels which are not strongly labelled as either class. The result is a series of modified probability images for each date.

7. Reduce the probability images to yes/no ‘bush masks’ for each date, using probability thresholds of 50% for each year.

8. Inspect for errors of omission and commission. A number of commission errors on cleared land for the 2000 layer were digitised and removed. Comments are made below.

4. Accuracy and Limitations of the data

The woody vegetation masks are derived from reflectance signals detected by Landsat TM, and depend on a contrast between vegetation and other cover types (soil, crops, bare rocks etc). The thresholds and indices for classification of woody vegetation have been derived from analysis based on sites selected by interpretation across the MVC region.

This classification as ‘woody vegetation’ relies on the spectral contrasts of cover types resulting from physical differences on the ground, and effectively requires a certain density of vegetation. Hence thin, scattered vegetation with a high proportion of soil or rock background may be omitted. Certain highly-reflective vegetation types may also be omitted, but no cases of this are known.

In particular, bare or very thin forest areas will not be classified as ‘woody vegetation cover’. Common examples are tracks, rocks and fire-scars. Hence the areas mapped as vegetation at particular dates will not necessarily correspond to administrative definitions of reserves etc.

Errors of commission occur when other land covers give a similar spectral response to perennial vegetation. In the MVC, the variability of seasonal conditions and the great variability of landcover in farming areas results in a number of misclassifications in some years. The temporal smoothing of the CPN removes many of the transient cultivation effects which cause these errors. Examples however do remain and include cleared areas with dark soil. The neighbourhood smoothing in the CPN produces a more pleasing set of woody masks by relabelling many of the isolated spots. In many cases, the procedure has removed errors; in other cases, it will have relabelled thin or mixed woody pixels, which are isolated or scattered, as non-woody.
Manual post-processing may be applied to remove some errors but has not been done at this stage due to the risk of hiding real changes. Interpretation of the results using the input images and local knowledge should be effective in identifying these errors and removing them by manual digitising. Note that until this process is complete, statistical summaries based on these results will not be reliable.

For change detection, the CPN processing and on-ground condition can affect the time of detection. In particular, there is a time-lag in detection of revegetated areas, which varies with region and vegetation type. Revegetated areas will not be mapped until the woody vegetation achieves a sufficient density. Hence some recent, slow-growing or sparse revegetated areas will not be detected at each date. The CPN processing reduces errors arising from misclassifications at each single date by assuming temporal relationships. Cloud cover affects the time of detection of change but should not affect the mapping in unchanged areas. The CPN 'simulates' most likely cover type under cloud based on neighbouring image. For unchanged woody or non-woody landcover, these interpolations will be correct.

Any areas of cloud and cloud shadow which have not been detected and masked out are likely to cause erroneous change areas in the results.

5. Disclaimer

The information contained in these vegetation maps is necessarily based in part upon various assumptions, and the Commonwealth agency CSIRO Mathematical and Information Sciences accepts no responsibility for any inaccuracies in these maps and persons relying on these maps do so at their own risk.

6. CD Contents covered by this report : Meander Valley

All georeferenced files are in map projection AMG Zone 55, Datum AGD66; pixel size is 25 metres.

Vegetation Extents 1991-1999 file processed with neighbourhood smoothing :

MVCmask_6date_smoothed.bil (.ers   .hdr)

6 band raster file in ERMapper and ARCview format, each band providing a map of vegetation cover for the corresponding image date

CLASSIFICATION CODES

0= not processed
1= woody vegetation
2= non-woody land cover

A single band mask of areas which have been classified as woody on ANY of the dates (codes as above) based on the neighbourhood smoothed file

MVC_everwoody_6date.bil (.ers .hdr)

An ERMapper algorithm to produce a colour display of vegetation and change 1991-2000. This can be readily modified by ERMapper users to alter the dates for display.

display_vegchange.alg

Vector Files in ERmapper Format: Cloud-masked areas from 1991, 1995, 1998 and 1999. (1997 was cloud-free). Interpreted and digitised.

mvc_cloud91.erv
mvc_cloud95.erv   … etc

Report on data and processing [this report]

MVC_6date_vegmask_nbhd.doc

Acknowledgements

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References

Caccetta P.A. 1997. Remote Sensing, Geographic Information Systems and Knowledge-Based Methods for Monitoring Land Condition. PhD Thesis. School of Computing, Curtin University.

