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SLATS 2004–2005

Land Cover Change in Queensland 2004–2005

A Statewide Landcover and Trees Study Report

Queensland the Smart State

Queensland Government
Natural Resources and Water

Land Cover Change in Queensland 2004–2005

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A Statewide Landcover and Trees Study Report

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List of Acronyms

ACRES Australian Centre for Remote Sensing
AVHRR Advanced Very High Resolution Radiometer
BA Basal area (in m^2/ha)
AGO Australian Greenhouse Office
BRDF Bi-directional Reflectance Distribution Function
DEM Digital Elevation Model
DNR Department of Natural Resources
DNR&M Department of Natural Resources and Mines
DNR&W Department of Natural Resources and Water
DPI&F Department of Primary Industries and Fisheries
EPA Environmental Protection Agency
ETM+ Enhanced Thematic Mapper Plus
FPC Foliage Projective Cover
GIS Geographic Information System
MGA Map Grid of Australia
NCAS National Carbon Accounting System
NFI National Forest Inventory
NHT National Heritage Trust
NRW Department of Natural Resources and Water
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

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Section 1. Summary of Results

- The Statewide average annual woody vegetation clearing rate for the 2004–2005 period was 351,000 ha/year. This is 54% lower than the peak measured woody vegetation clearing rate in 1999–2000 of 758,000 ha/year and 27% lower than the previous period (2003–2004) of 482,000 ha/year (Figure 1, this page).
- Clearing of remnant *woody* vegetation, as defined by the Queensland Herbarium Regional Ecosystem mapping (Accad *et al.,* 2006 (based on 2003 data)), for the period 2004–2005 was 172,000 ha/year. This remnant woody clearing rate is 66% lower than the peak remnant clearing rate of 1999–2000 of 505,000 ha/year (Figure 1).
- Remnant woody clearing in 2004–2005 amounted to 49% of total woody vegetation clearing. The average remnant woody proportion of clearing prior to commencement of the Vegetation Management Act (the period 1995–2000) was 67%, and since then (the period 2000–2004) the average proportion of remnant woody clearing has reduced to 56% of total woody vegetation clearing (see Table 4 on page 20).

