Monitoring Land Cover Change

SPECIFICATIONS
for the
REMOTE SENSING OF AGRICULTURAL LAND COVER CHANGE
PROJECT 1990–1995

Version 4.0

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Foreword

Australia's first National Greenhouse Gas Inventory, completed in 1994, contained a surprise for many scientists and policy makers. While the energy sector was identified as the main contributor to both carbon dioxide and total greenhouse gas emissions, it was estimated that land clearing could have been responsible for a quarter of total emissions. However, the clearing estimates, which were compiled from land clearing permits, expert opinion and regional studies using remote sensing, were regarded as very uncertain.

The Commonwealth Government, noting the importance of contributions from agricultural clearing to Australia's total greenhouse gas emissions and the substantial uncertainties in the inventory calculations, provided $3.108 million to the Bureau of Rural Sciences to establish a land cover monitoring program. The program has been jointly funded by State agencies.

The data sets needed to improve estimates of Australia's emissions due to land cover change are being developed collaboratively with State agencies. The detailed specifications contained in this report have been established to ensure that the data sets address the present, and where foreseeable, future inventory information requirements, and are in a format ready for compilation of a nationally consistent data base. The data sets will also form the basis of a spatially explicit National Greenhouse Gas Inventory for Land Use Change and Forestry being developed within a geographic information system format.

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Participating Agencies

Commonwealth

Bureau of Rural Sciences

State and Territory

Agriculture Western Australia
Department of Environment, Heritage & Aboriginal Affairs, South Australia
Natural Resource Systems, Victoria
Northern Territory Department of Lands, Planning and Environment
Primary Industries and Resources South Australia
Queensland Department of Natural Resources
Surveyor General's Department New South Wales
Tasmanian Department of Primary Industry and Fisheries
Western Australian Department of Land Administration

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Summary

This document sets out the specifications for the Remote Sensing of Agricultural Land Cover Change 1990–1995 project. This collaborative Commonwealth–State and Territory project was set up to document the rates of agricultural land cover change due to tree clearing and planting over the period 1990–1995.

Preparation of Australia's first National Greenhouse Gas Inventory highlighted the need for an accurate assessment of the rates of land cover change across the Australian continent. Australia, like other signatories to the United Nations Framework Convention on Climate Change, is required to prepare an inventory of greenhouse gas emissions and report on how its international obligations under the Convention are being met. Results from the first inventory indicated that clearing was much more extensive than widely believed, and that the resulting fluxes of carbon to the atmosphere could be contributing almost a quarter of Australia's annual greenhouse gas emissions.

The project will produce three digital data sets with a nominal scale of 1:100 000. Land cover change 1990–1995 will document the losses and gains in woody vegetation over this five–year period. Structural Vegetation 1990 will establish a baseline data set showing the distribution of broad structural classes (including vegetation type, density and height) for woody vegetation. This data set will provide a spatial basis for estimating the biomass of vegetation lost (and hence carbon released to the atmosphere) through clearing. The Land Cover Themes 1990 data set will provide a template for the development of a digital data set showing land use and land management practices across the continent.

The area mapped includes the most intensively used agricultural landscapes in Australia, covering almost three million square kilometres, 40 percent of the continent, or about one thousand two hundred and fifty 1:100 000 mapsheets. The project, coordinated by the Bureau of Rural Sciences, is being funded jointly by the Commonwealth Government and nine participating State and Territory agencies on a dollar–for–dollar basis. The estimated cost of the project is $6 million**.**

The data sets are being derived from Landsat Thematic Mapper satellite imagery in conjunction with aerial photography, existing vegetation mapping and other digital data sets, including land tenure information. The data sets, stored in digital format for use in geographic information systems, are supported by detailed attribute tables and metadata files.

Introduction

Genesis of the Remote Sensing of Agricultural Land Cover Change Project

Australia's first National Greenhouse Gas Inventory (Department of Environment, Sport and Territories 1994a) identified that agricultural land clearing could be contributing almost a third of the country's carbon dioxide (CO_2) emissions or a quarter of total greenhouse gas emissions. However, these estimates were regarded as very uncertain, largely due to the difficulties of obtaining information on the rates of clearing and the type of vegetation cleared.

Australia, as a signatory to the United Nations Framework Convention on Climate Change, is required to prepare an inventory of greenhouse gas emissions as part of its' national report. The report sets out how Australia is meeting its international obligations under the Convention. The inventory is based on the internationally agreed method developed by the Intergovernmental Panel on Climate Change (IPCC), with some modifications to take into account country–specific conditions. In accordance with Convention requirements, the inventory only accounts for anthropogenic (human induced) sources and sinks of greenhouse gases.

The IPCC method for calculating carbon fluxes from the Land Use Change and Forestry sector is based on two assumptions:

- the flux of CO_2 to or from the atmosphere is equal to changes in the existing biomass and carbon stocks

- changes in carbon stocks can be estimated by establishing rates of land use change and the practice used to bring about the change (eg clearing for agriculture, selective harvesting of commercial forests).

Assumptions are then applied about the impact of these activities on carbon stocks and the biological response to a given land use.

The IPCC method is designed to cover all of the main land use change and forestry activities, and to be implemented at several levels of complexity, depending on the availability of information and capabilities of national experts.

The estimates of clearing made for the Land Use Change and Forestry sector in the first National Greenhouse Gas Inventory were compiled from several sources, including clearing permit applications, information from satellite data, the activities of clearing contractors and chemical usage rates. The results showed that over the period 1983–1993, rates of clearing in Australia could have been as high as 500,000 hectares a year, and that this clearing could have contributed up to 156 mega tonnes (Mt) of CO_2 to emissions (Department of Environment, Sport and Territories 1994a). These figures were regarded as very uncertain, particularly since there was insufficient information to identify precisely which areas had been cleared and the amount of biomass removed through clearing.

The Commonwealth Government, noting the importance of contributions from agricultural clearing to Australia's total greenhouse gas emissions and the uncertainties in the inventory calculations, responded by providing $3.108 million to the Bureau of Rural Sciences to establish a land cover monitoring program. As land management is a State and Territory responsibility, the program has been established jointly with the States and Territories. Participating State and Territory agencies are listed on page iv.

This project will use high resolution remotely sensed imagery (Landsat Thematic Mapper (TM)) in combination with land tenure data, aerial photography and existing vegetation mapping to produce digital data sets at a scale of 1:100 000. These data sets will enable detailed inventory calculations to be carried out at a regional level within a geographic information system.

The aims of the project are to produce:

- Land Cover Change 1990–1995
  a digital data set to quantify the rates of agricultural land cover change (tree clearing and planting) in the intensively used agricultural areas of Australia over the period 1990–1995.

- Land Cover Themes 1990
  a digital database showing land cover themes as a template for proposed agricultural land use mapping.

- Structural Vegetation 1990
  a digital structural vegetation data set for the agricultural areas of the continent as a basis for estimating the type of vegetation that has been cleared and its biomass.

Data needed to improve the estimates of greenhouse gas emissions from agricultural land cover change

The IPCC method for the land use change and forestry sector (IPCC/OECD 1995) identifies three land use changes (clearing for agriculture, grasslands conversion to agricultural lands and land abandonment) and one land use practice (forest management) which can modify CO_2 fluxes between the terrestrial biosphere and the atmosphere.

The biological responses to these land use changes result in fluxes of carbon to or from the atmosphere for many years after the change has taken place. To quantify these fluxes on an annual basis as required by the IPCC method, it is necessary to obtain estimates of land use changes for many years prior to the inventory year, and to estimate the effects of these on current fluxes.

Land clearing directly alters the amounts of carbon moving from the terrestrial biosphere to the atmosphere, and the amount of carbon stored in living vegetation, litter and soils. For example, clearing and burning forest or woodland (where nearly half the woody biomass is carbon) and replacing it with an annual crop, releases carbon stored in the vegetation and soil, adding it in the form of CO_2 to the atmosphere. Similarly, conversion of natural grasslands to croplands or to improved pastures where the original biomass is removed and the soil disturbed, will result in losses of CO_2 to the atmosphere.

In the Australian environment, clearing for agriculture and forest management are the most important land use factors operating to modify CO_2 fluxes between the terrestrial biosphere and the atmosphere. Most of the natural grasslands suitable for agriculture were converted to croplands many years ago. Land abandonment and subsequent regrowth of native species occurs on a local scale, most commonly where very steep slopes have been cleared, and possibly in the grazed woodlands, where invasion of woody shrub species has substantially reduced productivity.

Tree planting produces another change in agricultural land cover which affects the calculation of fluxes. Concern about the rate of disappearance of native vegetation and associated land degradation problems resulted in the establishment of the ‘One Billion Trees Program’ by the Commonwealth Government. Some States also established programs to encourage on–farm tree planting. The extent of this tree planting has generally not been documented.

As tree loss (clearing) and gain (planting) are the major changes in agricultural lands and managed forests affecting greenhouse gas fluxes, the method focuses on detecting changes in the distribution of woody vegetation. Woody vegetation is defined as all vegetation, native or exotic, with a height equal to or exceeding two metres and a crown cover density equal to or greater than 20 percent (McDonald, et al. 1990).

The IPCC method (1993–4) requires estimates of clearing rates to be made for the inventory years (1988 and 1990 for the first inventory) and over the previous 10 and 25 years (ie back to 1965). The latter are for calculation of the rates of decay of any aboveground carbon remaining after initial clearing and oxidation of soil carbon after disturbance, respectively. These time periods are the default values suggested in the IPCC’s Greenhouse Gas Inventory Reporting Instructions, and will be used to calculate Australia’s emissions until data specific to Australian conditions are available.

This project will document changes over the period 1990–1995. The year 1990 was chosen because it is used in the Framework Convention on Climate Change as a baseline year against which progress in greenhouse gas emission abatement is measured. Additionally, several State agencies have substantial Landsat Thematic Mapper data holdings for 1990 which will be used in the project. An assessment of land cover change for the previous decade, 1982–1990, using a combination of Advanced Very High Resolution Radiometer (AVHRR) and Landsat Multi–Spectral Scanner (MSS) data is already underway (Graetz, pers. comm.). Landsat Multi–Spectral Scanner data, available for the continent from 1972 onwards, could be used to calculate rates of clearing 1972–1982. However, there are no suitable data sets for the period 1965–1971.

A recent assessment of land cover disturbance across the Australian continent, undertaken by Graetz, Wilson and Campbell (1995) indicated those regions most likely to be affected by clearing for agriculture (Figure 1). They occupy almost three million square kilometres, about 40 percent of the continent. Approximately 165 Landsat TM scenes are needed to cover this area.

To calculate the fluxes of carbon due to clearing, it is also necessary to know how much carbon is contained in the vegetation (aboveground biomass) removed. There are relatively few direct measurements of biomass for Australian vegetation. Data such as basal area, mean standing volume, and gross standing volume are available for some species or stands, and can be used to calculate biomass.

Linking these data with information on the spatial distribution of vegetation types will provide a basis for estimating the biomass of cleared vegetation. At present the only digital information on the distribution of all vegetation types across the continent is Carnahan's digital 'Present Vegetation' (Australia's Vegetation in the 1980s) map (Australian Surveying and Land Information Group 1990) at a scale of 1:5 million. As the smallest area represented on this map is 30,000 hectares, this is clearly inadequate, for example to determine what type of vegetation has been lost (and hence the carbon lost) as the result of clearing a 50 hectare patch.

The Murray–Darling Basin's Basincare project (Ritman 1995) used Landsat TM data to produce a 1990 baseline digital data set for the vegetation structure of the Basin at a scale of 1:100 000. As the Basin covers almost a third of the intensively used agricultural zone, it was decided to extend this data set to cover as much of the agricultural zone as possible. This data set will provide the basis for estimating the biomass of the cleared vegetation. In the longer term, it is likely that remote sensing will provide more efficient techniques for estimating biomass.

Tree clearing also results in CO_2 emissions through soil disturbance, as a fraction of the soil carbon is released through oxidation of organic matter, particularly when the cleared land is cultivated. The Bureau of Rural Sciences is currently compiling a data set which will be used to derive a soil carbon surface for the continent. This information will be used to estimate soil carbon losses in cleared areas.

Land cover change detection using satellite data

Data from the Landsat TM satellite were chosen to monitor land cover because of their high spectral and spatial resolution. The Murray–Darling Basin's 'Basincare' project has demonstrated that TM data can be used to map land cover reliably at the one hectare level, enabling capture of information about larger on–farm tree plantings. Its mid infra–red bands 5 and 7 enhance discrimination in some environments. New South Wales, South Australia and Victoria have substantial TM data holdings for 1990, used in the 'Basincare' project.