Caccetta P.A., Allen A., and Watson I. 2000. The Land Monitor Project. Proceedings 10th Aust Remote Sensing & Photogrammetry Conference. Vol1, p97. Adelaide. August 2000.

Furby S.L. 2001. Remote Sensing Methodology for mapping Land Cover Change 1972-2000. Australian Greenhouse Office Technical Document.

Kiiveri H.T. and Caccetta P.A. 1998. Image fusion with conditional probability networks for monitoring salinisation of farmland. Digital Signal Processing. 8:4 pp225-230 October 1998.

McDonald E.R., Wu X., Caccetta P.A. and Campbell N.A. 2000. Illumination Correction of Landsat TM data in South East NSW. Proceedings 10th Aust Remote Sensing & Photogrammetry Conference. Vol1, p1375. Adelaide. August 2000.

Wu X., Danaher T., Wallace J.F. and Campbell N.A. 2001. A BRDF-corrected Landsat 7 mosaic of the Australian continent. To appear in IGARSS, Sydney. July 2001.

Appendix : Derivation of indices and thresholds for mapping of woody vegetation

This appendix contains a summary of the steps and results of the analysis which produced the individual woody-nonwoody masks for each scene. The process is based on discriminant analysis and follows the approach used in WA's Land Monitor and the national AGO projects. The steps are summarised below.

(1) Examine image sequence for seasonal differences; choose sample scenes which represent the range of seasonal responses:

February 1991 (dry) and December 1995 (apparently 'greenest') were chosen.

(2) Select a broad representative sample of woody and non-woody land cover types as training data, with a concentration of 'thin woody' and dark or green non-woody sites.

Training sites were selected by interpretation using multiple-date image displays; a total of 94 sites were selected (28 woody, 66 non-woody)

(3) Carry out discriminant analysis (CVA) for sites at each date. Examine the discrimination of woody and non woody sites in spectral space and identify groups for spectral contrast.

Results are illustrated on the plots below. On a CV1 vs CV2 plot, the woody sites formed a distinct cluster at both dates; further, at both dates the non-woody sites were more variable (as would be expected), and one dimension was not adequate to separate wood from all non woody sites. Accordingly, groups of sites for two spectral contrasts were selected from each date. Details of these analyses and relevant file are kept at CMIS Perth.

(4) Identify simplified spectral indices (and thresholds) for separation of woody and non-woody cover types, using contrast groups above and band-reduction routines. Choose if possible simple indices which maintain separation for different image dates, in comparison with the optimal indices from the contrasted CVA.