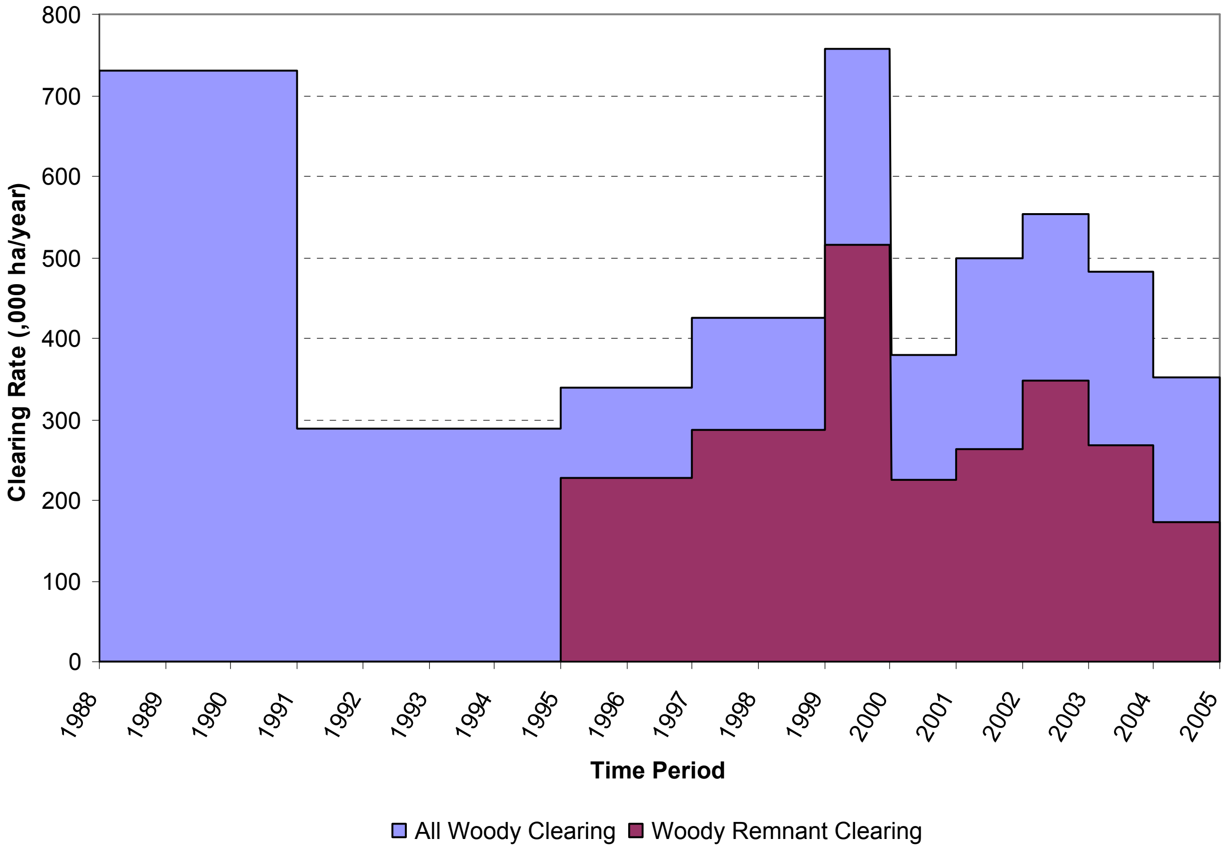

Figure 1: Annual woody vegetation clearing rate in Queensland (1988–2005).[1]

- Figure 10 on page 21 shows that woody vegetation clearing on freehold tenure is responsible for most of the volatility in clearing rates through reporting periods. The rate of woody vegetation clearing on leasehold tenure has fluctuated far less than that on freehold since 1995.
- For 2004–2005, 43% of the State woody vegetation clearing was on leasehold land and 55% was on freehold land (Table 6 on page 23).
- Clearing to pasture remained the single major replacement cover, making up 94% of State woody vegetation clearing for 2004–2005 (Table 7 on page 24). Notably, clearing for crop is now less than for all other replacement classes.

[1] The earliest available Regional Ecosystem remnant mapping is for 1995

- The biogeographic region with the highest woody vegetation clearing rate for 2004–2005 was the Brigalow Belt, with 143,000 ha/year, or 41% of all State woody vegetation clearing for the period, followed by the Mulga Lands, with 36% of State woody vegetation clearing (Table 10 on page 39). Woody vegetation clearing in the Desert Uplands bioregion has been declining since 1999–2000 and is now at its lowest reported level of 20,600 ha/year (Figure 23 on page 38).
- The increasing woody vegetation clearing rate for the South East Queensland bioregion has continued. South East Queensland biogeographic region now ranks third in terms of woody vegetation clearing rate, after the Brigalow Belt and the Mulga Lands.
- In 2001–2003 the biogeographic region with the highest woody vegetation clearing rate was the Mulga Lands. Compared to the peak woody vegetation clearing rate during 2002–2003 (partly attributed to fodder tree clearing in drought), Mulga Lands woody vegetation clearing continued to decrease in 2004–2005 (Figure 23 on page 38).
- The Queensland Murray Darling was the Drainage Division with the highest 2004–2005 woody vegetation clearing rate, with 183,000 ha/year or 52% of state woody vegetation clearing (Table 13 on page 55). However, this represents a 27% decrease on the previous year. Gulf Rivers was the only Drainage Division that saw increased woody vegetation clearing to 14,900 ha/year (Figure 26 on page 54).
- For 2004–2005 the National Heritage Trust Natural Resource Management Region with the highest woody vegetation clearing rate was the South West Region (35% of the State woody vegetation clearing), followed by Fitzroy (14%), the Maranoa Balonne (14%) and Desert Channels (9%) (Table 17 on page 77).

Section 2. Background

The Statewide Landcover and Trees Study (SLATS) is a major vegetation monitoring initiative of the Queensland Department of Natural Resources and Water (NRW). 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 from 1988 to 2005 (see Table 1), and to provide baseline land cover mapping over the entire State of Queensland as at 1991. Satellite images used in this report were captured during the period from June–October 2004 and from May–October 2005.