Although the greenhouse gas inventory is compiled annually, the IPCC Land Use and Forestry guidelines recommend that for land use and forestry emissions, data averaged over several years be used in place of annual data. Victorian studies of tree cover change using Landsat TM have shown that five years is a practical and cost effective monitoring period (Gilbee in press).

Scenes have been chosen by State and Territory agencies undertaking the processing. The scenes were selected for the driest time of the year (to maximise discrimination between the ground layer and tree canopies), and scene dates were matched where possible to reduce differences in illumination. Due to problems with the Landsat sensor, and the preference for cloud free imagery, the data chosen are for the periods June 1989–March 1992 and May 1994–February 1996. Bands 1–5 and 7 were purchased for all scenes.

The spatial accuracy of the Landsat TM data sets has been of particular concern because inadequate registration and geocoding procedures could result in misclassification and subsequent overestimation of the extent of clearing. Pilot projects demonstrated that to achieve the required level (sub pixel) of spatial accuracy, it is necessary to use the same ground control points for each data set for registration. Each scene will be coregistered to the matching scene. The final products will be rectified to map coordinates. Data purchased for the project were processed by the Australian Centre for Remote Sensing (ACRES) to the specifications outlined in Appendix 1.

The need for atmospheric calibration was carefully considered (see Kitchin, Johnston and Barson in preparation). Where the change detection method is to classify the difference image, differences due to atmospheric effects will be included and classified in the range of observed differences, and it is not necessary to specifically identify these differences first. While this approach may be satisfactory when images from two dates are being compared, some form of atmospheric calibration will be needed if more dates are added. As the monitoring is likely to be continued over some parts of the study area, and date matching of the imagery was poor for some areas, the invariant targets approach to atmospheric calibration (Campbell, Furby and Fergusson 1994) was used where adequate resources were available.

Change detection methods

Change detection methods were chosen by participating State agencies after testing alternatives in pilot projects. These methods vary between States and Territories and depend on the nature of ancillary digital data available for masking or thresholding. A summary is given in Table 1. Methods used include image differencing, where a threshold separating types of change is identified (threshold), and unsupervised classification of multi–temporal imagery, where each class is allocated to a type of change (spectral–temporal).

The threshold method is based on using an index of band combinations incorporated into a series of thresholds which equate to rules to identify areas of change. Queensland incorporated a normalised difference vegetation index (NDVI) difference into the thresholds. The spectral temporal method combines the bands from 1990 and 1995, then uses an unsupervised classification to distinguish classes of change.

Table 1. Methods used to detect change (loss and gain) in woody vegetation 1990–1995

State	Change detection method	Band combinations
Western Australia	Threshold	TM3, TM5
South Australia	Spectral temporal	TM1–5, 7
Northern Territory	Threshold	TM5
Queensland	Threshold	TM2–5
New South Wales (including ACT)	Spectral temporal	TM3–5
Victoria	Spectral temporal	TM2–5 (1990) + 1–5, 7 (1995)
Tasmania	Threshold	TM3, TM5

Estimating greenhouse gas emissions from agricultural land cover change

CO_2 emissions from land cover change are calculated from:

- the net change in aboveground biomass carbon
- the portion of this biomass that is burnt in the first year versus the amount left to decay on the ground
- for the burned portion, loss to the atmosphere versus long–term storage in charcoal
- emissions in the inventory year from decay of biomass ('slash') cleared over the previous decade
- releases of carbon from soils during the inventory year due to clearing over the last 25 years.

Information from the Land Cover Change 1990–1995 and 1990 Structural Vegetation digital data sets will be used to calculate the net change in aboveground biomass carbon for the inventory years 1990–1995. Data from the Land Cover Change 1982–1990 being undertaken by Graetz will provide the basis for estimating contributions from 'slash' remaining on the ground following clearing over the decade prior to 1990. Soil carbon estimates for the cleared areas identified in the land cover change data sets will be estimated using the continental soil carbon surface currently being developed. In the absence of information on clearing before 1982, it is likely that estimates of releases from soil carbon for the period 1970–1982 may need to be based on clearing rates for 1982–1990.

Several factors will affect the relative proportions of cleared biomass burnt and released as CO_2 and other greenhouse gases in the inventory year, and the amount stored as charcoal and unburnt biomass left to decay on the ground. These include the composition of the biomass being removed, and fuel loads and burning efficiency, which are best estimated in the inventory sector dealing with non–CO_2 gases from the biosphere. Research is also required on rates of biomass decay, which are expected to vary across the continent, particularly in relation to climate. These issues are not being addressed in the current project.

Development of data set specifications

The Land Cover Change and Structural Vegetation data sets needed to improve estimates of Australia’s greenhouse gas emissions are being developed collaboratively by State and Territory agencies around the country. These detailed specifications have been established to ensure that the data sets address the present and, where foreseeable, future inventory information requirements as set down in the IPCC/OECD guidelines (1995) and subsequent draft revisions, and are in a format ready for compilation of a nationally consistent database.

Specifications are provided for each of the three data sets, and include data coverage and resolution, coordinate systems for digital data sets, geographic information system data formats and data fields for the attached relational database. The methods being used to develop each data set are briefly described, and the extent to which these are expected to meet inventory information requirements are discussed. Resource constraints have resulted in the integration of some existing information, such as the 'Basincare' Structural Vegetation data set, (Ritman 1995) which provides less than the level of detail preferred for biomass estimates. However, the relational databases have been developed to accommodate the additional data needed when they are collected.

The specifications have been developed by the Bureau of Rural Sciences in collaboration with the State and Territory government agencies participating in the project.

Summary of Project Outputs

1. Vegetation Change 1990–1995

A 1990–1995 vegetation change digital data set, with all change areas of one hectare or greater attributed with:

(a) 1990 land cover (ie. FROM–the vegetation prior to change)
(b) type of change (TYPE)
(c) cause of change (CAUSE)
(d) replacement vegetation (ie. TO–what the vegetation is changing to)

2. 1990 Land Cover Themes

A 1990 generalised digital land cover data set which includes 'woody' (≥2 m height, ≥20 percent crown cover) vegetation plus an attached attribute table defining land cover themes.

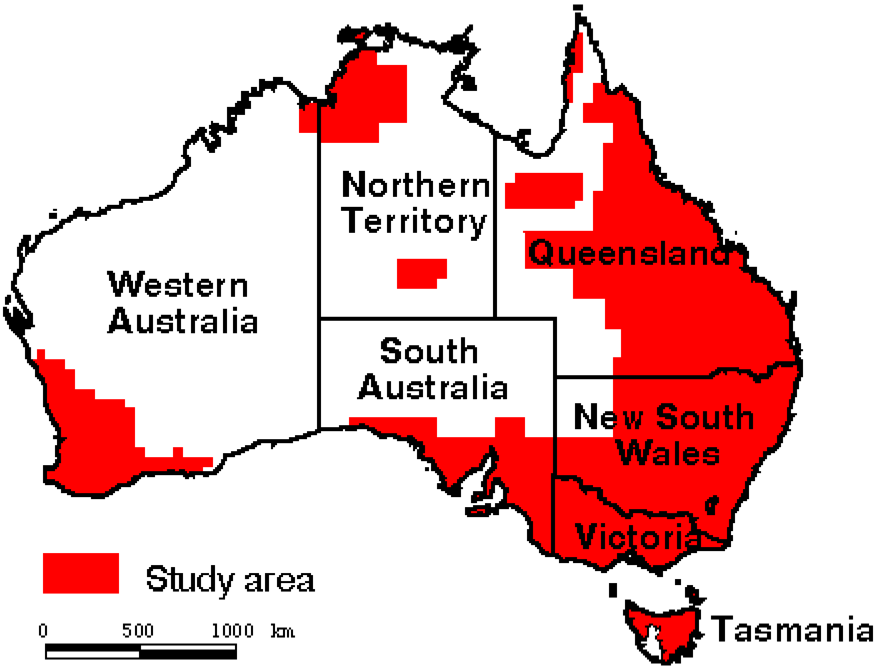
3. 1990 Structural Vegetation

A digital data set for all 'woody' (≥2 m height, ≥20% crown cover) with areas greater than 50 hectares having attached attribute tables describing vegetation type and density.

Coverage	Agricultural lands (Intensive Land Use Zone) of Australia
Final Data Format	Digital raster–Arc/Info GRID of 25 metre pixel resolution with attached attribute tables
Coordinate System	Transverse Mercator (Australian Map Grid) Australian National Spheroid Datum: AGD 66 or 84
Data Processing Pixel Size	Processed at no greater than original pixel size
Maximum Scale	1 : 100 000
Tile Format	1 : 100 000 mapsheets with 1 km overlapping borders (mapsheet corner coordinates, to include as a minimum a 1 km border.)
Primary Data Sources	Landsat TM data from 1989–1991 and 1994–1996. Level of Landsat TM data purchased: 10 Western Australia 9 Northern Territory 4 South Australia 5 Queensland 5 New South Wales 5 Australian Capital Territory 5 Victoria 10 Tasmania
Positional Accuracy	Image rectification sub pixel root mean square (RMS) error absolute image displacement less than 100m.
Attribute Accuracy	90% or greater overall accuracy.

The Vegetation Change 1990—1995 data set

Investigations by Graetz, Wilson and Campbell (1995) identified the intensively used agricultural lands shown in Figure 1 as being the region affected by clearing. A substantial proportion of this area was cleared prior to 1980. However, estimates made for the first National Greenhouse Gas Inventory suggested that clearing continued at a rate of half a million hectares annually through the 1980s and early 90s.



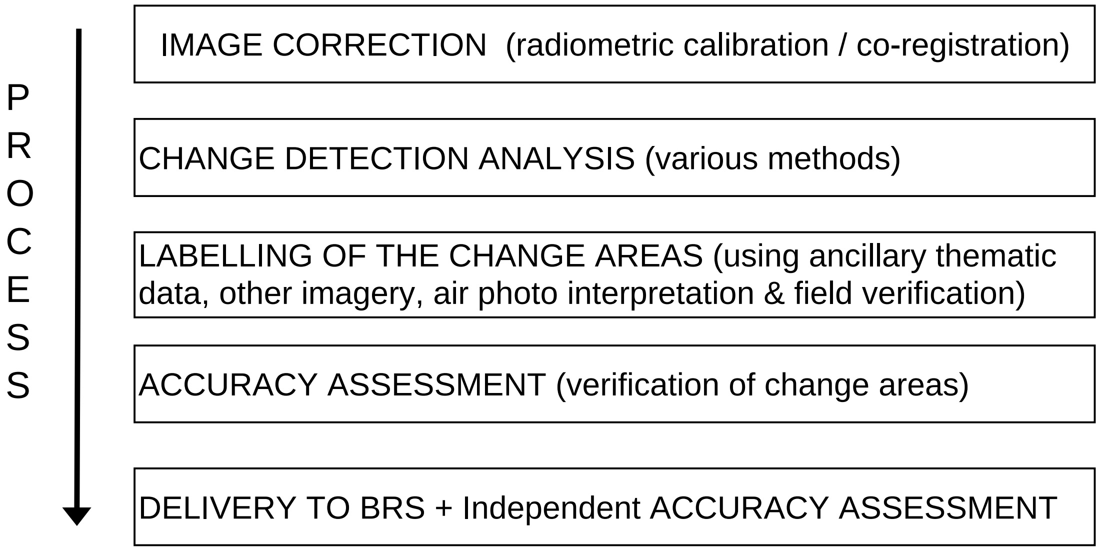
Source: After Graetz et al. (1995)

Figure 1. Regions likely to be affected by clearing for agriculture in Australia

Land cover change during the 1980s is being documented by Graetz using a combination of AVHRR and Landsat MSS data. Landsat Thematic Mapper data have been chosen to establish a woody vegetation baseline for 1990 and to document changes over the following five years. This will provide a spatially accurate data set with a minimum mappable unit of one hectare, showing loss and gain (planting) of woody vegetation, suitable for catchment management and conservation planning purposes as well as calculation of greenhouse emissions. States and Territories will also be able to use the data in support of vegetation management programs.

Woody vegetation is defined as all vegetation, native or exotic, with a height equal to or greater than two metres and a crown cover equal to or greater than 20 percent (McDonald, et al. 1990). The change detection procedures aim at documenting changes in gross vegetation boundaries caused by vegetation clearance and replanting. Landsat TM pixel size is sufficient to resolve the majority of windbreaks and small remnant patches of trees down to about 0.25 hectare (Ritman 1995). Provided that image rectification errors are at sub pixel level, it is anticipated that change at the one hectare level will be detected.

