

# **Land Cover Change in Queensland 1988 – 1991**

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Natural Resource Sciences  
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## Summary of Results

- The Statewide average annual clearing rate for the 1988-1991 period was 730,000 ha/year. Compared to the period from 1988 to 2001, this rate is 58 percent higher than the thirteen year average of 462,000 ha/year. It is also 153 percent higher than the 1991-1995 average rate of 289,000 ha/year, and 27 percent higher than the average annual clearing rate for 1999-2001 (see Figure 1).

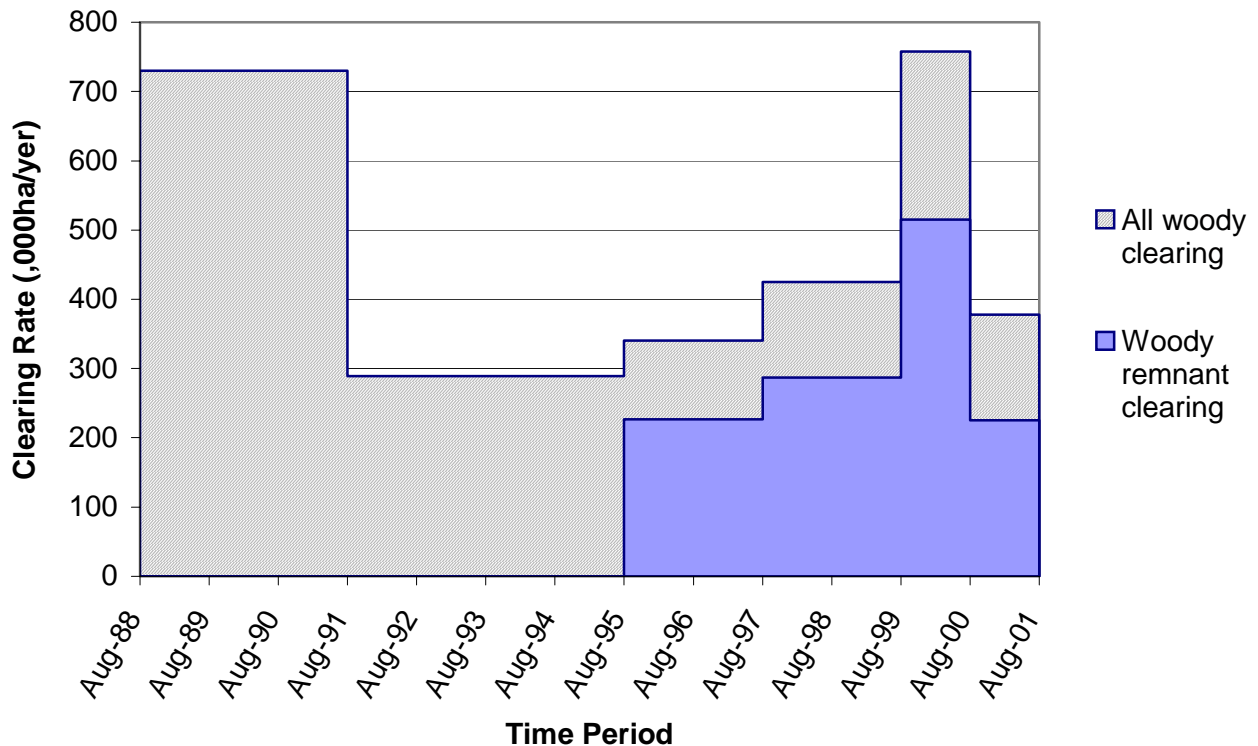


Figure 1: Annual Clearing Rate in Queensland from 1988-2001 <sup>1</sup>

- For the 1988-1991 period 53 percent of clearing occurred on leasehold tenure and 46 percent occurred on freehold tenure. This proportion is similar to the 1991-1995 and 2000-2001 periods but is in contrast to the 1995-1997, 1997-1999 and 1999-2000 periods where the majority of clearing occurred on freehold tenure.
- The area of remnant vegetation cleared in the 1988-1991 period cannot be calculated since the earliest version of remnant mapping available is 1995. However, a visual analysis done by the Statewide Landcover and Trees Study (SLATS) scientists using satellite imagery indicates that approximately 34 percent of clearing in that period was young or immature vegetation. This is a similar proportion to the non-remnant clearing proportions for periods between 1995 and 2000, which ranged between 32 and 33 percent.
- During the period 1988-1991, 89 percent of woody vegetation change was due to clearing for pasture, 8 percent for crop, and the remaining 3 percent for forest, mining, infrastructure and settlement (see Figure 9 on page 22).

<sup>1</sup> Earliest Remnant mapping available is for 1995.

- The Brigalow belt is the biogeographic region with the largest percentage of Queensland's clearing, containing 62 percent of the total 1988-1991 clearing. Clearing in the Mulga lands accounted for a further 17 percent and clearing in the Desert Uplands 6 percent of the State total.
- Approximately 82 percent of the 1988-1991 Statewide clearing occurred in three major river catchments. The Queensland Murray-Darling catchment contained 37 percent, the Burdekin 24 percent and the Fitzroy contained 21 percent of the Statewide total clearing rate.
- The statewide distribution of clearing is shown in Figure 2 on page 14. The clearing is widespread with the highest concentration of clearing in the area north west of Emerald containing the Suttor River, Belyando River and Mistake Creek catchments.

