

Land Cover Change *in* Queensland **2001–2003**

Incorporating 2001–2002 and 2002–2003 change periods

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A Statewide Landcover and Trees Study Report

QNRM05002

This report may be cited as:

Department of Natural Resources and Mines (2004). Land cover change in Queensland 2001–2003: a Statewide Landcover and Trees Study (SLATS) Report, Feb, 2005. Department of Natural Resources and Mines, Brisbane.

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List of Acronyms

AGO	Australian Greenhouse Office
BRDF	Bi-directional Reflectance Distribution Function
CART	Classification and Regression Trees
DNR	Department of Natural Resources
DPI	Department of Primary Industries
EPA	Environmental Protection Agency
ETM+	Enhanced Thematic Mapper Plus
FPC	Foliage Projective Cover
GIS	Geographic Information System
MRVI	Multiple Regression Vegetation Index
NCAS	National Carbon Accounting System
NFI	National Forest Inventory
NR&M	Natural Resources and Mines
RE	Regional Ecosystem
SLATS	Statewide Landcover and Trees Study
TM	Thematic Mapper
UNFCCC	United Nations Framework Convention on Climate Change
USGS	United States Geological Survey
VMA	Vegetation Management Act

Section 1. Summary of Results

- The Statewide average annual tree clearing rate for the 2002–2003 period was 554,000 ha/year, 27% lower than the peak clearing rate in 1999–2000 of 758,000 ha/year.
- The average annual tree clearing rate declined following the enactment of the Vegetation Management Act (VMA) in September 2000, but has increased steadily since that time (Figure 1).
- The Statewide average annual tree clearing rate for the 2001–2003 period was 528,000 ha/year (Figure 1). This 2001–2003 clearing rate is 30% lower than the peak clearing rate of 1999–2000 of 758,000 ha/year. The 2001–2003 average annual tree clearing rate is 12% higher than the 1988–2003 (15 year) average clearing rate of 471,000 ha/year.
- Clearing of remnant woody vegetation, as defined by the Queensland Herbarium Regional Ecosystem mapping (Accad *et al.*, 2001, 2003), for the period 2002–2003 was 366,000 ha/year. This remnant clearing rate is 28% lower than the peak remnant clearing rate of 1999–2000 of 505,000 ha/year. However, there has been a steady increase in remnant clearing from 2000 to 2003 since the VMA was proclaimed (Figure 1).