SLATS mapping is used at the State, regional and local levels, and having a spatial resolution of 30 metres is typically used to produce maps at a scale of 1:100 000 or coarser. SLATS provides a consistent data set covering the entire State at a medium resolution. This mapping is not intended to be a substitute for high resolution studies of riparian vegetation or small patches of remnant bushland, that would conventionally use high resolution satellite imagery or aerial photography. Landsat reliably maps areas of woody vegetation change of one hectare or greater. However the image resolution of 30 metres could limit its suitability for mapping narrow vegetation corridors, such as riparian vegetation.

This report gives statistics on woody vegetation clearing *rates*, expressed as thousands of hectares cleared per year. Quoting rates of clearing instead of actual areas of clearing allows for comparison of change over time. To give areas of actual clearing would be misleading because variations in the satellite overpass scene dates give periods which may be significantly longer or shorter than a year, therefore cannot be compared from year to year. In practice, to capture suitable cloud-free Landsat satellite images for the entire state each year in the preferred season (winter), a range of satellite overpass dates are acquired, covering a period of up to five months (typically June to October). Since 1999, imagery has been acquired each year and analysed to derive statistics. For the period 1988–1999, the time periods for reporting varied from two to four years (see Table 1 below), however the statistics are still calculated as yearly clearing rates for consistent comparison, as can be seen in Figure 1 on page 1.

Table 1: Imagery source and data resolution of SLATS reports.

Reporting Period	Satellite and sensor source	Resolution (pixel size)	
		Imagery used	Statistics calculations
1988–1991 (DNR&M, 2004)	Landsat–5 TM	30m (resampled to 25m)	100m
1991–1995 (DNR, 1999b)	“	“	1km
1995–1997 (DNR, 1999c)	“	“	“
1997–1999 (DNR, 2000)	Landsat–5 TM and Landsat–7 ETM+	“	“
1999–2001 (DNR&M, 2003a)	Landsat–7 ETM+	“	100m
2001–2003 (DNR&M, 2005)	Landsat–7 ETM+ and Landsat–5 TM	”	“
2003–2004 (DNR&M, 2006)	Landsat–5 TM	“	25m
2004–2005 (DNR&W, 2007)	Landsat–5 TM	“	25m

Statistics for 2003–2005 in this report have been produced using full resolution datasets (resampled to 25m resolution), thereby giving slightly higher accuracy. Statistics from 1988–2003 in this report are based on the generalised 100m resolution as provided in previous reports.

While this report contains figures on the change in area of remnant vegetation, this refers to change in *woody* remnant vegetation only. The Queensland Herbarium reports on all *(woody and non-woody)* changes to remnant status as part of its Regional Ecosystem (RE) mapping program (Accad *et al.,* 2006).

The following supplementary reports have also been produced:

- 1999–2000 clearing in the Murray-Darling (DNR&M, 2003b), Fitzroy (DNR&M, 2002), Burdekin (DNR&M, 2003c) catchments, and the Burnett/Mary National Action Plan (NAP) Region (DNR&M, 2003d) and the Western South-East National Action Plan (NAP) Region (DNR&M, 2003e).
- 2001–2003, 2003–2004 and 2004–2005 clearing in each of the NHT Natural Resource Management Regions.

Detailed baseline landcover mapping that discriminates areas of trees from pasture, crop, water, settlement and other areas has been completed for the entire State using 1991 imagery, referred to as the 1991 baseline Landcover mapping. This was the first medium resolution map of woody vegetation cover for the entire State of Queensland. However for more recent mapping of *landuse*, it is recommend that mapping from the Queensland Land Use Mapping Project (QLUMP) be used (Witte *et al.,* 2006).

Land clearing in Queensland contributed to a significant proportion of Queensland's and Australia's total greenhouse gas emissions (Henry *et al.,* 2002; DEH, 2006). 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 legally binding national emissions targets, the Australian Government has undertaken to meet its target under the Protocol. The accounting rules have strict definitions for forest and for the areas to be counted as "deforestation" (direct human-induced conversion of forests to other non-forest land use). Whereas SLATS reports all areas of land where loss of perennial woody vegetation can confidently be identified using Landsat imagery, the NCAS reports a subset of this total area that meets the definitional and reporting rules for national greenhouse inventory reporting (DEH 2006; Macintosh 2007).