Very sparse woodlands, where the crown cover is less than 20 percent, cannot be classified as 'woody' consistently from Landsat TM data. Changes in these communities may not be detected. The extent to which the thinning of trees to improve pasture growth, or selective logging in forests will be identified, is not yet known. The process for change detection analysis is given schematically:



The method used to clear woody vegetation will have a significant impact on the proportion of biomass left to decay over time, and on the fluxes of carbon from the soil. Clearing land for cropping usually entails bulldozing of the vegetation, and heaping and burning of most of the biomass, followed by root ploughing and further cultivation to prepare for planting. This method results in most of the biomass carbon moving into the atmosphere in the inventory year, together with a substantial proportion of the soil carbon, and most closely approximates the IPCC default method, which assumes that 90 percent of the aboveground biomass is destroyed immediately after clearing and ten percent decays over the following ten years. This form of clearing is readily detectable on Landsat TM imagery.

Heavy machinery is commonly used to remove the aboveground components of vegetation (Figure 2) or trees are stem–injected with chemicals (Figure 3) where clearing is done to improve pasture production. The former method is usually followed by heaping and burning of the cleared biomass, although not necessarily in the year the clearing takes place. The soil carbon loss is likely to be substantially lower than in those areas where clearing is followed by ploughing (Figure 4). In some regions the woody vegetation may regrow within a few years of clearing (Figure 5) and reclearing may be required in ten years or so to maintain pasture production. It has been claimed that a substantial proportion of the clearing being undertaken in Queensland is clearing of this woody ’regrowth’ (Burrows 1995). The losses of above ground biomass and hence greenhouse gas emissions arising from clearing of woody ’regrowth’ (which may only be 10 years old) are likely to be smaller than those from previously uncleared areas.

Figure 2. Clearing of aboveground biomass

Figure 3. Trees killed as a result of stem injection with chemicals

Figure 4. An area that has been root–ploughed after clearing

Figure 5. Regrowth of woody vegetation after clearing

Calculation of carbon fluxes to the atmosphere under this scenario (clearing/vegetation regrowth/reclearing) will need to take into account the annual carbon fluxes to the terrestrial biosphere due to the regrowth of woody vegetation. Where stem injection is used to clear trees, the proportion of carbon released to the atmosphere in the inventory and subsequent years will depend on the rates of decay for the standing dead biomass, and whether the dead trees are bulldozed and burnt or left standing.

The amount of biomass removed will depend to some extent on whether the area has previously been cleared and if so, whether the biomass approaches that of the original vegetation. It is likely to be difficult, if not impossible, to determine from the 1990 Landsat TM imagery alone, whether an area cleared by 1995 had been previously cleared. Vegetation cleared and regrowing in the period 1990–1995 may be detectable on the imagery, but is more likely to be identified during field checking. Chemical clearing results in death of the canopy; preliminary results indicate that this form of clearing is readily identified from Landsat TM imagery.

Vegetation Change 1990–1995–Technical specifications

A 1990–1995 vegetation change digital data set, with all change areas of one hectare or greater attributed with:

(a) 1990 land cover (FROM–the vegetation prior to change)
(b) type of change (TYPE)
(c) cause of change (CAUSE)
(d) replacement vegetation (TO–what the vegetation is changing to)

The digital data set will be accompanied by all the metadata as described in the section titled 'Metadata Requirements'.

Relationship between change grid and structural vegetation data

The following shows how the change data is related to the structural vegetation tables. It comprises the initial change data attached to the GRID and the related tables holding the structural vegetation attributes for all change areas.

CHANGE GRID (.VAT)

LAND COVER	TYPE	CAUSE	REPLACE	VEGTYPE	VERSION	RELIABLE

vegtype.lut

VEGTYPE	SPEC_GROUP1...n	PROPORTION1...n (+other attributes in vegtype.lut)

species.lut

SPEC_GROUP	SPECIES	DOMINANCE	(+other attributes in species.lut)

Minimum Attributed Unit one hectare

File Names

All digital data sets of change will have a standard name starting with the State or Territory letter(s) given below, the mapsheet number followed by _CH eg. the NSW change data for mapsheet number 8448 would be named N8448_CH.

W	Western Australia
NT	Northern Territory
S	South Australia
Q	Queensland
N	New South Wales
A	Australian Capital Territory
V	Victoria
T	Tasmania

Classification Method

Each State and Territory will provide detailed information on the classification method used for each mapsheet with the metadata as a text field, under the item ‘Classification Method’.

Change Attributes

For all areas of change, one hectare or greater, the following attributes are required; 1990 land cover (prior to change), type of change, cause of change and replacement land cover.

1990 Land Cover (prior to change)

The change for any given area can be a gain or loss in woody vegetation. For example, the land cover could change from non-woody or bare to woody through on–farm tree planting, or from woody vegetation to crop. To ascertain the land cover prior to the change (and estimate the biomass lost), information on the land cover themes for the non-woody areas in 1990 and the 1990 vegetation structure, using the mandatory attributes given below, is required.

The land cover themes are listed in Table 2. These are attached to the change grid using an item called landcover, they are defined in Table 2.

Table 2. Land cover lookup table

Attribute name:	LANDCOVER
Database description:	Input width = 1 Output width = 2 Item type = Integer
LANDCOVER.LUT	
0	Not classified
1	Pasture / Crop including herbfields, grasslands (ie. Non-woody)
2	Urban
3	Bare Ground
4	Water
5	Plantation
6	Orchard
7	Native or exotic woody vegetation (excluding plantations, orchards)

Change areas of one hectare and greater which were covered by woody vegetation (Land Cover Theme 7) in 1990, will also have structural vegetation attributes attached. The structural vegetation information is required to estimate biomass loss, and subsequently greenhouse gas emissions from cleared areas for the National Greenhouse Gas Inventory. Standard biomass tables will be developed for land cover themes 1, 5 and 7 to estimate biomass loss.

Structural Vegetation 1990 is one of the data sets being compiled for this project. The Structural Vegetation 1990 information will be linked through the attribute VEGTYPE and labelled using the attribute definitions and expansion tables given in Table 12 and Tables 17 and 18.

Attribute name:	VEGTYPE
Database description:	Input width = 10 Output width = 10 Item type = Character

Type of change

All areas of one hectare and greater will be attributed for the type of change, according to the following table:

Table 3. Type of change lookup table

Attribute name:	TYPE
Database description:	Input width = 4 Output width = 5 Item type = Binary
TYPE.LUT	
1	No detectable change in woody cover between 1990 and 1995
2	Increase in woody cover from 1990–1995
3	Decrease in woody cover from 1990–1995

Cause of change

All areas one hectare and greater will be attributed with the cause of change. In the Guidelines for the National Greenhouse Gas Inventory Workbook (IPCC/OECD 1995) CO_2 losses and gains for the following are calculated:

Land clearing for agriculture

1. 'forest' (ie woody vegetation ≥ 2m tall with ≥ 20 percent crown cover) clearing for agriculture (–)

2. grassland conversion for agriculture (–)

Changes in 'forests' and other woody biomass stocks

3. management of commercial native hardwood 'forests', including logging and thinning as practised by commercial forest products industries (+ and –)

4. establishment and harvesting of commercial plantations (+ and –)

5. reforestation projects on farmland (+)

6. fuelwood gathering (–)

7. abandonment of managed lands (+), managed lands including cultivated lands and pasture which have been abandoned and which are regrowing towards a 'natural' state and which if not disturbed, will reach a height ≥2 m and canopy cover ≥20 percent

8. on–site burning of forests (–).The current IPCC inventory method ignores CO_2 emissions from biomass burning except for land clearing, on the basis that the outputs are balanced by inputs from subsequent plant growth. However, the inventory does account for non–CO_2 trace gases (CH_4, CO, N_2O, and NO_2) produced by anthropogenic burning.

In preparing the estimates for the 1988 and 1990 inventories, the Working Group on Carbon Dioxide and the Biosphere did not include grassland conversion for agriculture, abandonment of managed lands or reafforestation projects on farmland in calculating CO_2 gains and losses, primarily due to lack of data. The Working Group thought that there was little grassland conversion for agriculture or abandonment of managed lands occurring in Australia (Department of Environment, Sport and Territories 1994b).

Reforestation on farmland is occurring through an increase in private forestry activities such as the Bunnings scheme in Western Australia, as well as smaller plantings done under the auspices of Landcare or Greening Australia, and by individual land holders. There is substantial interest by governments and communities in establishing the extent of these activities and their impact on carbon sinks.

The data sets being prepared will not produce all the information relating to CO_2 emissions from the biosphere required for inventory calculations. Grassland conversion for agriculture is unlikely to be detected since the method chosen focuses on changes to the woody biomass. Thinning of native commercial forests and plantations will probably not be picked up by the change detection methods being used, nor changes due to fuelwood gathering. Nor is abandonment of managed lands and subsequent 'regrowth' likely to be detected, at least not consistently. However, Table 4 includes some of these categories, because they may be identified during field work.

Table 4. Cause of change lookup table

Attribute name: CAUSE
Database description: Input width = 4 Output width = 5 Item type = Binary

CAUSE.LUT	
1	on–farm tree planting (<20 ha)
2	forest management
3	plantation management
4	orchard management
5	agriculture
6	abandonment
7	grazing
8	bush fire (natural)
9	bush fire (managed)
10	grassland conversion
11	development (urban/infrastructure)
12	other
13	no change

Change detection analyses will classify losses and gains of trees at the pixel level, however, the deliverable data set will be produced at one hectare resolution. These areas of change will be attributed according to reason for change using ancillary data such as land tenure and land use information. Taking into account the inventory data requirements listed above, land tenure data will provide an initial basis for identifying whether losses and gains in woody vegetation are associated with agriculture (on freehold or leasehold land) or forestry activities (State forests/timber reserves). Since there are also significant private forestry operations on freehold land, principally plantations, but also some private native forest harvesting and regeneration (particularly in Tasmania), these will need to be identified from other sources such as databases and information held by industry groups.

Table 4 lists the causes of change. Forest management (cause.lut 2) is defined as activities being undertaken to manage native forests for commercial purposes, and includes areas within native forests that have been regenerated following logging. In Tasmania, northeast New South Wales and southern Queensland, some management of native forest occurs on freehold land. Elsewhere this occurs principally on public land designated as Multiple Use Forests or Forests Managed for Timber Production. Plantation management (cause.lut 3) covers activities in intensively managed stands of trees, of either native or exotic species, created by the regular placement of seedlings or seed, and may be undertaken on freehold or public lands.

Separation of changes in woody biomass on freehold land associated with private plantation management activities (see cause.lut 3 in Table 4) and those due to on–farm tree planting (cause.lut 1) will be done on size, and perhaps shape, of the forested or wooded area. If the area is >20 hectares, the change will be ascribed to plantation management. If the area is smaller, or looks like a wind break, boundary or roadside planting, it will be labelled as on–farm tree planting. For example, in Western Australia on–farm plantings under the Bunnings or the Department of

Conservation and Land Management's broadacre tree planting scheme would be labelled as plantation management, whereas smaller plantings established through Greening Australia or Landcare would be labelled 'on–farm tree planting'.

There are no sources of information on the area of managed lands that have been abandoned (cause.lut 6). It has been suggested that some steeper areas of land in the Illawarra (New South Wales) district previously used for dairying have been abandoned and are being recolonised by predominantly native species. State Department of Agriculture or land management agencies' district staff may be able to advise where this has occurred. If woody biomass gains are identified and their size and shape (or field information) indicates that they should not be attributed to on–farm tree planting or plantation management; this may be the appropriate category.

Changes associated with grazing (cause.lut 7) will include decreases where clearing has been undertaken to improve pastoral production, and gains where so called 'regrowth' is occurring. Regrowth, that is, even aged regeneration of usually native species, occurs on land used for grazing where clearing has not removed all the rootstock. The extent to which 'regrowth' will be identified through change detection procedures is not yet known.

Some changes in woody biomass will be due to 'natural' bush fire (cause.lut 8) or managed bushfires, such as burning after logging (cause.lut 9). As noted earlier, the area burnt is needed to calculate emissions of non CO_2 gases. It is important that biomass loss due to bush fires on agricultural land is identified as bush fire (natural) (ie cause.lut 8) to ensure that this change is not attributed to land clearing for agricultural purposes.

On land managed for forestry, biomass changes due to bush fires (natural bush fires, cause.lut 8) or burning such as that following logging operations (managed bush fires, cause.lut 9) will probably be identified on the basis of shape of the changed area. However, it may not be possible to decide whether the change is due to bush fire, or burning following logging unless additional information is available.