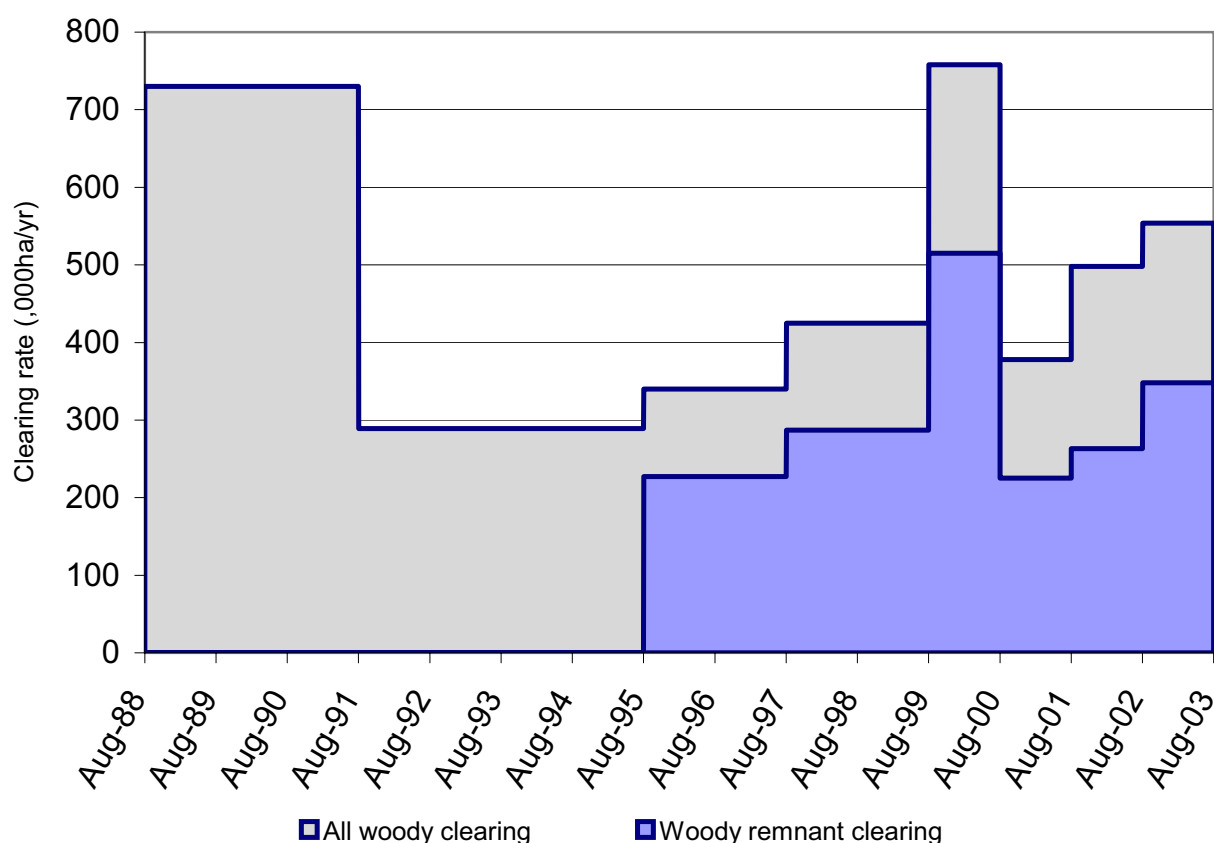


Figure 1: Annual clearing rate in Queensland (1988–2003).¹

- Since 2000, the rate of total clearing on freehold tenure has been steadily increasing. Over the same period, there has been a much smaller increase in the leasehold total clearing rate.

¹ The earliest available Regional Ecosystem remnant mapping is for 1995.

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- Clearing over the Mulga Lands Biogeographic Region has reached its highest level since SLATS monitoring began in 1988. In 2002–2003 Mulga Lands clearing reached a peak of 309,000 ha/year, which amounted to 56% of all State clearing for that period. Conversely, in 2002–2003 clearing rates in the Brigalow Belt and Desert Uplands Biogeographic Regions have reduced to their lowest reported levels since the 1995–1997 period.
 - Clearing rates in the South East Queensland and the Wet Tropics Biogeographic Regions have remained constant since the 1999–2001 period.
 - The clearing rate over the 2002–2003 period for the Queensland Murray Darling Drainage Division catchment was 371,000 ha/year. This rate is almost equal to that of the 1999–2000 clearing rate for this region (376,000 ha/year).
 - The Natural Resource Management Region with the highest clearing rate was the South West Region (42% of the state clearing), followed by the Maranoa Balonne (14%), Burdekin (11%) and Fitzroy (10%) Regions.
 - Clearing to pasture remained the single major replacement cover, making up 95% of State clearing 2001–2003 (Table 5).
 - Natural tree death was estimated to be 13,000 ha/year for 2001–2003. Eighty percent of the 2001–2003 natural tree death occurred in the Desert Uplands Biogeographic Region. Natural tree death is not included in State clearing figures.

Section 2. Background

The Statewide Landcover and Trees Study (SLATS) is a major vegetation monitoring initiative of the Queensland Department of Natural Resources and Mines (NR&M). SLATS gathers accurate woody vegetation cover and land cover change information for vegetation management planning and compliance, and for state government greenhouse gas inventory purposes. Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) satellite imagery have been used to compare the vegetation cover between 1988, 1991, 1995, 1997, 1999, 2000, 2001, 2002 and 2003, and to provide baseline land cover mapping over the entire State of Queensland for 1991.

Landsat TM and ETM+ imagery have a spatial resolution of 30 metres, enabling most areas of vegetation change (one hectare or greater) to be detected. SLATS mapping is used at the State, regional and local levels. Typically, it is used to produce maps at a scale of 1:100 000 or coarser. This study provides a consistent data set covering the entire State at a medium resolution. It is not intended to be a substitute for high resolution studies of patchy remnant bushland, which would conventionally use aerial photography. Landsat TM/ETM+ satellite imagery should be used with caution when mapping narrow vegetation corridors, such as riparian vegetation, as the resolution of the imagery may be less than the aerial extent of the vegetation to be mapped.

An analysis of 2001–2003 woody vegetation change has been completed for the entire State and is the subject of this report. Previously, imagery for the following periods has been analysed for change and reported on:

- 1988–1991 (NR&M, 2004)
- 1991–1995 (DNR, 1999B)
- 1995–1997 (DNR, 1999C)
- 1997–1999 (DNR, 2000)
- 1999–2001 (NR&M, 2003A).

For the 1999–2000 period, reports were also released outlining the clearing rates in the Murray-Darling (NR&M, 2003B), Fitzroy (NR&M, 2002), and Burdekin (NR&M, 2003C) catchments, as well as the Burnett/Mary National Action Plan (NAP) Region (NR&M, 2003D) and the Western South-East NAP Region (NR&M, 2003E).

Detailed baseline landcover mapping that discriminates areas of trees from pasture, crop, water, settlement areas etc. has been completed for the entire State using 1991 imagery. This is the first medium resolution map of woody vegetation cover for the entire State of Queensland.