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; Henry *et al*., 2005).

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 just prior to the release of statistics from SLATS reports, with additional meetings as required. The Committee consists of representatives of NRW, Department of Primary Industries and Fisheries (DPI&F), 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 provide an overview only. Scientific papers describing various aspects of the methods in greater detail are available from the SLATS web site www.nrw.qld.gov.au/slats.

Image analysis methods used to map woody vegetation and change have advanced significantly from early SLATS reports. Improvements in image rectification and the understanding of geometric anomalies (Armston *et al.,* 2002) and radiometric matching (de Vries *et al.,* 2007) have enhanced the basis for assessing image differences. Further development of the method for mapping woody FPC (foliage projective cover) has been undertaken using more than 2000 vegetation sites throughout Queensland (Danaher *et al.,* 2004; Lucas *et al.,* 2005). This has enabled further refinement and validation of the SLATS Woody FPC Index, denoted as V2.0. Additionally, a new method of mapping woody vegetation change was developed for the 2003–2004 period, and continues to be used for the 2004–2005 period.

3.1 Definition of Woody Vegetation

Statistics for clearing rates and woody vegetation cover quoted in this report refer to *woody* vegetation. This includes stands of native vegetation, disturbed areas of native vegetation, regrowth, plantations of native and exotic species, some woody weeds and urban woody vegetation.

There are many definitions of what constitutes a forest or woody vegetation. A common definition used by foresters is where the tree crowns cover greater than 20% of the ground area (20% crown cover). Preliminary SLATS research suggests that this equates to 10% FPC on average. 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 tree height.

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. If the best imagery available was acquired during a wet season characterised by green pastures, then the discrimination degrades and the minimum detectable level of woody vegetation cover will be higher. The method used by SLATS to map FPC and change in woody vegetation, now uses the time series of Landsat TM and ETM+ imagery from 1988–2005. This method accounts for variation such as wet season imagery and enables consistent mapping of woody vegetation at 2004, to a minimum threshold of approximately 8% FPC.

The minimum level of vegetation mapped as change in woody vegetation in 2004–2005 also depends on the conditions at the time of the 2004 and 2005 satellite imagery data capture. Green pastures are spectrally similar to woody areas, making separation of woody from non-woody cover more difficult in open woodland. It may not be possible to detect change in vegetation with FPC less than 10% using automated processing. However, it is often possible to map clearing of vegetation with cover less than 10% FPC using imagery with some green pasture, with additional visual interpretation and field work to maintain accuracy.

3.2 Imagery Selection and Pre-processing for 2004–2005

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 2004 and 2005. Landsat–5 TM imagery was the best available Landsat imagery for SLATS purposes since the partial failure of the ETM+ instrument on Landsat–7 (USGS, 2003). 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) are used to register the image base to Map Grid of Australia (MGA) coordinates. For the 2001–2003 and later change periods, 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™ ver 8.7 Landsat satellite model was used in the rectification. Semi-automated image correlation methods were used to register the 2004 and 2005 imagery to the 2002 rectified base. The mean RMS (root mean square) error for registering multispectral Landsat–5 TM images to the base was less than 0.5 pixels.

Radiometric standardisation was then applied to the Landsat 2004–2005 TM images. This 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.,* 2007). Additionally, an empirical radiometric correction was applied 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, and enabling the use of statewide field data for time-series analysis.

Cloud and smoke contamination in the imagery was masked to exclude these areas so that woody FPC and woody vegetation change models are not affected (Kitchen & Gillingham, 2006). Landsat scenes were trimmed to standard template areas to reduce overlap. This minimises duplication in the overlap areas and allows standard mosaic procedures.

3.3 Woody Vegetation Change Detection

The method for mapping woody vegetation change that was developed for the 2003–2004 period (DNR&M, 2006) has again been used for the 2004–2005 period. This method will be fully described in a separate publication. Briefly, it consists of an initial transformation of the data followed by a non-parametric classifier. Verified rasters from previous change periods are used to train the model. This model includes the six spectral bands and past change rasters, together with the time series of Woody FPC values for the entire SLATS Landsat TM/ETM+ dataset from 1987/88 to the present. This yields an index of change, which is then classified in conjunction with multitemporal statistics and Woody FPC difference to give a "probability of woody vegetation change" raster, which is then classified by the analyst. This change detection method has significantly improved efficiency.