## Background

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 greenhouse gas research purposes. Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper (ETM+) satellite imagery have been used to compare the vegetation cover between 1988, 1991, 1995, 1997, 1999, 2000 and 2001, and to provide baseline landcover mapping over the entire State of Queensland for 1991. The Landsat TM imagery has 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 but it is typically used to produce maps at a scale of 1:100 000 or smaller. This study provides a consistent data set covering the entire State at a medium resolution, but it is not intended to be a substitute for high resolution studies of patchy remnant bushland which would conventionally use aerial photography. Landsat TM 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 areal extent of the vegetation to be mapped.

An analysis of 1988-1991 woody vegetation change has been completed for the entire State and is the subject of this report. Imagery for the 1991-1995, 1995-1997, 1997-1999 and 1999-2001 periods have previously been analysed for vegetation change and reported (DNR, 1999B, 1999C, 2000A, NR&M, 2003).

There are some differences between SLATS clearing statistics and the Queensland Herbarium Regional Ecosystem clearing statistics. These differences exist primarily because SLATS maps woody vegetation measured as overstorey and shrub foliage projective cover. Hence, SLATS figures include clearing of non-remnant vegetation and do not include the modification of grasslands nor the gaps in sparse woodland canopies in areas being modified.

In contrast, the Queensland Herbarium records changes in Regional Ecosystems, i.e. change (conversion) of native vegetation, which includes grassland and sparse woodland but excludes changes in non-remnant vegetation.

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

Land clearing contributes a significant proportion of Queensland's and Australia's total greenhouse gas emissions (Henry *et al.* 2002). As a signatory to the 1992 United Nations Framework

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

Although Australia made a commitment not to ratify the Kyoto Protocol, it undertook to use the Kyoto accounting rules for its national inventory. These rules have strict definitions for forest and for areas to be counted as "deforestation" (conversion of forests to other land use) that are different to those used in National Greenhouse Gas Inventories (NGGIs) reported prior to 2002.

The first NCAS land use change inventory was released in August 2002. Unlike earlier inventories that used remotely sensed areas of tree clearing from SLATS figures for Queensland, the NCAS uses an independent remote sensing program to give a nationally consistent estimate of forest conversion according to Kyoto 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, so that the two estimates are 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 contribute to the scientific understanding of the carbon stock change associated with the woody vegetation cover change assessed by SLATS and collaborative work through the Co-operative Research Centre (CRC) for Greenhouse Accounting (Henry *et al.* 2002, Burrows *et al.* 2002).

A project advisory committee was established to provide feedback from a wide range of stakeholders and assist with communication to industry and the wider community. The committee provides input with regard to overall direction and methods, and assists in the dissemination of project results. It meets annually and prior to the release of statistics from SLATS reports. The committee consists of representatives of NR&M, Department of Primary Industries (DPI), Environment Protection Agency (EPA), Queensland Conservation Council, Brisbane Region Environment Council, Wildlife Preservation Society of Queensland, Agforce, Canegrowers Association, Local Government Association, Australian Forest Growers and Emeritus Professor of the University of Queensland Department of Botany.

## **Methods**

The following description of the methods used in this study is intended to be an overview only. There are scientific papers available from the SLATS web site [www.nrm.qld.gov.au/slats/](http://www.nrm.qld.gov.au/slats/) that describe aspects of the methods in greater detail.

### **Definition of Woody Vegetation**

There are many definitions of what constitutes a forest or woody vegetation. A common definition used by foresters is 20 percent crown cover and at least two metres height. This is also the definition of forest used in the Australian Greenhouse Office, National Carbon Accounting System.

In contrast, SLATS maps vegetation based on the foliage projective cover (FPC) of vegetation including all perennial woody plants of all sizes that can be distinguished with Landsat TM imagery. Hence, 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.

The minimum level of woody vegetation FPC that can be measured using satellite imagery is partly a function of the choice of image dates, but is usually less than 12 percent FPC. 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 seven percent. If the imagery was acquired during a wet season with greener grasses, then it is more likely that the minimum level of woody vegetation cover detected is 12 percent FPC. It is often possible to map clearing of vegetation with cover less than 12 percent using imagery with some green pasture, but additional visual interpretation and fieldwork is required to maintain accuracy.

There is no direct conversion between crown cover and FPC measurements as the relationship varies with vegetation type and structure, both of which vary with location in Queensland. For a typical open woodland in Queensland, 20 percent crown cover would be approximately 12 percent FPC. However, within Queensland, vegetation of 20% crown cover could possibly range in FPC from 10 to 15 percent.