While this report contains some preliminary figures on the change in area of remnant vegetation, the 2001–2003 woody change mapping and satellite imagery will be used by the Queensland Herbarium to update its Regional Ecosystem (RE) mapping (Accad *et al.*, 2003). Previously, differences between the SLATS and Queensland Herbarium remnant clearing figures have been observed. These differences are a function of what is included as clearing in each case. The SLATS figures include clearing of all remnant and non-remnant woody vegetation, where woody vegetation includes both overstorey and shrub foliage projective cover (FPC). The SLATS figures do not include modification of natural grassland ecosystems, nor detectable non-woody regions within sparse woodland communities. In contrast, the Queensland Herbarium records changes to the natural state of the RE, which includes changes to native grasslands and sparse woodlands, but does not include changes in non-remnant vegetation.

Land clearing contributes to a significant proportion of Queensland's and Australia's total greenhouse gas emissions (Henry *et al.*, 2002; AGO, 2004). As a signatory to the 1992 United Nations Framework Convention on Climate Change (UNFCCC), Australia is required to produce an

annual report of greenhouse gas emissions, including those contributed by clearing of forested land for uses such as agriculture or infrastructure. The Australian Greenhouse Office (AGO), established in 1997, is responsible for overseeing this reporting. In 1998, the National Carbon Accounting System (NCAS) was set up to improve the accuracy of Australia's estimates of greenhouse gas emissions and sinks associated with land use, land use change and forestry, including clearing of forests and woodlands for grazing and cropping (AGO, 2003).

Although the Australian Government has chosen not to ratify the Kyoto Protocol, which would introduce binding national emissions targets, the Australian Government has undertaken to use the Protocol's accounting rules for its national inventory. These rules have strict definitions for forest and for the areas to be counted as "deforestation" (conversion of forests to other land use) that are different to those for UNFCCC reporting used in the National Greenhouse Gas Inventories.

The first NCAS land use change inventory was released in August 2002 (AGO, 2002). Unlike earlier inventories that used the SLATS tree clearing figures for Queensland, the NCAS uses an independent remote sensing program to give a nationally consistent estimate of forest conversion according to the Kyoto Protocol rules. These rules restrict accounting to a subset of the SLATS broader assessment of woody vegetation change, as well as having the objective of strict calendar year change detection. The NCAS and SLATS estimates are therefore not directly comparable. The NCAS framework uses complex modelling to estimate greenhouse gas emissions and sinks for the areas included as "Kyoto lands". Queensland scientists continue to monitor international and national developments in greenhouse accounting and the implications for land management in Queensland (Burrows *et al.*, 2002).

The SLATS Advisory Committee was established to provide feedback from a wide range of stakeholders and to assist with communication of results/data to industry and the wider community. The committee provides input to SLATS with regard to overall direction and methods, and assists in the dissemination of project results. Annual meetings are held prior to the release of statistics from SLATS reports, with additional meetings as required. The Committee consists of representatives of NR&M, Department of Primary Industries (DPI), Environmental Protection Agency (EPA), Queensland Conservation Council, Brisbane Region Environment Council, Wildlife Preservation Society of Queensland, Agforce, Local Government Association, Australian Forest Growers and an Emeritus Professor from the University of Queensland's Department of Botany.

Section 3. Methods

The following description of the methods used in this study is intended to be an overview only. Scientific papers describing various aspects of the methods in greater detail are available from the SLATS web site.

There have been some significant developments in the methods since the 1999–2001 change analysis. Improvements in image rectification and enhanced understanding of geometric anomalies (Armston *et al.*, 2002) and radiometric matching (de Vries *et al.*, 2004) have also improved the basis for assessing image differences. Additionally, further development of the multiple regression based approach for mapping woody FPC has been undertaken using the more than 2000 vegetation sites throughout Queensland (Goulevitch *et al.*, 2002; Armston *et al.*, 2004; Danaher *et al.*, 2004). This has enabled further refinement and validation of the Multiple Regression Vegetation Index (MRVI), now called the SLATS Woody FPC Index.

3.1 Definition of Woody Vegetation

There are many definitions of what constitutes a forest or woody vegetation. A common definition used by foresters is 20% crown cover which equates to approximately 12% FPC (NFI, 1998). The definition of forest used in the NCAS is based on a minimum crown cover of 20%, a height of 2 m and other constraints related to the definition of forests according to the Kyoto Protocol (AGO, 2003). In contrast, SLATS maps vegetation change for all perennial woody vegetation that can be distinguished with Landsat TM/ETM+ imagery irrespective of height.

The statistics for vegetation change and woody vegetation cover quoted in this report include all woody vegetation. This includes remaining areas of native vegetation, disturbed areas of native vegetation, regrowth, plantations of native and exotic species and domestic woody vegetation. Natural tree death due to drought is not included in the clearing figures in this report. However, some preliminary figures relating to the area of natural tree death are given.