In some parts of the continent, particularly the Northern Territory, low intensity fires result in little change to the vegetation canopy. This, plus the rapid regrowth of vegetation, makes changes due to bushfires difficult to detect over a five–year interval. For this reason, changes due to fires will not be labelled in the Northern Territory data sets.

The category 'other' (cause.lut 12) should be used to record woody biomass changes due to disease (eg die back), pests, wind throw and drought.

The cause of change attributes are summarised in Table 5.

Table 5. Cause of change attribute summary

TYPE	**CAUSE** No Change	*On–farm tree planting (<20 ha)	*Forest Manage–ment	*Plantation manage–ment	Orchard establish–ment	*Agriculture	Abandon–ment
No Change	No change in woody biomass						
Increase		on–farm tree planting	regenera–tion of logging coups	* plantation planting	orchard establish–ment	'regrowth' of predomin–antly native vegetation	'regrowth' of predomin–antly native vegetation
Decrease			* logging of native forest	* logging of plantation	orchard removal	* clearing for agriculture	

TYPE	**CAUSE** Grazing	* Bushfire (natural)	* Bushfire (managed)	Grassland Conversion	Develop–ment	* Other
No Change						
Increase	'regrowth'	regrowth after bushfire	regrowth after fire		urban planting	
Decrease	* clearing for grazing	* bushfire	* burning after logging	conversion for agriculture	roads, airstrip, mines, urban, infrastruct–ure etc.	

(* mandatory for the final deliverable data set).

Replacement vegetation

The replacement vegetation will be attributed using the Land Cover Themes as defined in Table 2. The attribute definition is:

LANDCOVER.LUT
Attribute name: REPLACE
Database description: Input width = 1 Output width = 2 Item type = Integer

Filtering of change data

The aim of filtering is to enhance the accuracy of the data by removing pixels erroneously identified as change due to image misregistration. The change data after image processing will be filtered to remove individual pixels or clusters no larger than

2–3 pixels. Each State and Territory will record in the metadata the impact (in pixels gained or lost) of applying the filter and the type of filter used.

Attribute accuracy

An accuracy assessment of the change data will be undertaken to check consistency in change detection and its attributing between and within scenes and between operators. Accuracy checks will also be made for each scene during the processing stage to meet the following accuracy levels:

For States and Territories undertaking image rectification:

Image Rectification	sub pixel RMS error absolute image displacement < 100m
Image Coregistration	sub pixel RMS error relative image displacement < 1 pixel or 30 m

The approaches to accuracy assessment of the change data set adopted by each State and Territory will depend on the availability of information additional to the Landsat TM imagery, and the extent of field checking undertaken. Most States and Territories are checking all change areas using a source other than the imagery, such as aerial photography, SPOT images, field checking or other ancillary data sets. Where possible, it will be carried out by a second operator. This process may lead to some errors of omission, because only those areas identified as having gained or lost woody vegetation will be examined. Areas which may have been incorrectly classified as 'no change' will not be detected.

In States and Territories where there are few other sources of information suitable for verifying the results of the change detection process, at least 100 random points will be checked across the image, where possible by a second operator. An overall accuracy of greater than 90 percent is required. Where accuracy is below 90 percent, the scene is reprocessed.

A reliability attribute will be recorded for each change area, showing the data source used to label the change area with the cause of change category. The RELIABLE attribute will be labelled from Table 6.

A Quality Assurance Checklist Form, (Appendix 2) must be completed for each scene.

Quality assurance procedures

The procedures should be repeated until the prescribed level of accuracy is achieved. Where possible, they will be implemented on full Landsat scenes and are applicable to all the change detection techniques being used in the project.

The quality assurance procedures require key processing milestones to be completed and signed off against a checklist. Once the described level of quality is achieved, a record will be made on the 'Quality Assurance Checklist Form' (see Appendix 2) and the processing continued. Milestones, accuracy levels and recording facilities on the Checklist are described below (pages 27-30).

Input data

It is important to view and compare the image histograms (spectral range) of each Landsat TM band. Radiometric corrections could be applied for image normalisation. If image difference techniques are to be conducted, the image histograms must have similar properties.

Milestone	Equivalent image histograms (spectral range)
Accuracy Level	Subject to interpretation and application
Record	Print of image histograms for each band

Image rectification

Imagery will be orthorectified using the best digital elevation model (DEM) available. An image displacement of a maximum of 100 m is acceptable.

The 1995 image will be rectified using 15–20 evenly spread, accurate control points using 1:25 000 mapsheets. About six control points (selected in areas exhibiting high relief displacement) will be compared to the 1:25 000 data. If significant image displacement (> 100m) has occurred, an orthorectification will be applied.

Although ACRES guarantee a 60 metre geometric accuracy for Level 9 and 45 metre for Level 10, images may still require an image to image registration to ensure pixel to pixel accuracy in the change analysis.

Milestone	Image rectified to AMG
Accuracy Level	Sub pixel RMS error Absolute image displacement of no more than 100m
Record	Print of control points and RMS errors Print of control point comparison

Image coregistration

Comparisons of multi–date imagery for change detection must be made with accurately coregistered data to ensure that the extent of change is not misrepresented. At least six evenly spread control points will be taken from the 1995 image and coregistered to the 1990 image. Both images will then be compared for at least six points. The difference (relative displacement) should be no more than 1 pixel.

Milestone	1990 image coregistered to the 1995 image
Accuracy Level	Sub pixel RMS error No more than 1 pixel relative image displacement
Record	Print of control points and RMS errors Print of 1990 image to 1995 image comparison

Thematic attribute accuracy

The Victorian Tree Cover Mapping project (Gilbee in press) indicates that an overall accuracy of 90 percent can be achieved. As techniques have improved since this work was completed, it is expected that this will be a minimum overall accuracy. The measurement of overall accuracy is achieved by comparing ground truth and classified data for a random sample of control points.

Two measurable and one non–measurable quality assurance procedures will be implemented to ensure the image is attributed as accurately and efficiently as possible.

The first will be implemented directly after the completion of the image classification and labelling. The accuracy of the labelled classification will be assessed using a random sample of 100 points and checked using information from other data sets such as vegetation maps or air photos. This will ensure that the change class achieves an overall accuracy of at least 90 percent and that classes are re–labelled where the accuracy level is not acceptable.

Milestone	Accuracy assessment of Labelled Classification
Accuracy Level	Greater than 90 percent overall accuracy
Record	Print of accuracy assessment results.

The second (non-measurable) approach involves verifying every occurrence of change greater than the minimum area specified. By determining the reason for change, the reliability of that change will be improved. Any area of change that is found to be incorrectly labelled will be changed. This will also improve the classification. This will be achieved by using ancillary data, SPOT images where available, aerial photographs and the original Landsat images.

Milestone	Verification of change equal to or greater than one hectare
Accuracy Level	All change labelled with reason for change
Record	Reasons for change are recorded in data set

Following verification and editing of change the classes will again be accuracy assessed. This will take into account any edits made and will provide a final data set accuracy statement.

Aerial photography (optimum scales 1: 25 000–1: 40 000) will be used where available to assess ground truth for 100 randomly generated control points. A stratified sample may be used if the scene is dominated by one particular class. The assessment is done for a three x three pixel patch.

Milestone	Accuracy assessment of Post Edit Classification
Accuracy Level	Greater than 90 percent overall accuracy
Record	Print of accuracy assessment results.

Output data

Following attribution of the classified image, the data will be combined with Structural Vegetation, Land Cover Themes and the reasons for change information. The final output must be validated to ensure that the specifications are met.

Milestone	Completion of data to final deliverable stage
Accuracy Level	Passed all validation tests
Record	Print validation results and 'official stamp' of completion

Data received by BRS are checked against the specifications using an automatic checking procedure in Arc/Info and Arcview.

Notes on selection of random points

The selection of random points will be stratified according to the variability in the scene (eg. by land use and/or physiography). Within this stratification, sites will be selected at random. For each site (within the size groupings) the best independent data will be examined (aerial photographs where available, but Landsat TM image data may be the only information available) to record in a table:

- Occurrence of change (y/n).

- Area in pixels of real change, to compare with the classified pixel count (maybe over or under).

This will then be summarised to area accuracy (the effect of filtering can be similarly examined using the same sites). If errors are associated with a particular zone of the image, then stratification is indicated and should be tested.

Consistency across scenes

In processing the scene blocks, the scene overlap areas provide a large area to check the consistency of the results. The classified change areas must be compared over all the overlap areas and EVERY discrepancy examined (ie. a total census). Any significant discrepancy (say 5 percent of total changed estimate) will require explanation and reworking of at least one of the scenes.

An independent accuracy assessment will be undertaken for the national coverage. The method for this assessment has yet to be determined.

Table 6. Reliability attributes for each cause of change category

RELIABLE.LUT

Attribute name: REPLACE
Database description: Input width = 4 Output width = 5 Item type = Binary

RELIABLE	DESCRIPTION
1	Airphoto
2	Landsat TM imagery
3	SPOT imagery
4	ancillary thematic data (name of data recorded in the metadata)
5	field work
6	Other

A summary of the attributes for the vegetation change data set is given in Table 7 and an example for the Robinvale Mapsheet (Victoria–New South Wales) is shown in Figure 6.

Table 7. Summary of attributes for the Vegetation Change 1990–1995 data set

The final grid will be linked to the database using the item descriptions outlined below.

Database name	Description	Database definition	Source of information
LANDCOVER*	1990 land cover type	1,2,Integer	Acceptable values = 1–7 LANDCOVER.LUT
TYPE*	Type of change (increase, decrease or no change).	4,5,Binary	Acceptable values 1–3 TYPE.LUT
CAUSE*	Cause of change	4,5,Binary	Acceptable values 1–13 CAUSE.LUT
REPLACE*	1995 land cover type	1,2,Integer	Acceptable values = 1–7 LANDCOVER.LUT
VEGTYPE#	Database record for woody vegetation type = 7	10,10,Character	See attribution for Structural Vegetation data set
VERSION*	Date of data delivery	8,8,Date	Date of data delivery
RELIABLE*	Record of reliability of cause of change attribute	4,5,Binary	Acceptable values 1–6 RELIABLE.LUT

* Mandatory.
# Mandatory attributes depend on the level of attribution chosen by State agency.

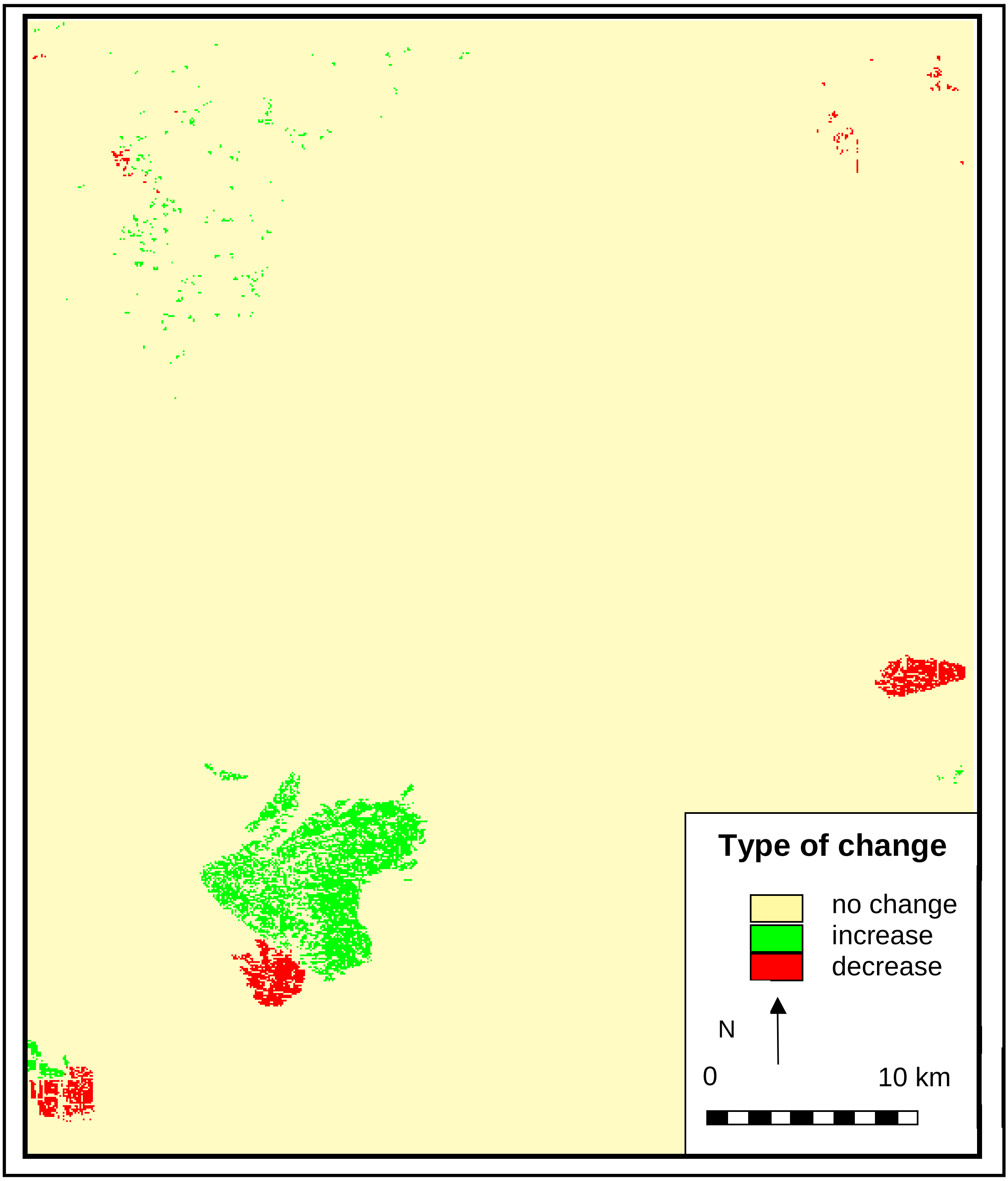


Figure 6. Vegetation change 1990–1995 for Robinvale (Vic-NSW) 1:100 000 mapsheet

Table 8. Vegetation change 1990–1995, Robinvale mapsheet

TYPE OF CHANGE	FROM	TO	CAUSE	AREA (ha)
Decrease	Eucalyptus woodland	Pasture	Fire	950
			Agriculture	304
Increase	Pasture	Eucalyptus woodland	Fire	4,067
			Other	3