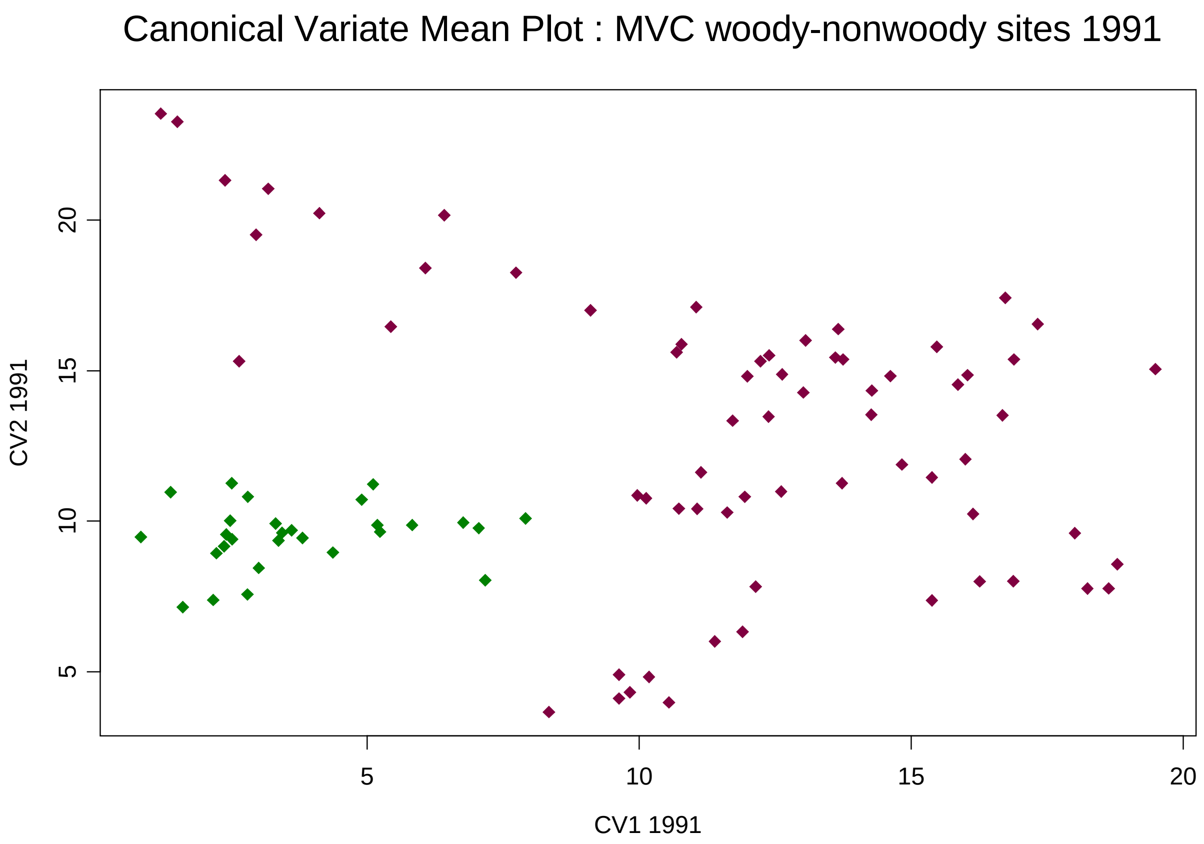
Using the terrain corrected data, it was found that two single bands (band 7 and band 4) provided close to optimal separation in the two contrast dimensions for both dry and green images. The graph plots below illustrate this. Initial thresholds were chosen from the analysis plots, and then modified by visual inspection for each date.

Image date	Thresholds Index 1 (Band 7) min uncertain, min certain, max certain, max uncertain	Thresholds Index 2 (Band 4) min uncertain, min certain, max certain, max uncertain
February 1991	5, 11, 29, 34	30, 43, 71, 95
December 1995	5, 10, 26, 34	29, 40, 64, 84
November 1997	5, 10, 26, 37	29, 43, 62, 93
November 1998	5, 10, 27, 40	29, 43, 70, 95