The minimum level of woody vegetation cover that can be measured using satellite imagery is partly a function of the choice of image dates. Where images are chosen in a dry season, there is good discrimination between the woody plants and grasses and it is possible to map woody vegetation with cover as low as 7%. While SLATS aims to use a constant FPC threshold definition for woody vegetation cover, if the best imagery available was acquired during a wet season characterised by green pastures, then the minimum detectable level of woody vegetation cover is more likely closer to 12% FPC. It is often possible to map clearing of vegetation with cover less than 12% using imagery with some green pasture, with additional visual interpretation and field work to maintain accuracy.

3.2 Imagery Selection and Pre-processing

Landsat–7 ETM+ and Landsat–5 TM satellite imagery was purchased from the Australian Centre for Remote Sensing (ACRES). A statewide coverage of imagery with relatively low levels of cloud cover was obtained for 2001, 2002 and 2003. The Landsat–7 ETM+ 2002 data was the last acquired by SLATS before the partial failure of the ETM+ instrument (USGS, 2003). The 2003 imagery was captured by the Landsat–5 TM instrument. Further details of the current status of the Landsat satellites is discussed in Section 3.12.

Prior to conducting change detection and mapping procedures, the imagery was geometrically corrected (Armston *et al.*, 2002). This involved the geometric registration of all scenes to an orthorectified image base. Ground control points measured in the field with differential Global

Positioning Systems (Fugro and Garmin type, with sub 10 m accuracy) were used to register the image base to map coordinates. For the 2001–2003 change period, the reference image base was changed from the 1999 to the 2002 ETM+ image mosaic. This migration resulted in significant improvements in geometric accuracy due to updated Landsat–7 ETM+ calibration parameter files and the incorporation of definitive ephemeris in the geometric preprocessing of Landsat–7 ETM+ imagery conducted by ACRES.

Imagery was corrected for relief displacement using a merged three second and nine second digital elevation model (DEM) of Queensland supplied by Geoscience Australia. The ERDAS Imagine™ 8.6 Landsat satellite model was used in the rectification. Semi-automated image correlation methods were used to register the 2001 and 2003 imagery to the 2002 rectified base. The mean RMS (root mean square) error for registering multispectral Landsat–7 ETM+ images to the base was better than 0.5 pixels.

The Landsat 2001–2003 TM/ETM+ images were radiometrically standardised. For TM imagery, this standardisation included the removal of the onboard radiometric calibration and replacement with a newly developed vicarious calibration based on a model of the lifetime response of the sensor (de Vries *et al.*, 2004). Additionally, an empirical radiometric correction was applied to both the TM and ETM+ imagery to correct for variation in solar incidence angle, solar azimuth, earth-sun distance, viewing angle, systematic atmospheric effects, and the effect of bi-directional reflectance distribution function (BRDF) of the surface measured (Danaher, 2002). Radiometric standardisation allows scene to scene matching over space and time improving mosaicing and classification development, as well as enabling the use of field data on a statewide basis, rather than on a scene by scene basis.

Landsat scenes were trimmed to standard template areas to reduce overlap. This minimises duplication of effort in processing woody vegetation change and aids in mosaicing images.

3.3 Woody Vegetation Change Detection

Improved radiometric and geometric correction procedures, along with the inclusion of additional field data, have enabled the refinement of the multiple regression based Woody FPC Index (Armston *et al.*, 2004; Danaher *et al.*, 2004). The model incorporates the field data with various reflectance bands, band interaction terms and transformations in a best-subsets multiple regression. Separate Woody FPC Indices were developed for TM and ETM+ image sequences. The resulting indices are robust throughout the State, with adjusted r^2 values of 0.82 and 0.79 for TM and ETM+, respectively. Moreover, the indices have overcome some of the previous limitations in areas of varying soil type and fire scar. The indices have been incorporated into the woody change detection procedure. In the future, these indices will be used to enhance monitoring of long-term trends in vegetation such as thinning, thickening, dieback and regrowth.

A new image classification method based on Classification and Regression Trees (CART) (Steinberg and Colla, 1995) data analysis was implemented. CART separates data into target classes by recursive binary splitting of classification nodes until a “tree” is produced. Each node is split at a value such that the deviance of the target variable is minimised. CART is a flexible classifier in that it will accept input from continuous variables (such as reflectance bands) and categorical variables (such as land cover classes). The variables chosen for the 2001–2003 change classification included a range of reflectance bands, conventional vegetation indices (eg. Normalised Difference Vegetation Index) and variables based on the Woody FPC Index. Differences in these variables between years were also used as input to the classifier. Pixel values were obtained by the operator defining areas of interest of each of the target classes (clearing, regrowth and no change).

The CART classification produced a more “refined” preliminary classification than previous change detection methods, with decreased misclassification and increased sensitivity. The superior performance of CART was particularly evident in areas of sparse or open woodlands, and marginal regrowth where the detection of change has been historically more challenging. Nevertheless, manual raster editing (recoding) of the preliminary CART classification was necessary to correct misclassification errors.