The 1990 Land Cover Themes data set

Broad land cover classes are identified for this data set. These land cover types (see Table 2) comprise features that can be reliably identified on Landsat TM images. This data set will provide a template for future land use mapping.

The specifications for this data set are the same as those developed for the Murray–Darling Basin 'Basincare' project (Ritman 1995). The land cover themes data layer previously produced for the 'Basincare' project (which covers the Australian Capital Territory, and parts of New South Wales, South Australia and Victoria within the Murray–Darling Basin) will be incorporated into the State and national land cover themes data sets.

Technical specifications

This data set comprises 1990 digital land cover themes including 'woody vegetation' (≥2 m height, ≥20% crown cover) plus an attached attribute table defining the remaining land cover themes.

The digital data set is to be accompanied by all metadata as described in the section on ‘Metadata requirements’.

Minimum Attributed area 50 hectares

File Names

All digital data sets of change will have a standard name starting with the State or Territory letter/s given below, the mapsheet number followed by _LC eg. the New South Wales land cover themes data for mapsheet number 8448 would be named N8448_LC. Where the State or Territory delivers the Land Cover Themes and the Structural Vegetation data set as one, the mapsheet will end with _VEG eg. N8448_VEG.

W	Western Australia
NT	Northern Territory
S	South Australia
Q	Queensland
N	New South Wales
A	Australian Capital Territory
V	Victoria
T	Tasmania

Classification Method

The classification method for land cover themes will vary between State and Territory agencies; some are based on methods developed for the Murray–Darling Basin’s M305 project, see Ritman (1995), for further detail. A summary of each method is given in Table 9.

Table 9. Classification method for land cover themes

State	Land cover themes classification method
Western Australia	Threshold
South Australia	Spectral temporal
Northern Territory	Threshold
Queensland	Supervised classification
New South Wales (including ACT)	M305 technique
Victoria	M305 technique
Tasmania	Threshold

The threshold method is based on an index of band combinations incorporated into a series of thresholds which equate to rules to identify particular land cover classes. The spectral temporal method combines the bands from 1990 and 1995, then uses an unsupervised classification to distinguish the classes. The supervised classification method uses training sites to distinguish vegetation areas. The M305 techniques are described in Ritman (1995).

Each State and Territory will record the details of the classification method used to map land cover themes in the metadata, under the item 'Classification Method'.

Attributes for Land Cover Themes

Definitions for the classification of woody and non-woody areas are listed below. These should be attached to the landcover grid using the item LANDCOVER (1,2,Integer).

Table 10. Land cover themes lookup table

LANDCOVER.LUT

Attribute	Input Width	Output Width	Item Type
LANDCOVER	1	2	Integer

0	Not classified
1	Pasture / Crop including herbfields, grasslands (ie. Non-woody)
2	Urban
3	Bare Ground
4	Water
5	Plantation
6	Orchard
7	Native or exotic woody vegetation (excluding plantations, orchards)

Attribute accuracy

The 1990 woody–non-woody vegetation data set will be checked against an external data source such as aerial photographs, SPOT images, other digital data sets or ancillary data (preferably with a scale no coarser than 1:100 000). One hundred randomly selected points will be used; these may be clustered within available air photo coverage, but will be randomly selected. The areas checked will be no greater than one hectare units, with the aim of achieving a 90 percent accuracy.

Lack of vegetation mapping at a suitable scale will result in Queensland supplying information on the density and basal area of woody vegetation rather than on the distribution of species or genera. The accuracy of the vegetation density theme will be assessed using aerial photography at scales from 1:25 000 to 1:80 000. One hundred points will be placed within the image so that a range of vegetation types and densities are sampled. The points will be clustered in up to five areas so that only a limited number of aerial photos need to be used. At each site a density class will be interpreted from the photography. A graph showing the relationship between classified density (Foliage Projective Cover) against photo interpreted density will be produced.

A statement of the source and origin of data used to derive the land cover attributes will be supplied with the metadata under the section on data quality in the item titled 'Lineage'.

Estimates of the accuracy of the mapped land cover attributes will be provided for each scene, based on the accuracy assessment described for all data sets in the section on Quality Assurance Procedures.

States and Territories will supply the Land Cover Themes and the Structural Vegetation information as one data set. The following summary of attributes for these data sets demonstrates how the Land Cover Themes attribute will be accompanied by the VEGTYPE attribute for Structural Vegetation. An example of the Land Cover Themes data set for Robinvale, Victoria is shown in Figure 7.

Table 11. Summary of Attributes for 1990 Land Cover Themes and Structural Vegetation data set

Attribute	LUT Name	Input Width	Output Width	Item Type
LANDCOVER	landcover.lut	1	2	Integer
VEGTYPE	vegtype.lut	10	10	Character
VERSION		8	8	Date

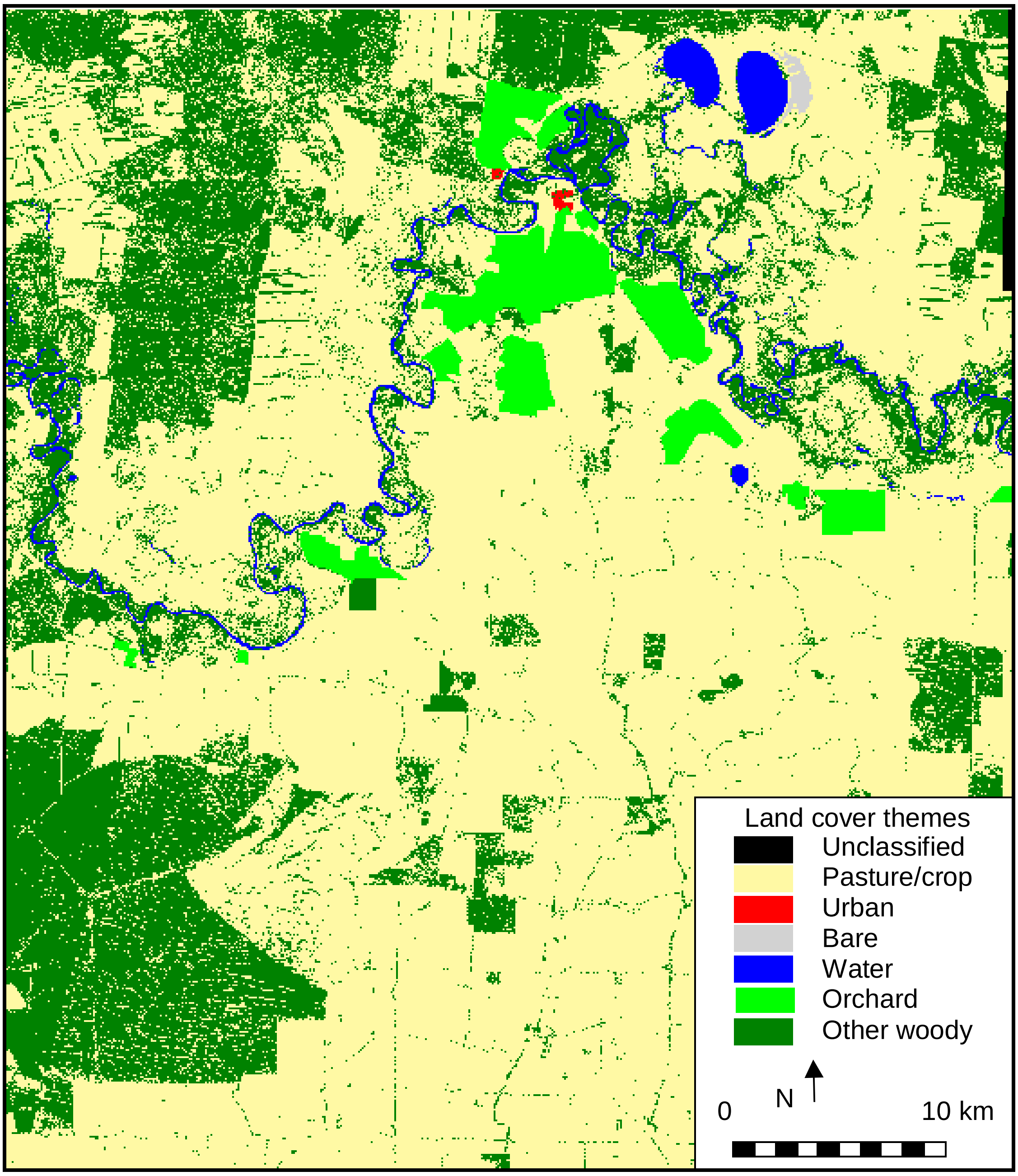


Figure 7. Land Cover Themes data set for Robinvale 1:100 000 mapsheet

The 1990 Structural Vegetation data set

Spatial information for the estimation of biomass

For calculating carbon fluxes to the atmosphere due to land clearing, it is necessary to know how much biomass has been removed. In the current inventory (Department of Environment, Sport and Territories 1996) values for above ground biomass prior to clearing are based on estimates of biomass prepared by Gifford, et al. (1992) and Grierson, Adams and Attiwill (1992) from the limited data available for Australian vegetation types. These values are applied to three forest classes; tropical and temperate closed forest, open forest, and woodland and scrub, used for inventory reporting purposes.

As noted in the inventory, there is a pressing need to obtain better data on the biomass of vegetation types. Until remote methods of determining biomass (eg. through laser altimetry) become available, the most practical approach is to use information on the spatial distribution of vegetation types and to attach biomass values to these types.

A Structural Vegetation data set at a scale of 1:100 000 will be developed by attributing the 'woody' land cover mapped in the Land Cover Themes data set using data from existing vegetation mapping. A Structural Vegetation data set at this scale is already available for the Murray–Darling Basin (Ritman 1995), although the data set does not contain information about height of all the mapped communities.

As resource limitations require us to make the best use of available data, we will build on the mapping of density, genus and growth form done for the Murray–Darling Basin. Specifications for the additional structural vegetation structure mapping are compatible with those for the Basin mapping, and allow for inclusion of data on species, height and volume or basal area (where available) which will assist in the estimates of aboveground biomass.

For regions mapped by the Murray–Darling Basin project, density class, genus and growth form data will be provided for the Structural Vegetation database. Height data will be added where available. The preferred standard is based on the National Forest Inventory Standards Taskforce (1996) Core Attributes and Layer Design for the Classification of Forest and Woodland Vegetation requirements. This provides a format which can be readily expanded to incorporate additional data.

Technical specifications

The 1990 Structural Vegetation comprises a digital data set for all 'woody' (≥2 m height, ≥20% crown cover) vegetation with polygons greater than 50 hectares having attached attribute tables describing vegetation type and density. Where the scale of the vegetation data set used for attributing is sufficiently detailed, polygons smaller than 50 hectares will be attributed.