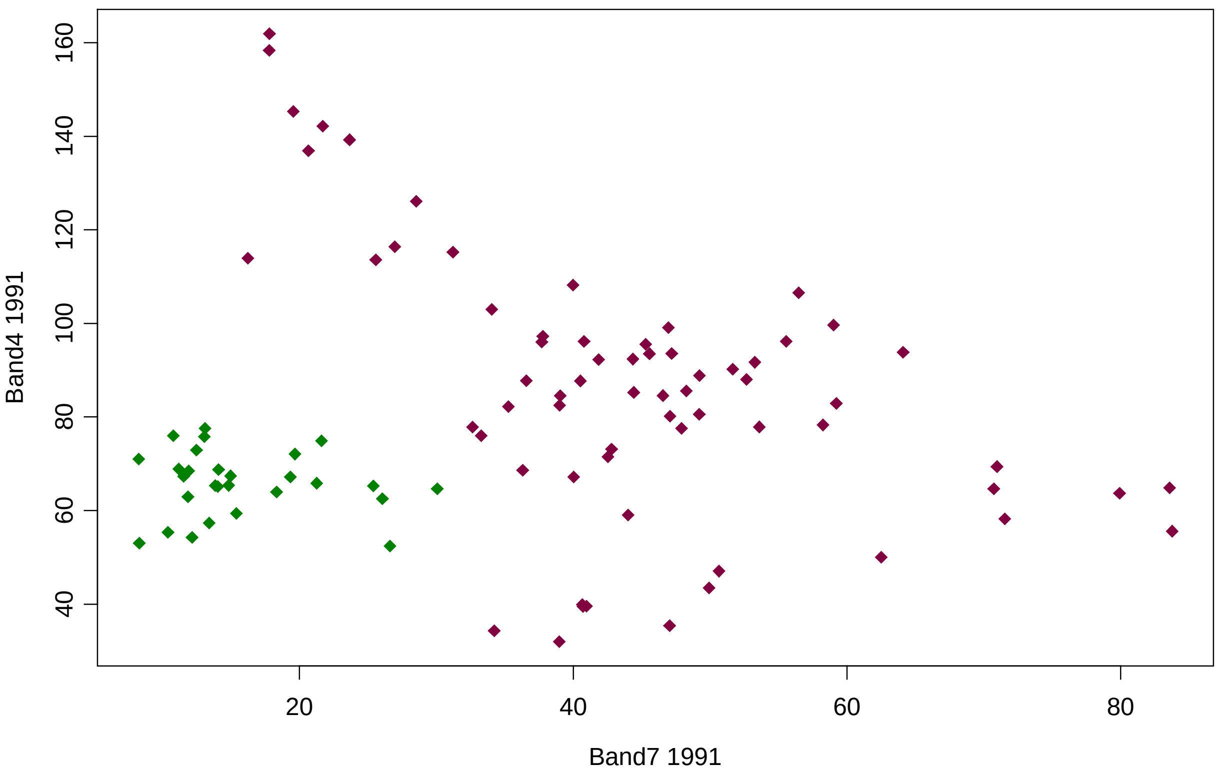
November 1999	5, 10, 26, 37	29, 43, 62, 93

Table A1 : Numerical thresholds used to produce the probability images from the five images

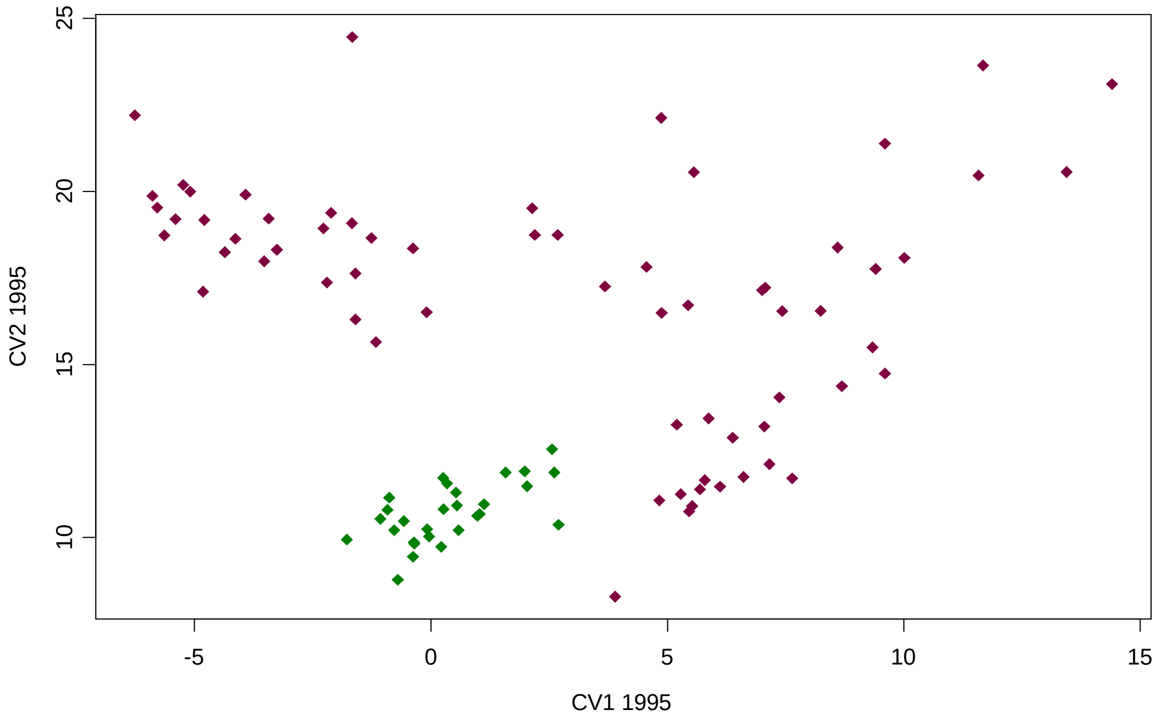
The plots below illustrate the mean locations for CV1 vs CV2 and for the chosen bands (band7 vs Band4) for 1991 and 1995. Woody sites are plotted in green, non-woody in red.