Both clearing and regrowth of woody vegetation were classified, where regrowth represented a change from non-woody to woody vegetation in the 2001–2003 period. Regrowth, however, is difficult to measure due to the relatively slow rate of growth and the low initial density of some regrowth stands. The accuracy of regrowth mapping can be quite variable from scene to scene and influenced by the amount of herbaceous vegetation present, regrowth figures were therefore not included in this report. Methods based on longer term trends are being developed to more accurately determine increases in woody vegetation over time.

Areas affected by fire have not generally been mapped as woody vegetation change. While fires can remove a significant proportion of the woody vegetation foliage it is usually a temporary effect, and in most cases the foliage on mature trees recovers quickly. SLATS site data show that on average a fire removes less than 2 m²/ha basal area (John Carter, NR&M, pers. comm.). Hence, it is not common for fire to change the landcover from woody to non-woody in a single event.

3.4 Natural Tree Death

The severity of drought during the 2001–2003 period led to extensive areas of natural tree death, particularly in the Desert Uplands Biogeographic Region. This category of tree death was included in the 2001–2003 monitoring, but areas were not included in the State statistics of woody clearing. Natural tree death amounted to 13,000 ha/year, with 80% occurring in the Desert Uplands Biogeographic Region. These figures are not included in the published tables, but are available in spreadsheet form on request. Natural tree death can be confused with tree herbicide treatment, therefore particular attention was paid to these areas in the field. Tree death related to herbicide treatment can be identified by the signs of stem injection (axe cuts in the sides of the tree) or aerial herbicide application (where all tree species, large and small are dead). Although natural tree death also occurs in localised areas, it is often related to species, local topography and geology, and it is rare for all trees in a stand to die.

Experience with previous ‘natural tree death’ events, such as those which occurred between 1991 and 1995 (DNR, 1999B), indicates that some areas of apparent tree death do recover in subsequent years. Trees that appear dead do re-sprout from the stem or base, therefore it is difficult to confirm the extent of natural tree death until later imagery (eg. 2004) is acquired and analysed to identify possible vegetation recovery. Photos of woodlands affected by natural tree death are shown in Figure 2.

3.5 Fodder Clearing

Anecdotal evidence (including field observations and an increase in permits for fodder clearing) suggests that fodder clearing was significant in the 2001–2003 period. However, it was not possible to directly map fodder clearing as a separate class using satellite imagery alone. In this report, fodder clearing is included as clearing to pasture. In future, the extent of fodder clearing during this period will be examined by the Department using geographic information system (GIS) methods (by intersecting the fodder permit areas, Local Government Area boundaries, drought declaration status and the SLATS change mapping). Examples of fodder clearing are shown in Figure 3.

3.6 Woody Thinning

Thinning (partial removal of woody vegetation) is becoming more prevalent as a method of clearing woody vegetation. Thinning is carried out for: property management (allowing pasture to grow within woodlands), weed control, rural residential development, in plantations and native forests where there has been selective logging, and certain types of fodder clearing. Examples of thinning are shown in Figure 4.

Thinning as measured by SLATS is defined as a decrease in woody vegetation at the sub pixel level (i.e. where a decrease in woody FPC has occurred but the pixel is still classified as woody). Using the SLATS change detection methods, thinning can be detected where part of the foliage cover is removed, particularly where there is soil disturbance or changes in groundcover. However, using Landsat imagery to map sub pixel change has limitations and although some of these thinned areas were field verified, thinning areas may not be as accurately mapped as other clearing categories. Hence, thinning has not been included as a separate class. Rather, it is included as clearing to pasture. The thinning rate identified for 2001–2003 was 10,000 ha/year.

Landsat TM/ETM+ satellite imagery is limited in its ability to reliably detect woody thinning using only two imagery dates. SLATS is planning to use its entire Landsat imagery time series to more accurately determine long term changes in vegetation cover such as regrowth, thinning and woodland thickening as described by Burrows *et al.* (2002). The development of methods that analyse change over the entire time series of imagery (1988–2003) are well advanced and will soon be tested in selected areas.

3.7 Replacement Landcover

Each area of clearing identified in the change analysis was assigned to one of the replacement landcover classes in Table 1. The assignment of these classes is primarily based on visual interpretation. All clearing within State Forest boundaries was coded as forest clearing. In areas where there are many different forms of land use, it is sometimes difficult to interpret the final replacement class. For example, land cleared to pasture may later be converted to urban development. The interpretation accuracy for replacement class is therefore lower than the accuracy for identification of woody vegetation change.



Figure 2: Examples of natural tree death in the Desert Uplands.



Figure 3: Examples of fodder clearing in Mulga Lands.



Figure 4: Examples of woody thinning.

Table 1: Replacement landcover classes for woody vegetation change (2001–2003).