State and Territory agencies producing both 1990 Land Cover Themes and 1990 Structural Vegetation data sets will deliver these as a single data set by combining the attributes for both, ie. the final data set will comprise the 7 land cover themes with the woody theme attributed for structural vegetation.

Minimum Attributed Area 50 hectares

File Names

All structural vegetation data sets have the standard naming ending in _VEG Standard mapsheet number preceded by the State or Territory letter/s: (eg. New South Wales = N8448–vegetation grid = N8448_VEG, assuming both deliverable 2 and 3 are being combined into one grid.)

W	Western Australia
NT	Northern Territory
S	South Australia
Q	Queensland
N	New South Wales
A	Australian Capital Territory
V	Victoria
T	Tasmania

Classification Method

The Structural Vegetation data sets are prepared using the Land Cover Themes data set as a base, and adding vegetation information (genus or species, density, height) to the native or exotic woody vegetation (attribute 7) and plantation (attribute 5) themes. The precise form of the attributes used for the Structural Vegetation data set will depend on the nature and scale of information currently available. This will vary between and within States and Territories, as State or Territory wide mapping of forest or vegetation resources at scales suitable for use in this project will not always be available. These existing vegetation data are generally held in a geographic information system. In some cases, older data sets will need to be digitised before they can be used to attribute the woody–non-woody data layer. Each State and Territory will provide information on the method used to derive the Structural Vegetation data for each mapsheet area in the metadata.

Attributes for 1990 Structural Vegetation Mapping

All woody areas of 50 hectares and greater will be attributed. Smaller areas should be attributed if the information needed to do so is available at a suitable scale.

As discussed for the 1990–1995 Vegetation Change data set, the level of attributing undertaken (eg genus or species) will depend on the availability of structural vegetation data of a suitable scale. The options are listed below; the item definitions are given at the end of this section. The attributes are based on Ritman (1995) and the National Forest Inventory Standards Taskforce (1996). Table 12. shows the three levels of possible attributing.

Table 12. Levels for attribution of Structural Vegetation

M305	**M305 + Height**	**NFI**
DENSITY*	DENSITY*	CROWN COVER#
GENUS*	GENUS*	GENUS & SPECIES#
GROWTH FORM*	GROWTH FORM*	GROWTH FORM #
	HEIGHT#	HEIGHT #
		BIOMASS #

* As defined in M305 Specifications (Ritman 1995)
# As defined by NFI Specifications (1996).

The M305 level of attributing will be the minimum level of data collated and will only be acceptable in those areas that were mapped in the M305 project. The M305 + height attributes will be the minimum level of data accepted for areas of new mapping being funded (whole or in part) through the land cover project. Due to funding limitations, only basal area attributes will be provided for Queensland.

Relationship between floristic and Structural Vegetation data

The following shows how the floristic and structural vegetation data are to be related. It will comprise the initial vegetation data attached to the GRID, and related tables holding the structural vegetation attributes.

VEGETATION GRID (.VAT)

LANDCOVER VEGTYPE VERSION

vegtype.lut

VEGTYPE SPEC_GROUP1...n PROPORTION1...n (+ attributes in vegtype.lut)

species.lut

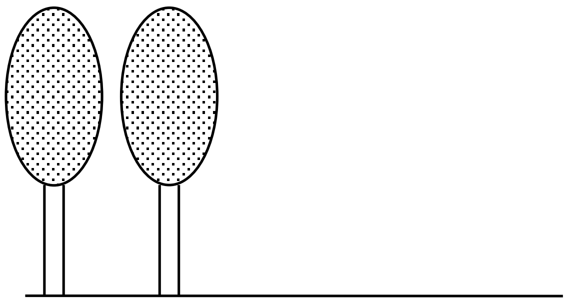
SPEC_GROUP SPECIES DOMINANCE (+ attributes in species.lut)

Example showing attributing of Structural Vegetation data

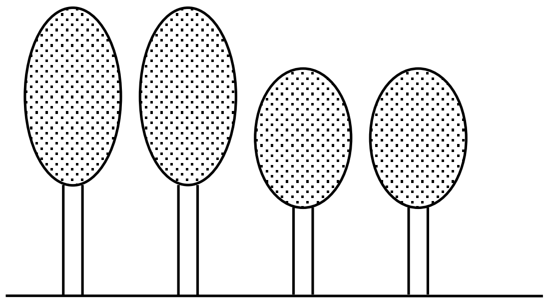
The following example demonstrates how the structural vegetation data will be attributed (using change detection examples). The vegetation database for the Land Cover Themes and Structural Vegetation data sets will use the same format. This example shows the original data schematically, and the attributes and tables to be delivered. The prefix used is 'A' for ACT.

AREA 1 (on–farm forestry)

This first example shows a patch of woody vegetation on a farm, which is then expanded with some on–farm tree planting.



1990
woody vegetation + bare



1995
woody vegetation (expanded) + bare

Resulting land cover values in the image

1990 Image (landcover values)

7	7	3	3	3	3
7	7	3	3	3	3
7	7	3	3	3	3
7	7	3	3	3	3

1995 Image (landcover values)

7	7	7	7	7	3
7	7	7	7	7	3
7	7	7	7	7	3
7	7	7	7	7	3

RESULTING CHANGE GRID

NC = no change
C = change

NC	NC	C	C	C	NC
NC	NC	C	C	C	NC
NC	NC	C	C	C	NC
NC	NC	C	C	C	NC

Attributes for change area:

LANDCOVER	3
TYPE	2
CAUSE	1
REPLACE	7
VEGTYPE	ACT1
VERSION	25/6/96
RELIABLE	2

ACT1 is the first vegetation combination.

vegtype1.lut.

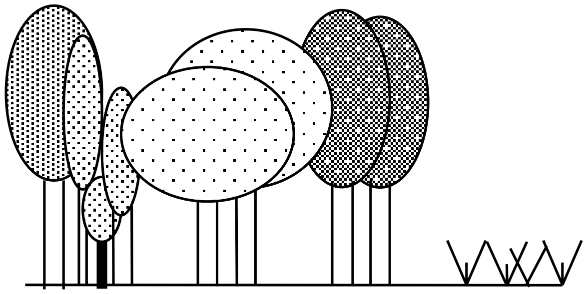
VEGTYPE	ACT1
SPEC_GROUP1	S_ACT1
PROPORTION1	100
COVER_MIN	20
COVER_MAX	50
COVER_MED	35
COVER_TYPE	30
HEIGHTD_MIN	5
HEIGHTD_MAX	50
HEIGHTD_MED	35
BAS_AREA	–9999
GBV_HA	–9999
GSV_HA	–9999
STEM_HA	–9999

Species1.lut

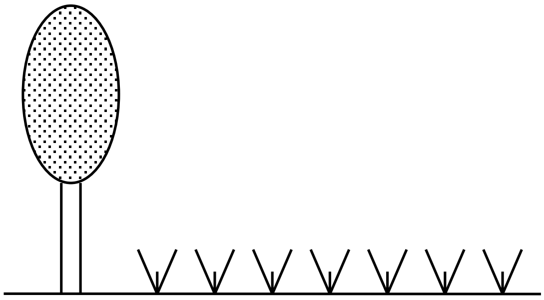
SPEC_GROUP	S_ACT1
SPECIES	Eucalyptus melliodora
DOMINANCE	1
ABUNDANCE	–1
STRATUM	overstorey
GF	T

AREA 2 (clearing for agriculture)

The second example shows a more complex data structure for a vegetation mosaic. This is based on the M305 example in Ritman (1995, p22) to show how M305 structural vegetation data will convert to this structure.



1990
woody vegetation (mix with under and and overstorey) + crop



1995
woody vegetation (reduced)+crop

Resulting land cover values in the image

1990 Image

7	7	7	1	1	1
7	7	7	1	1	1
7	7	7	1	1	1
7	7	7	1	1	1

1995 image

7	1	1	1	1	1
7	1	1	1	1	1
7	1	1	1	1	1
7	1	1	1	1	1

RESULTING CHANGE GRID

NC = no change
C = change

NC	C	C	NC	NC	NC
NC	C	C	NC	NC	NC
NC	C	C	NC	NC	NC
NC	C	C	NC	NC	NC

Attributes for change area:

LANDCOVER	7
TYPE	3
CAUSE	4
REPLACE	1
VEGTYPE	ACT2
VERSION	25/6/96
RELIABLE	4

vegtype1.lut

VEGTYPE	ACT2
SPEC_GROUP1	S_ACT2
PROPORTION1	40
SPEC_GROUP2	S_ACT3
PROPORTION2	35
SPEC_GROUP2	S_ACT4
PROPORTION2	25
COVER_MIN	20
COVER_MAX	50
COVER_MED	35
COVER_TYPE	–9999
HEIGHTD_MIN	5
HEIGHTD_MAX	50
HEIGHTD_MED	35
BAS_AREA	–9999
GBV_HA	–9999
GSV_HA	–9999
STEM_HA	–9999

species1.lut

SPEC_GROUP	S_ACT4
SPECIES	Eucalyptus spp
DOMINANCE	1
ABUNDANCE	–1
STRATUM	overstorey
GF	S

SPEC_GROUP	S_ACT3
SPECIES	Casuarina spp
DOMINANCE	1
ABUNDANCE	–1
STRATUM	overstorey
GF	T

SPEC_GROUP	S_ACT2
SPECIES	Eucalyptus spp
DOMINANCE	1
ABUNDANCE	–1
STRATUM	overstorey
GF	T

SPEC_GROUP	S_ACT2
SPECIES	Callitris spp
DOMINANCE	2
ABUNDANCE	–1
STRATUM	overstorey
GF	T

SPEC_GROUP	S_ACT2
SPECIES	Casuarina spp
DOMINANCE	2
ABUNDANCE	–1
STRATUM	understorey
GF	M

If any of these species types had occurred in area 1, a new species record would not be required, the VEGTYPE would link to the previous SPEC_GROUP number.

Vegetation type information (VEGTYPE) and related tables: database entry rules

The following section describes the detail in the database.

As the completed data will be delivered as groups of 1:100 000 mapsheet tiles throughout the project, each new set of data will be delivered with a vegtype.lut and species.lut. These will be numbered sequentially and throughout the project each of the values of VEGTYPE and SPEC_GROUP will remain unique ie. will not be used for a different vegetation type.

VEGTYPE is a unique identifier linked to vegtype.lut, recording every unique combination of attributes in vegtype.lut.

Numbered by <State or Territory initial><sequential no>

State Initial:(in upper case)	
AC	Australian Capital Territory
NS	New South Wales
NT	Northern Territory
QL	Queensland
VI	Victoria
SA	South Australia
TA	Tasmania
WA	Western Australia

Example: The number for each unique vegetation type for Victoria being:
VI1, VI2, VI3 etc.

These initials are two characters long, to enable database extraction based on the first two letters. **VEGTYPE** will only contain a unique number if LANDCOVER or REPLACE contain a value where additional vegetation information is available (ie. land cover themes 5 = plantation or 7 = native or exotic woody vegetation). If additional information is available (floristics or structural vegetation at 1995), then it is attached through the attribute VEGTYPE.

If LANDCOVER or REPLACE do not have structural vegetation information to be added then VEGTYPE is recorded as –9999 to indicate that the information is not available. In areas where the land cover (as mapped from satellite imagery) cannot be matched with the structural vegetation data due, for example, to differences in scale in the data sets, the resulting area will be labelled –9998.

Table 13. Structural Vegetation lookup table

vegtype.lut

Attribute	Input width	Output width	Item Type	LUT (if required)
VEGTYPE	10	10	Character	
SPEC_GROUP1 ... n	40	40	Character	species.lut
PROPORTION1...n	4	5	Binary	
COVER_MIN	4	5	Binary	
COVER_MAX	4	5	Binary	
COVER_MED	4	5	Binary	
COVER_TYPE	4	5	Binary	
HEIGHTD_MIN	4	5	Binary	
HEIGHTD_MAX	4	5	Binary	
HEIGHTD_MED	4	5	Binary	
BAS_AREA	4	5	Binary	
GBV_HA	4	5	Binary	
GSV_HA	4	5	Binary	
STEM_HA	4	5	Binary	

A map unit may comprise a single group of species, or a mosaic of more than one group of species where it is not feasible to map these as separate units.

SPEC_GROUP1..n: a relateable code which will link to species.lut. There can be as many SPEC_GROUPs as required. Multiple entries (one to many) relationships will occur where more than one species make up the species group. These will be numbered sequentially, ie. for three different species in one mosaic, there will be three SPEC_GROUP and PROPORTION records.

Naming Convention: as for VEGTYPE but preceded with the S_ prefix.
Using the example above: The number for each unique species group for Victoria would be: S_VI1, S_VI2 and S_VI3.