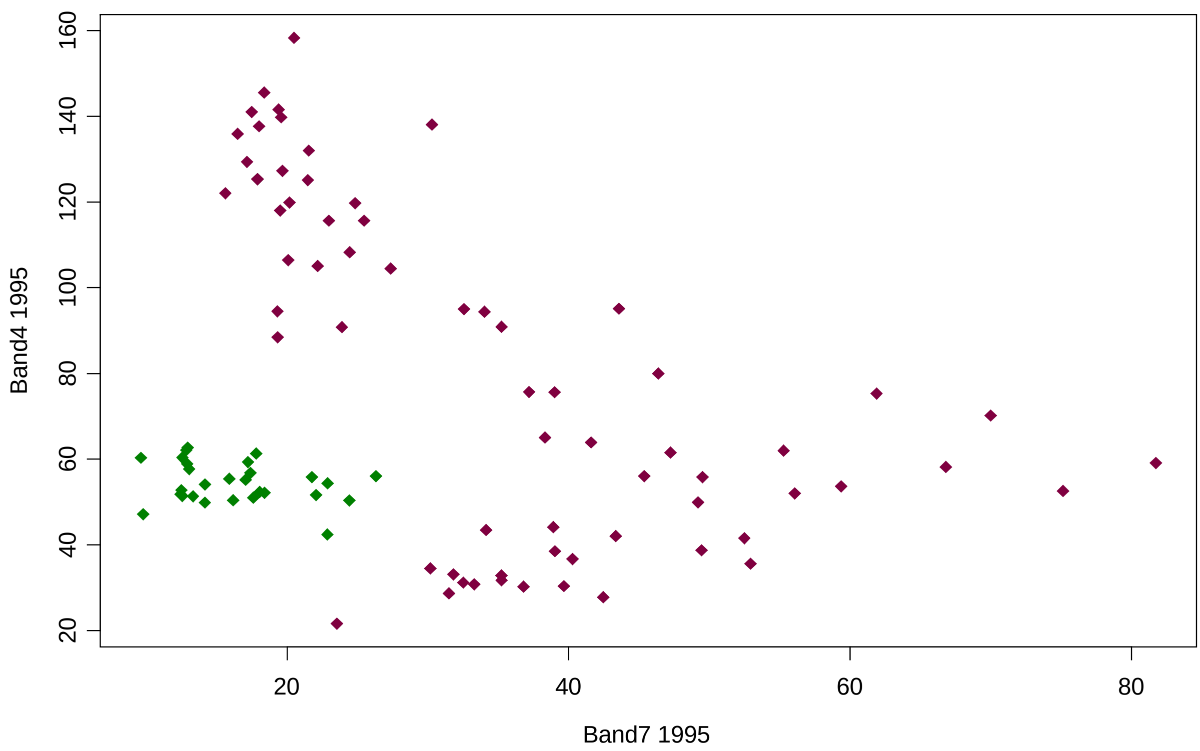
Band7 vs Band 4 means : MVC woody-nonwoody sites 1991



Canonical Variate Mean Plot : MVC woody-nonwoody sites 1995



Band7 vs Band 4 means : MVC woody-nonwoody sites 1995



(5) CPN processing. Calculate ‘woody probabilities’ from each index using the indices and thresholds. The aim is to represent the confidence of mapping as woody. Areas within the ‘uncertain’ index range are given probabilities from 0-100% scaled linearly. The probability image sequence was then processed using a single time-step CPN to produce a modified set of probability images.

(6) Produce a Woody-Nonwoody mask for each date using a probability cut-off of 50%. According to the assumptions, this represents the woody mask at each date. The original and CPN-derived probability images have been backed up at CMIS.