Replacement landcover	Description
Pasture	Cleared for pasture: includes clearing for grazing, rural residential, future urban land use, native forestry on private land and privately owned plantations cleared for pasture (i.e. not replanted as plantations)
Crops	Cleared for growing crops
Forest	State forest clearing: includes plantation and native forest, and cleared private plantations which are replanted
Mining	Cleared for mining
Infrastructure	Cleared for roads, railways, water storage, etc.
Settlement	Cleared for current urban development

3.8 Validation Process

A preliminary change classification of woody vegetation change was verified in the field, focusing on areas where interpretation of change was uncertain. Typically trees killed by stem injection and thinning (such as plantation thinning and rural residential clearing involving understorey removal) cause classification uncertainty. These areas are detected in the automated change analysis but are difficult to interpret without field work.

Field verification was carried out over 56 of the 87 scenes analysed. These scenes accounted for more than 99% of the overall change in the State. The primary purpose of the field checks was to verify the 2001–2003 change analysis. Information on the method of change and the amount of coarse woody debris remaining after clearing were also gathered. Data logged at each site included the accuracy of the classification, the method of clearing used, a visual estimate of the percentage of cleared timber removed or decayed, the replacement land-cover, the maturity of timber cleared, the presence of regrowth, the original species, the current species, soil colour and the presence of termites and fire. A digital photograph was taken at each site. Many of these observations will be used for further site revisits during the next era of change classification.

Data were also gathered at previously visited field sites. These revisited sites are primarily used to collect data on timber decay rates, regrowth rates and regrowth clearing across the State. These data are yet to be analysed or reported.

The preliminary change classification was corrected based on the field observations. This involved editing and recoding areas of uncertainty and misclassified change to the field verified status. The edited classification was then closely peer-reviewed by those with first hand field knowledge. Once finalised, the classification was then further cross-checked by a third party. These two levels of checking ensure data consistency and quality across all scenes in the study.

Two final filters were applied to the corrected classification. The first removed areas mapped as clearing that were not woody at the earlier date. This filter applied a woody mask threshold based on the Woody FPC Index. The second filter removed clumps of two pixels (1250 m²) or less. This reduced the “speckle” effect in the classification, and was necessary due to residual scene misregistration (Armston *et al.*, 2002).

3.9 Compilation of Statewide Data Sets

Large, seamless mosaics of 2001–2003 vegetation change, landcover and vegetation cover were created by joining the 87 scenes covering the State of Queensland. When producing these mosaics, the scenes were overlapped in paths from south to north and paths were joined from west to east with the most recent image on top.

In order to calculate annual tree clearing rates, a vector GIS layer containing the extent and dates of each change raster in the mosaic was created. The mosaic raster of cleared areas was intersected with GIS overlays (including date, tenure type, 30' x 30' grid cell and catchments) to generate tabular statistics. For the 2001–2003 analysis, many new or revised data sets were used. These included new boundaries for updated tenure and Version 4 (2004) RE mapping.

A 100 m grid was used for the 2001–2003 analysis in the same manner as described in the 1999–2001 and 1988–1991 SLATS reports (NR&M, 2003A, 2004). Figures for 1991–1995, 1995–1997 and 1997–1999 were based on 1 km grids. These figures have been recalculated using the 100 m grid and are available in spreadsheet form only. They will be slightly different from those previously published.

In response to user needs, woody vegetation cover statistics are now reported. These figures are based on the 1991 land cover and vegetation cover mapping described by Kuhnell *et al.* (1998) and updated using the various change analyses from 1991 to 2001. When calculating woody vegetation cover statistics the unclassified areas were included as woody areas. They are mostly the result of shadowing and typically occur in steep, densely vegetated areas.

All statistics were generated based on an Albers equal-area projection, so that clearing rates for different regions are comparable. All the vegetation change statistics in this report have been converted to annual rates to account for the variation in scene dates. The units of clearing rate used in the tables are thousands of ha/year (,000 ha/year) not km²/year as used in some early reports. One thousand ha/year is equal to 10 km²/year.

It is important to note that the tabular statistics derived from the intersection of these data show slightly different State clearing totals due to the different scales of the GIS overlays used.

The vegetation change data from this report were used to update the 1991 landcover and vegetation cover data.

3.10 Accuracy of Interpretation

The traditional form of accuracy assessment uses an independent data source of higher resolution, but this is not always possible. While many change areas on each scene are checked in the field, access and cost limit the extent of this checking to a representative sample. The aerial photography coverage available does not usually align with the same dates of the satellite imagery, so in most cases it is not a viable option and other alternatives need to be considered.

An initial accuracy assessment based on scene overlaps of the 1991–1995 and 1995–1997 change periods was done. The north-south and east-west overlaps of the satellite scenes provided two measures of vegetation change. After analysing the change data for these overlaps, it was considered that the error term on the statewide clearing figures was approximately $\pm 8\%$ at a 95% confidence interval. In fact, the error term should be better than this, as the east-west scene overlaps used in this assessment contain some real change, due to path date differences.