PROPORTION1...n: The proportion of each species in the species group. The proportion is that of the total crown cover of the map unit occupied by the species group represented as a percentage. If the proportion is not known, –9999 will be placed in the field.

Crown Cover

Crown cover is the percentage of the sample site within the vertical projection of the periphery of the crowns. In this case crowns are treated as opaque. Actual crown densities will be recorded where these have been measured for a stand.

It has been suggested by the National Forest Inventory (Phillip Tickle, pers. comm.) that the density attribute (the cover classes) be recorded as percentage foliage cover rather than crown cover. The reason for this is that crown cover estimates assume an opaque crown. McDonald et al. (1990) (page 70) provide conversions from crown cover to percentage foliage cover and the measure of cover type to be recorded in the COVER_TYPE attribute field. The cover type is the degree of openness of the crowns. This will be an important attribute to record as it varies throughout Australia with species, location and climate, and is the key to converting from crown cover to percentage foliage cover or vice versa.

The cover measurements will be recorded as the actual cover rather than a class. This is to avoid ‘lumping’ measurements when specific data are available. Previous mapping exercises that have used classes for crown cover ie. M305 should be converted to the median value. For M305 data the conversion is given below.

Table 14. Conversion from density (M305) to crown cover

Density Code	M305 range	Description	COVER_MED
0		Not applicable/not mapped	0
1	0–0.2%	Isolated	0.1
2	0.2–20%	Very sparse	10
3	20–50%	Sparse	35
4	50–80%	Mid–dense	65
5	80–100%	Dense	90

Where there are no data on COVER_TYPE enter –9999, where COVER_TYPE is not applicable enter –9998. Where additional crown information is available the following should be recorded.

Table 15. Crown cover attribute definitions

Attribute	**Standards and Description**
COVER_MIN	The minimum recorded crown cover for each map unit.
COVER_MAX	The maximum recorded crown cover for each map unit.
COVER_MED	The median or most representative measure of crown cover for each map unit.
CROWN_TYPE	The degree of openness of the crowns–If the COVER attribute was derived from Projective Foliage Cover (Specht et al. 1974), a crown type estimate (Walker et al. 1990) should also be recorded as a percentage. –9998 should be used if it is not applicable.

Height

General height is measured at the top of the predominant canopy. Height is recorded in metres. If the height is constant across a map unit then the minimum, maximum and median values will be the same. If minimum and maximum values are unknown, then –9999 will be entered to indicate that no data are available for this record.

Table 16. Height attribute definitions

Attribute	**Standards and Description**
HEIGHTD_MIN	The lowest value for heightd recorded within a map unit
HEIGHTD_MAX	The highest value for heightd recorded within a map unit
HEIGHTD_MED	The median value for heightd recorded within a map unit.

Biomass

The attributes listed in Table 17 will be used to improve estimates of biomass for specific vegetation types. Where this information is available, it will greatly assist the final carbon estimates. These will be recorded on a per hectare basis. This figure will be used later to multiply the area statements for the Inventory measurements.

Table 17. Biomass attribute definitions

GSV	Gross Standing Volume–The total volume of all living and dead trees above breast height, including bark, branches and foliage (m^3/ha).
GBV	Gross Bole Volume–The underbark volume from the ground to the tip (m^3/ha).
BAS_AREA	Basal Area–The sectional area of the trees at breast height (1.3 m) recorded as m^2/ha.
STEM_HA	Stems per Hectare–The number of stems per hectare.

Species information and related tables

The data on the species type defined by a species group will be recorded in the SPECIES.LUT (Table 18). This will include information on the stratum in which each species occurs; the dominance of the species within the overstorey (if applicable), the abundance of the species and its growth form.

This format will be duplicated for each additional species in a species group. There can be multiple entries for SPEC_GROUP (one to many relationship) where more than one species makes up a species group. Table 19 shows the species definitions.

Table 18. Species lookup table (species.lut)

Attribute	Input width	Output width	Item Type	LUT name
SPEC_GROUP	40	40	Character	
SPECIES	80	80	Character	
DOMINANCE	4	5	Binary	
ABUNDANCE	4	5	Binary	
STRATUM	12	12	Character	
GF	2	2	Character	gf.lut

Where data are not available or not mapped enter –9999.

SPECIES will include genus and species name. Genus is recorded with first letter in upper case, the remainder in lower case with one space between genus and species. Where species name is not available, enter sp. ie. *Eucalyptus blakelyi* or *Eucalyptus* sp.

Table 19**.** Species lookup table definitions

Attribute	**Standards and Description**
SPEC_GROUP	The relateable code attached to VEGTYPE.LUT Multiple entries (a one–many relationship) will occur where more than one species makes up the species group.
SPECIES	Species 1..n in order of predominance. Plantation species should also be recorded using the species attribute.
DOMINANCE	A code indicating a dominance rating for the species if it occurs within the overstorey. The following codes must be used: 1 = dominant; 2 = codominant; 3 = subdominant; –9999 = unknown.
ABUNDANCE	A percentage abundance figure for SPECIESn. Where a percentage cannot be given the following codes should be used: –1 = abundant;–2 = common –3 = occasional; –4 = rare; –9999 = unknown; –9998 = not applicable.
STRATUM	The stratum in which SPECIES occurs. eg. emergent; overstorey; midstorey; understorey, or ND for unknown.
GF	SPECIES Growth Form as defined in GF.LUT (Table 20).
ASSOCIATION	OPTIONAL–The formal plant association name used by the custodian of the data or a general description eg. Damp Eucalypt.

Growth form

Table 20. Growth form lookup table (gf.lut)

Code	Description
T	TREE–Woody plant more than 2 m tall with a single stem or branches well above the base.
M	TREE MALLEE–Woody perennial plant usually of the genus *Eucalyptus.* Multi–stemmed with fewer than 5 trunks of which at least 3 exceed 100 mm at breast height (1.3 m). Usually 8 m or more tall.
S	SHRUB–Woody plant multi–stemmed at the base (or within 200 mm from ground level or if single stemmed, less than 2 m tall).
Y	MALLEE SHRUB–Commonly less than 8 m tall, usually with 5 or more trunks, of which at least three of the largest do not exceed 100 mm at breast height (1.3 m).
Z	HEATH SHRUB–Shrub usually less than 2 m tall, commonly with ericoid leaves (nanophyll or smaller leaves).
C	CHENOPOD SHRUB–Xeromorphic single or multi–stemmed halophyte exhibiting drought and salt tolerance.
G	TUSSOCK GRASS–forms discrete but open tussocks usually with distinct individual shoots or if not, then forming a hummock. These are the common agricultural grasses.
H	HUMMOCK GRASS–Coarse xeromorphic grass with a mound–like form often dead in the middle; genera are Triodia and Plectrachne.
D	SOD GRASS–Grass of short to medium height forming compact tussocks in close contact at their base and uniting as a densely interfacing leaf canopy.
V	SEDGE–Herbaceous, usually perennial, erect plant generally with a tufted habit and of the families Cyperaceae and Restionaceae.
R	RUSH–Herbaceous, usually perennial, erect plant. Rushes are grouped into families Juncaceae, Typhaceae, Restionaceae and the genus Lomandra.
F	FORB–Herbaceous or slightly woody, annual or sometimes perennial plant; not a grass.
E	FERN–characterised by large and usually branched leaves (fronds), herbaceous to arborescent and terrestrial to aquatic; spores in sporangia on the leaves.
O	MOSS–Small plant usually with a slender leaf–bearing stem with no true vascular tissue.
L	VINE–Climbing, twining, winding or sprawling plant usually with a woody stem.
GU	UNKNOWN GRASSES–Use this code where grasses are known to occur but the actual growth form is not known.
HG	UNKNOWN HERBS and GRASSES–Use this code where grasses and herbs are known to occur but the actual growth form is not known.
A	CYCAD
P	PALM
X	XANTHORRHOEA
N	LICHEN
W	LIVERWORT
P	PARASITES
RO	ROCKS–Where rocks make up the understorey.
BA	BARE GROUND–Where bare ground makes up the understorey.
SA	SALINE–Where saline scalding makes up the understorey.
NA	NOT APPLICABLE

Source: Walker and Hopkins (1990) **.**

Table 21. Mapping the M305 values to the expected entries in gf.lut

Growth Form (M305)	Growth Form (for Land Cover Project)
T	T
M	M
S	S
H	HG

Filtering of the woody–non-woody data

There is no evidence to suggest that the 1–2 pixel areas in the 1990 woody vegetation data are not related to vegetation on the ground. Hence it has been decided not to filter these data. It should be noted that the NSW woody–non-woody data set, which was prepared for the M305 project, will be incorporated in the Land Cover Themes data set. These data have already been filtered using the M305 majority filter (Ritman 1995).

Attribute Accuracy

Each State and Territory will record in the metadata the source/origin of the data sets used to derive the Structural Vegetation attributes and the scale of these data. An example of the Structural Vegetation data for the Robinvale mapsheet is shown in Figure 8.

Table 22. Summary of attributes for Structural Vegetation data

1990 Vegetation (Woody Land Cover components)#

Attribute	Input width	Output width	Item Type	LUT (if required)
VEGTYPE	10	10	Character	
SPEC_GROUP1 . n#	40	40	Character	species.lut
PROPORTION1...n	4	5	Binary	
COVER_MIN#	4	5	Binary	
COVER_MAX#	4	5	Binary	
COVER_MED#	4	5	Binary	
COVER_TYPE	4	5	Binary	
HEIGHTD_MIN	4	5	Binary	
HEIGHTD_MAX	4	5	Binary	
HEIGHTD_MED	4	5	Binary	
BAS_AREA	4	5	Binary	
GBV_HA	4	5	Binary	
GSV_HA	4	5	Binary	
STEM_HA	4	5	Binary	
SPEC_GROUP	40	40	Character	
SPECIES	80	80	Character	
DOMINANCE	4	5	Binary	
ABUNDANCE	4	5	Binary	
STRATUM	12	12	Character	
GF	2	2	Character	gf.lut

Mandatory attributes will vary between States and Territories

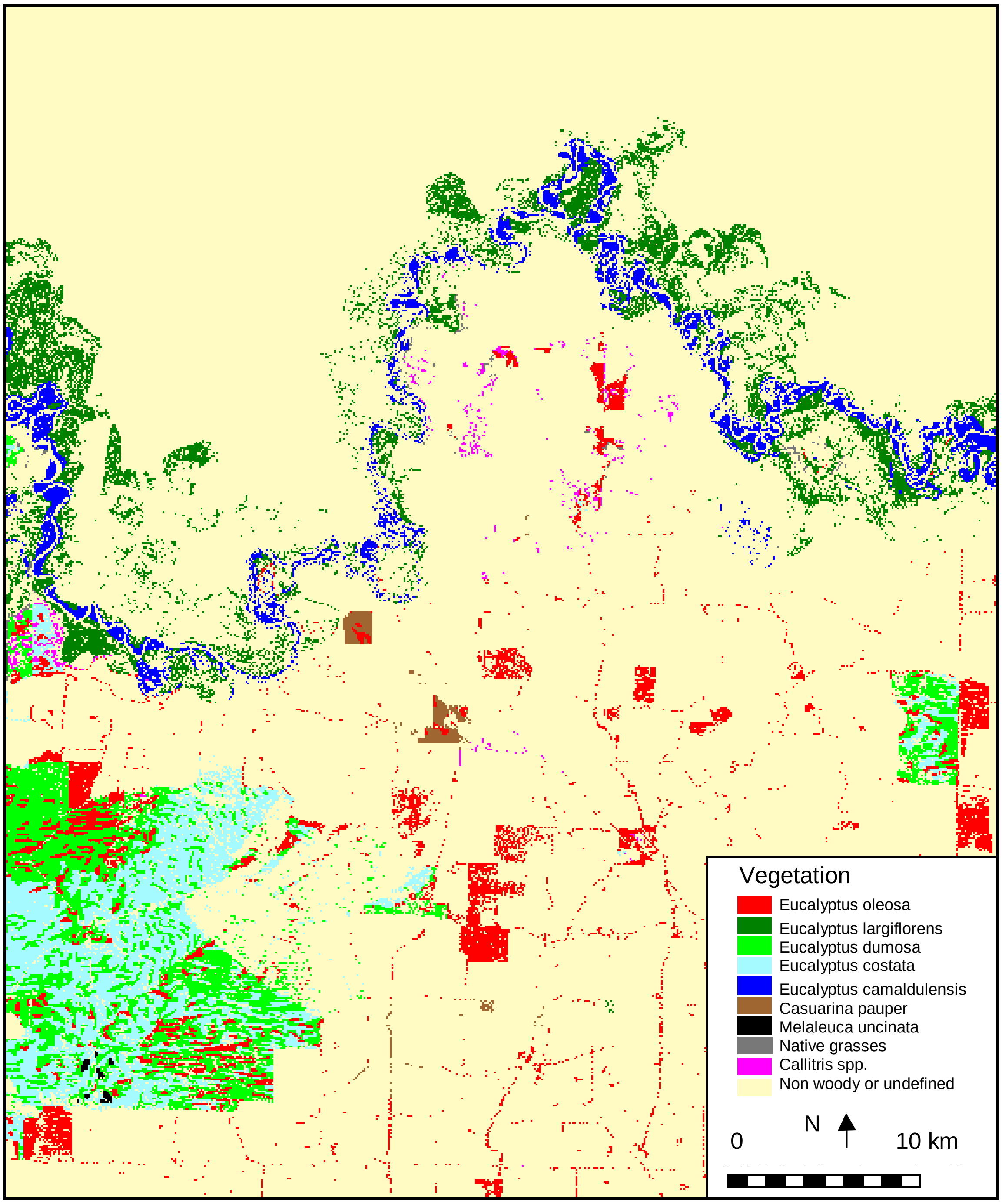


Figure 8. Structural Vegetation 1990 data set for Robinvale 1:100 000 mapsheet

Metadata requirements

The project will adopt the Australian and New Zealand Land Information Council's (ANZLIC) 'Core Metadata Elements for Land and Geographic Directories in Australia and New Zealand' 1996 (see URL: http://www.anzlic.org.au/metaelem.htm for more information) plus some additional attributes specific to the land cover project. There will be some slight variation in the names of fields, as these have been modified to suit the 'DOCUMENT' template in Arc/Info. However, the content will meet the ANZLIC standard. The proposed framework is given below.