Similar to the method presented in the 2001–2003 and 2003–2004 reports, the focus of this method is on detecting and mapping decreases in woody vegetation (clearing) for 2004–2005. Regrowth is difficult to measure over a one year period due to the relatively slow rate of growth and the low initial density of some regrowth stands. Methods suitable for measuring longer term trends are being developed to more accurately determine increases in woody vegetation over time. Longer term woody vegetation change will be the subject of a separate report.

Areas affected by fire only have not 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 m^2/ha basal area (John Carter, DNR&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

During 2004–2005 very little natural tree death was mapped (131 ha/year, or less than 0.05% of Queensland clearing). Photos of woodlands affected by natural tree death are shown in Figure 2 on page 9. These areas mapped as natural tree death are not included in calculating woody vegetation clearing rates in this report.

3.5 Fodder Clearing

Anecdotal evidence (including field observations and an increase in permits for fodder clearing) suggests that clearing for animal fodder was significant in the 2004–2005 period. However, it is not possible to directly and consistently map fodder clearing as a separate class using satellite imagery alone because it may appear similar to certain other types of broadscale clearing. Although some areas of fodder clearing were identified in the field, these areas have been included as clearing to pasture. Examples of fodder clearing are shown in Figure 3 on page 9.

3.6 Woody Thinning

Thinning (partial removal of woody vegetation) is becoming more prevalent as a method of clearing. Thinning is carried out for: property management (allowing pasture to grow within woodlands); weed control; rural residential development; and 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 on page 9.

Thinning as measured by SLATS is defined as a decrease in woody vegetation FPC at the sub-pixel level (i.e. where a decrease in woody FPC has occurred but the pixel may still be 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, thinned 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 in the total figure for clearing to pasture. The statewide thinning rate identified for 2004–2005 was 1,360 ha/year, less than 1% of total State clearing.

Landsat TM 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 (1988–2005) are being tested in selected areas.

3.7 Replacement Landcover

Each area of woody vegetation clearing identified in the change analysis was assigned to one of the replacement landcover classes in Table 2. The assignment of these classes is primarily based on visual interpretation. All woody vegetation 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.

Table 2: Replacement landcover classes for woody vegetation change.

Replacement landcover	Description
Pasture	Cleared for pasture: includes woody vegetation clearing for grazing, woody thinning, fodder clearing, rural residential, future urban land use and privately owned plantations cleared for pasture (i.e. not replanted as plantations)
Crops	Cleared for growing crops
Forest	Forestry clearing: includes all woody vegetation clearing within State Forests, 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 imminent urban development

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

Figure 3: Examples of clearing for fodder in Mulga Lands.

Figure 4: Examples of woody thinning.

3.8 Validation Process

A preliminary classification of woody vegetation clearing 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 because the woody foliage cover is not fully removed. These areas are detected in the automated change analysis but are difficult to interpret without field inspection.

Field verification of woody vegetation clearing on representative samples was carried out on 48 of the 87 scenes analysed. These 48 scenes accounted for more than 99% of the total detected woody vegetation clearing in the State. The primary purpose of the field checks was to verify the 2004–2005 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 are used for further site revisits during the next era of change classification.

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

The preliminary woody vegetation change classification was corrected based on the field observations. This involved editing and recoding areas of uncertainty and misclassified vegetation change to the field verified status. The edited classification was then thoroughly peer-reviewed by those with first hand field knowledge. Once finalised, the classification was then cross-checked by a third party. These two levels of checking ensure data consistency and quality across all scenes in the study. External clients such as the Queensland Herbarium scrutinise the change data very closely for incorporation in their Regional Ecosystem mapping (Accad *et al.,* 2006), and also provide feedback to SLATS on accuracy and errors.