A formal accuracy assessment of a Landsat TM vegetation change analysis was done as part of the national Remote Sensing of Agricultural Land Cover Change project (Barson *et al.*, 2000). It used independent methods rather than independent data to assess the accuracy of the land cover change analysis provided to BRS during this project. NR&M was a partner in this project and was responsible for providing the 1991–1995 change data for Queensland. The accuracy assessment showed that a high proportion of the individual sub-sample results were not significantly different at the 95% confidence level from the SLATS estimates of change for the scene and therefore no Queensland scenes required re-processing for BRS. The 1995–1997, 1997–1999, 1999–2001 and 2001–2003 change analyses were done with similar methods and by many of the same operators so similar or better accuracy could be expected.

An extensive amount of work has gone into ensuring the quality of the change analysis. The satellite imagery was selected at dates which maximise discrimination between grass and woody vegetation layers. Fully documented procedures have been developed to analyse the data. These are available to SLATS scientists on the project's intranet to ensure consistency between operators. Many of the procedures have been scripted with error traps to avoid errors and log files to allow errors to be traced. This change detection method offers the advantages of both automated and visual methods, with two independent checks ensuring a high level of accuracy and consistency.

Hence, it seems the largest source of variation is not misclassification of change, but determining the extent (area) of change at a clearing location. The woody vegetation mask is very important for determining the area of vegetation change, as it delineates how much woody vegetation existed before clearing. Considerable effort has gone into ensuring that the woody vegetation mask and Woody FPC Index are well calibrated to ground vegetation measurements. The extensive ground vegetation measurements and the improved radiometric correction methods used ensure that these layers are well matched across scene boundaries (Armston *et al.*, 2004). Further validation of the Woody FPC Index is planned using laser scanner data currently being collected.

3.11 Independent Science Quality Review

An independent panel consisting of Emeritus Prof. Henry Nix (Australian National University), Assoc. Prof. Stuart Phinn (University of Queensland), Dr Alex Held (Head, Commonwealth Scientific and Industrial Research Organisation Office of Spatial Science and Applications) and Mr Peter Woodgate (Chief Executive Officer, Cooperative Research Centre for Spatial Information) reviewed the research and management of remote sensing science within NR&M in 2004. Their brief was to review the quality of research, methods, relevance, quality and processes of remote sensing applications. SLATS was a major focus of the review.

The review panel '*was unanimous in judging that this research was of international standard and that it deserves an international science profile. Clearly, the researchers are meeting the highest standards*'.

The review panel also concluded '*that SLATS has progressively demonstrated an increasing and broadening usefulness and a consistently timely relevance for its primary and secondary users. Its shift from greenhouse monitoring to other areas of application is a clear demonstration of the ability of SLATS to evolve and maintain relevance*'.

3.12 Future SLATS Reporting

This report covers the period 2001–2003. Images from 2001, 2002 and 2003 were analysed, therefore a combination of statistics for both the yearly and two yearly periods are given.

Future SLATS reports will cover periods of one year. It is expected that the first of the yearly reports, covering 2003–2004, will be published in late 2005. The 2004 Landsat TM imagery for this study has already been acquired and analysis of this imagery is in progress.

One of the risks associated with completing the 2004–2005 change analysis on time is the availability of satellite imagery. In May 2003 a partial failure of the ETM+ instrument on the Landsat–7 satellite resulted in large areas of missing data within the ETM+ images (USGS, 2003). The Landsat–5 satellite acquiring TM imagery is over 20 years old and while still functioning it could fail at any time. A replacement Landsat satellite is not scheduled for launch until late 2009 (Irons & Ochs, 2004). The SLATS team is evaluating all options to replace Landsat–5 imagery should it fail. The implication of a failure of Landsat–5 is that there may be a period of delay in the analysis of vegetation change as new methods for a different sensor are implemented. The cost of the replacement imagery is likely to be much higher than current TM/ETM+ prices.

Section 4. Statewide Assessment of Woody Vegetation Change

4.1 Woody Vegetation Change by 30'x30' Grid Cell

The average annual clearing rate over the period 2001–2003 was calculated to be 528,000 ha/year or 0.30% of the land area of Queensland per year. In total, this clearing rate represents an area of 73 km by 73 km cleared in one year.

Using SLATS woody vegetation cover mapping based on 30 m resolution imagery, it was estimated that the area of wooded vegetation in Queensland was 80 million hectares in 2003. The 2001–2003 annual clearing rate represents 0.65% of this wooded area per year.

A spatial view of the rate of clearing (,000 ha/year) within Queensland in 30' x 30' (latitude/longitude) grid cells is shown in Figure 5 for 2001-2002 and in Figure 6 for 2002-2003. These cells are approximately the same size as a 1:100 000 map sheet. Figure 7 illustrates the rate of clearing for each of the periods where SLATS has analysed vegetation change.