Data set

Title
The name of the data set followed by, where applicable, an acronym enclosed in round brackets.

Custodian
The primary organisation associated with the data set and responsible for its maintenance.
The name of the organisation at the beginning, followed by the custodian and ending with the organisation's acronym.

Contact Address(es)

Contact Organisation
The name of the organisation, and where appropriate, the unit or Branch within an organisation with which contact may be made to inquire further about the data set. Include acronym.

Contact Position
The position title of the individual within the organisation who is responsible for the data set.

Mail Address
The mailing address of the contact position.

Suburb/Place Locality
The suburb, place or locality of the mailing address.

Country/State
Either the Country or the State or Territory of the mailing address.

Postcode
The postcode of the mailing address.

Telephone
The telephone number of the contact position including area code.

Facsimile
The fax number of the contact position.

Electronic Mail Address
The electronic mailbox address of the contact position or organisation.
Enter the words 'unknown' or 'none' if there is no e–mail address.

Description

Abstract
A characterisation of the data set, including a brief narrative, summary or abstract and the intended use for which the data set was developed.
May include the geographic area of the data set.

Keywords
A common use word or phrase used to describe the data set, chosen from a pick list (see Australia New Zealand Land Information Council 1996). Minimum of 1, maximum of 6.

Geographic Extent
A series of coordinate pairs (represented as latitude and longitude in decimal degrees) that define the area(s) covered by the data set. If using a rectangular box, define upper left and then lower right. The polygons must close and the boundary must not intersect. The minimum number of coordinate pairs per polygon is three. Use 4 decimal places for lat/long coordinates.

Data Currency

Beginning Date
The earliest date for which the information contained in the data set is current from. Format 'DD/MM/YYYY'.

Ending Date
The latest date, for which the information in the data set is current. Format 'DD/MM/YYYY'.

Data Set Status

Progress
Progress status of the data set chosen from pre–defined time period.

Maintenance and Update Frequency
The frequency with which changes and additions are made to the data set after the initial data set is completed, chosen from a pre–defined list.

Access

Available Format Types
A description of any format types, both digital and non digital, that the data set is available in.

Access Constraints
Any restrictions or prerequisites for using the data set. These may include access restraints aimed at protection of privacy or intellectual property and any special restrictions or limitations on obtaining the data set.

Data Quality

Lineage
Information describing the history of the data set, including source material from which the data set was derived, (date(s), scale(s), capture and transformation methods, reference to control information etc).

Positional Accuracy
An assessment of the accuracy of the positions of spatial objects and the assignment of attribute values to the spatial objects within the data set in relation to each spatial object's true ground position.

Attribute Accuracy
An assessment of the accuracy and details of the method used for the identification of spatial objects and the assignment of attribute values to the spatial objects within the data set.

Logical Consistency
An assessment of how well the logical relationships items in the data set are maintained eg. all polygons are labelled, all attribute values have been checked against sets of valid values.

Completeness
An assessment of the range of data captured with regard to completeness of data, completeness of classification and completeness of verification.

<u>Metadata Data</u>

Metadata Data
The date that the metadata were created or last updated. Format of 'DD/MM/YYYY'.

<u>Further Information</u>

Further Information
The name of any other directory system(s) where more detailed metadata are recorded.

<u>Mapsheet Number</u>

1:100 000 mapsheet number preceded by the State or Territory prefix

W	Western Australia
NT	Northern Territory
S	South Australia
Q	Queensland
N	New South Wales
A	Australian Capital Territory
V	Victoria
T	Tasmania

<u>Scene Path</u>

2 or 3 digit number of scene path.

<u>Scene Row</u>

2 or 3 digit number of scene row.

<u>Scene date 1990</u>

The date that the 1990 Landsat TM scene was captured. Format of 'DD/MM/YYYY'. Should the mapsheet cover more than one image, supply all dates–ordered from highest to lowest in the amount of each scene covered in the mapsheet area.

Scene data 1995

The date that the 1995 (or later where 1996 data used) Landsat TM scene was captured. Format of ‘DD/MM/YYYY’. Should the mapsheet cover more than one image, supply all dates, ordered from highest to lowest in the amount of each scene covered in the mapsheet area.

Collection Method

Information on the collection of field survey data, use of a global positioning system etc.

Classification Method used

Text description of the method used for the analysis and final delivery of digital data. Information on how the data were processed.

Field Survey date

The date that the field survey data was captured. Format of ‘DD/MM/YYYY’.

Source Material

Other source material that may have been used, references, texts etc.

Data Reduction

Description of any data reduction techniques used ie. spatial filters. The impact of the filter to be given in ‘Data Reduction Size’.

Data Reduction Size

When applying a spatial filter, record in hectares the area gained or lost due to the application of the filter.

Data availability

Access to and use of the three final data sets being produced by the project will be through a Custodianship and Data Exchange Agreement. Ownership of raw data collected as part of the project remains with the jurisdiction or agency routinely responsible for the collection and maintenance of such data.

Agriculture. Fisheries and Forestry Australia is a joint custodian of the final deliverable data sets, together with the collaborating agencies Agriculture Western Australia, South Australian Department of Environment, Heritage & Aboriginal Affairs, Department of Natural Resources Victoria, Northern Territory Department of Lands, Planning and Environment, Natural Resources Division, Primary Industries and Resources South Australia, Queensland Department of Natural Resources, Surveyor General's Department New South Wales, Tasmanian Department of Primary Industry and Fisheries and Western Australian Department of Land Administration.

The custodians are responsible for the collection, storage and maintenance of the deliverable data and authorising access, transfer and sale of the deliverable data. When the final data sets have been delivered by State and Territory agencies to the Bureau of Rural Sciences, they will be checked, validated and an independent accuracy assessment undertaken. The State and Territory data sets will be compiled to prepare national data sets showing Land Cover Change 1990–1995, 1990 Structural Vegetation and 1990 Land Cover Themes. It is proposed to make the digital data sets and their associated databases available on CD ROM through the Custodianship and Data Exchange Agreement discussed above.

Following the project's progress

The expected completion date for the project is December 1998. The project's progress can be examined on the World Wide Web at http://www.brs.gov.au/apnrb/landcov/lc_progress.html. Please note that the digital data will not be available until the project has been completed, all the data sets compiled and an independent accuracy assessment carried out.

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Appendix 1

Australian Centre for Remote Sensing (ACRES)
Processing specifications for the Agricultural land cover change project

1. Landsat Thematic Mapper data requirements

1.1. 1990 and 1995 LANDSAT TM data required.

1.2 GCPs and processing options

1.2.1 At least 1:50 000 scale maps, where available, and at most 1:100 00 scale maps will be used to control the Landsat TM data.

1.2.2 Where ACRES is supplying 1995 and 1990 data any ground control points (GCPs) used will be common to both data sets.

1.2.3 The selection of GCPs in difficult areas will be limited to ACRES normal production requirements aimed to meet the following overall requirements:

- Geometric accuracy:
  Level 9 Within 2 IFOV (60 m)
  Level 10 Within 1.5 IFOV (45 m)

- GCPs:
  A minimum of 9 well defined points where the terrain and mapping permit.

- Check GCPs:
  A minimum of 9 additional independent points on selected scenes to be assessed in a minimum of 10 percent of the products generated (approximately one per batch of 10 scenes).

- Geometric checks:
  ACRES will geometrically assess a minimum of 10 percent of the products generated for this project, being approximately one per batch. Where possible 1990 and 1995 pairs will be used.

1.2.4 Where possible the State and Territory agency can supply GICS reports/Work Order numbers, ACRES will use the GCPs supplied for the 1990 data for controlling the 1995 data. Otherwise ACRES will use its own GCPs.

1.2.5 ACRES will record in the product header/trailer the information that currently appears in the GICS report, plus the map scale used and the number of redundant points used. The geometrically checked scenes will be indicated by a coloured dot affix to the Exabyte tape.

1.2.6 No pass processing will be undertaken until the ACRES system is stable and tested, and can generate the products able to meet these specifications.

1.2.7 Resampling kernels will be selected from:

Level 4 or 5	Nearest Neighbour/DS8/Cubic Convolution
Level 8	DS16
Levels 9&10	KD16

1.2.8 TM bands: 6

1.2.9 Media: exabyte data cartridge

1.2.10 Format: BIL

1.2.11 Map system: Australian Map Grid (zone specified by each State or Territory)

1.3 DEM

1.3.1 ACRES will only use the Australian Surveying and Land Information Group (AUSLIG) 9' DEM or the DEM(s) supplied by the States to generate level 10 products. Where neither of these DEMs are available, the generation of level 10 products will be agreed on a case by case basis.

2. Further processing by the States and Territories

2.1 It is recognised by all parties that despite the ACRES processes above, it may be necessary for an image-to-image registration to be undertaken prior to any change detection to ensure pixel to pixel registration. This image-to-image registration should require no more than a block shift. If the image-to-image registration using the block shift does not result in pixel to pixel registration, then an affine transformation is recommended. If the data are still not registered pixel to pixel, the scene may be returned to AUSLIG for examination, together with the registration results. Before any data is returned it must be discussed with AUSLIG.

2.2 It is recognised by all parties that the ACRES level 10 digital product is generated using GCPs, a DEM, a satellite correction model and is resampled across track and along track in the one process. This is the most sophisticated process currently available for generating a level 10 product and aims at retaining the pixel value as close as possible to the raw data.

An equivalent level 10 digital product which has been independently produced in an Image Analysis System using the ACRES level 5 digital product as its source data undergoes two resamplings (one by ACRES and one by the user) and is likely to result in a less accurate geometric correction. However, a direct comparison of the two final products may not necessarily yield a great deal of difference, either radiometrically or geometrically.

Appendix 2

Quality Assurance Checklist

Scene Name : ______________________________

Image Date : ______________________________

Path /Row : ______________________________

Operator : ______________________________

Please note:

Grey sections must be completed!

Stage	Milestone	Process	Date Completed	Accuracy Required	Accuracy Achieved	Record
Input Data	Comparable Histograms	Check Histograms		Subject to interpretation & application		
		Radiometric Corrections				
		Histogram Matching				
Image Rectification	Image Rectified to AMG	Rectify 1995 Image		Sub pixel RMS error		
				Absolute image displacement < 100m		
Image Coregistration	1990 image registered to 1995	Coregister 1990 and 1995 images		Sub pixel RMS error		
				Relative image displacement < 1 pixel.		
Thematic Attribute Accuracy	Classification Assured	Classify Image/s Label Classification		Greater than 90% overall accuracy		
		Filter Change < Minimum Area				
	Edits Assured	Verify and edit change		Greater than 90% overall accuracy		
		Incorporate structural vegetation data				
		Incorporate land cover data				
Output Data	Completion of final data set	Run Validation AMLs		Pass all validation tests		