Two final filters were applied to the corrected classification. The first removed areas mapped as clearing that were not woody in 2004. This filter applied a woody mask threshold based on the Woody FPC Index V2.0. The second filter removed clumps of two pixels (0.125 ha) 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 2004–2005 woody vegetation change and FPC cover for 2004 were created by joining the 87 scenes covering the State of Queensland, where each scene was trimmed to the standard scene template to minimise overlap. When producing these mosaics, the scenes were overlapped in paths from south to north and paths were joined from west to east.

In order to calculate annual woody vegetation clearing rates, a vector geographic information system (GIS) layer containing the extent and dates of each individual scene change raster in the mosaic was created. The mosaic raster of cleared areas was intersected with GIS overlays (including, for example, date, tenure type, 7.5'x7.5' grid cell and catchments) to generate tabular statistics. For the 2004–2005 analysis, revised GIS data sets were used as required, including updated land tenure and Version 5 (2003) Regional Ecosystem mapping.

Woody vegetation clearing rate statistics for 2004–2005 were calculated using full resolution data (25m pixels), with GIS intersections using vector (not raster) data. This was done to give higher accuracy statistics. In contrast, statistics for the periods 1988–2003 were calculated using a 1km and 100m grid, as described in previous reports and summarised in Table 1 on page 3. These statistics for 1988–2003 may be recalculated at full 25m resolution in future reports, which may result in minor changes to previously published figures.

This report includes statistics on woody vegetation extent for 2004. These figures are based on the newly developed Woody FPC (V2.0) model derived using the time series of all satellite imagery from 1988 to 2004 (Danaher *et al.,* 2004; Lucas *et al.,* 2005). This method is more accurate than previous, as it minimises the effects of short term greening, drought, and seasonal variation.

All statistics were generated based on data rectified to an Albers equal-area projection, so that woody vegetation 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 km^2/year as used in some of the earlier reports. One thousand ha/year is equal to 10 km^2/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.

3.10 Accuracy of Interpretation

The traditional form of accuracy assessment uses an independent data source of higher resolution for validation, but this is not always feasible. 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 capture dates of the satellite imagery, so in most cases validation using aerial photography is not a viable option and other alternatives need to be considered.

An initial accuracy assessment (unpublished) 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 ±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 the Bureau of Resource Sciences (BRS) during this project. DNR&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, 2001–2003, 2003–2004 and 2004–2005 change analyses were undertaken using similar methods and by many of the same operators, so similar or better accuracy could be expected.

Extensive work has gone into ensuring the integrity of the change analysis. The satellite imagery was selected at dates which maximise discrimination between grass and woody vegetation layers. Procedures to analyse the data have been comprehensively documented and 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 occurring 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.

The largest limitation of the current method lies not in misclassification of change, but in 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 V2.0 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.,* 2004a). Further validation of the Woody FPC Index is in progress, in which the laser scanner data and site measurements are being analysed.

All SLATS woody vegetation change detection data is available at nominal cost. SLATS methods are published at conferences and in peer-reviewed journals (see bibliography), ensuring transparency and accountability.

3.11 Independent Science Quality Review

An independent panel of academic, CSIRO and industry members, 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 praised the quality of SLATS research and science and suggested that SLATS research be published in refereed publications. This is now being done, e.g. Lucas *et al.,* 2006; de Vries *et al.,* 2007; Armston *et al.,* 2007. Several more scientific papers are being prepared for publication.

3.12 Future SLATS Reporting

Although Landsat–5 imagery has been acquired for the 2005–2006 period, one of the risks associated with continuity of the woody vegetation change analysis 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 ensuing ETM+ images (USGS, 2003). Landsat–5 is still acquiring TM imagery, however it is over 22 years old and becoming less reliable. In November 2005 and March 2006 Landsat–5 was temporarily removed from service to investigate problems, creating a gap in its data acquisition, but later put back into service when problems were resolved. This gap did not affect the SLATS program.

A replacement Landsat satellite is planned but is not likely to be launched until 2011. The SLATS team is evaluating all options to replace Landsat–5 imagery should it fail. The use of Landsat composite imagery has been identified as one possible replacement. This product is a combination of several overpasses of the satellite to fill in the data gaps inherent in a single Landsat–7 image since its instrument failure. This option will impact least on costs and reporting timeliness. The implication of a failure of Landsat–5 is that there may be a period of delay in the analysis of woody 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 Landsat TM prices.