The distribution of woody vegetation cover in Queensland at 2003 is shown in Figure 8. This map was created by using the 1991 baseline landcover mapping (Kuhnell *et al.*, 1998) produced by SLATS and updated with the vegetation change mapping. The update procedure only includes changes resulting from the clearing of woody vegetation and does not include, for example, change of grassland to crop. Care should be taken when interpreting Figure 8 as the areas mapped as pasture include both natural grasslands and areas cleared to pasture. There are significant areas of natural grassland in Queensland, such as the extensive Mitchell Grass plains which never contained woody vegetation such as trees and shrubs during this period.

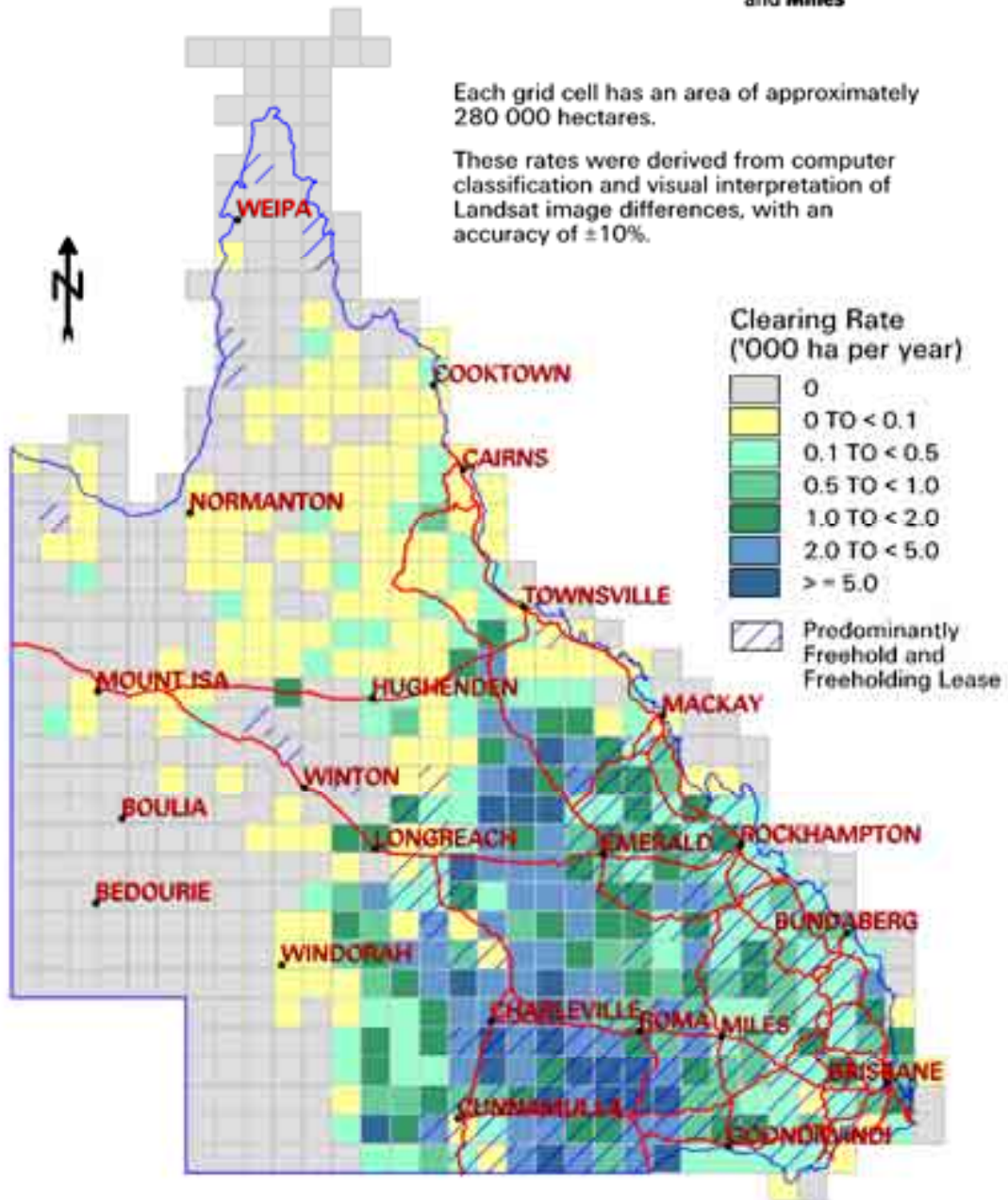
Detailed landcover data updated to 2003, along with other SLATS data is available from NR&M upon request.

QUEENSLAND
CLEARING RATE ('000 HECTARES PER YEAR)
BY 30' X 30' (LAT/LONG) GRID CELL

2001-2002



Queensland
Government
Natural Resources
and Mines



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Figure 5: Average annual clearing rate (2001–2002).