### **Imagery Selection and Pre-processing**

Landsat5 TM satellite imagery was purchased from the Australian Centre for Remote Sensing. In most cases 1988 imagery was used for the earlier date. There were four scenes without suitable 1988 images so 1987 dates were used for Cairns, Ingham, Princess Charlotte Bay and Thursday Island. The second image date for change analysis was 1991 except for six Cape York scenes which were selected from 1990 imagery. The satellite imagery used was acquired over the period April to October with most images acquired during July-September. Winter months are most suitable because they show maximum discrimination between woody and non-woody vegetation.

Imagery must undergo several pre-processing steps prior to use in change detection and mapping procedures. The imagery is first corrected for variation in solar zenith angle and then standardised for atmospheric variations between dates by radiometrically registering all dates to a reference year. Corrections are applied to improve scene to scene matching along each path, and an across-scene correction is also applied (Danaher, 2002).

Geometric correction involved registration of all scenes to the 1991 reference year. Semi-automated image correlation methods were used to register imagery to better than 0.4 pixels root mean square error. The majority of subsequent processing used these registered images. To enable rectification of change detection classifications, vegetation mapping and other products, scene to map transformations were calculated. Preliminary transformations were generated using ground control points identified on 1:100 000 and 1:250 000 scale topographic maps. The accuracy of these points was upgraded in the field using differential global positioning systems (Fugro and Garmin type, with sub 10m accuracy) to maintain a constant spatial accuracy of at least 1:100 000 scale (Kuhnell *et al.* 1998 and Armston *et al.* 2002).

## Woody Vegetation Change Detection

Vegetation change has been mapped using classification procedures similar to those described by Paudyal *et al.* (1997) and Wedderburn-Bisshop *et al.* (2002). The methodology was based on a hierarchical decision tree classification of a “difference” image. This three layer image consisted of the difference between the 1988 and 1991 images of the Normalised Difference Vegetation Index (NDVI), Landsat TM band 5 and Landsat TM band 2.

Simple thresholds in each difference band were used to define clearing and regrowth similar to a parallelepiped classifier. Manual raster editing (recoding) of this classification was often necessary to account for the classifier’s inability to adequately isolate woody vegetation change using thresholds alone. The extent of visual editing was largely determined by the availability of suitable quality imagery. Where possible, dry season imagery was chosen to maximise discrimination between grasses and the woody component of the vegetation. Field validation observations of the 1988-1991 change classification were undertaken during the 1997-1999 and 1999-2001 field trips. Any observed differences were incorporated in the final change raster.

A woody index mask was created for each image which was used to spectrally update the change classification, thereby ensuring all pixels mapped as clearing were defined as woody in the 1988 image.

This was achieved by creating a 1988 woody cover (FPC) image for each Map Grid of Australia 1994 (MGA94) zone using the entire State site data (1,915 sites) and any additional non-wooded signatures gathered. Once a suitable 1988 FPC image was created for the zonal mosaic, then for each scene, a simple thresholding approach was used to determine the 1988 woody/non-woody index mask, which was applied to remove non-woody pixels the 1988-1991 change image.

Finally, the change classification for each scene was checked by two independent operators.

Both clearing and regrowth of woody vegetation were classified. Regrowth was more difficult to measure due to slow rates of change (relative to clearing) and the low initial density of some regrowth stands. The “new woody regrowth” figures included in the tables are regrowth generation, i.e. areas which have changed from non-woody to woody within the 1988-1991 period. SLATS has not yet attempted to use Landsat imagery to map long term changes in vegetation cover such as the woodland thickening described by Burrows *et al.* (2002). Landsat TM satellite imagery is also limited in its ability to reliably detect woody thinning using automated methods.

Areas affected by fire have not been mapped as 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<sup>2</sup>/ha basal area (NR&M, unpublished data). Hence it is not common for fire to change the landcover from woody to non-woody in a single event.

In the 1995-1997 SLATS study (DNR, 1999C), significant areas of natural tree death were reported but not included in the total clearing rates. For the 1988-1991 period, no instances of natural tree death were observed.

## Identification of Regrowth Clearing

Image interpreters are often able to discern visual differences on the satellite image between mature forest/woodland, and regrowth forest/woodland. This interpretation is primarily based on the context of mature vegetation in areas surrounding clearing. For the 1988 to 1991 period, interpreters coded clearing into several categories of replacement land cover which included classes for both regrowth and mature growth clearing.

## Replacement Landcover

Every patch identified in the change analysis as clearing was assigned one of the replacement landcover classes in Table 1. The assignment of these classes is primarily based on visual interpretation. State forest boundaries are used to ensure that native forest clearing within State Forest is allocated to the forestry land use class. In areas where there are many different forms of land use, it is sometimes difficult to interpret the correct replacement class. Sometimes land is cleared to pasture then later converted to urban development. These factors will cause the interpretation accuracy for replacement class to be lower than the accuracy for identification of woody vegetation change.

**Table 1: Replacement landcover classes for 1988-91 woody vegetation change**

Replacement land cover or land use	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 including plantation and native forest; cleared private plantations which are replanted
Mining	Cleared for mining
Infrastructure	Cleared for roads (including on-farm tracks), railways, water storage
Settlement	Cleared for current urban development

## Compilation of Statewide Data Sets

Large, seamless mosaics of 1988-1991 vegetation change, landcover and vegetation cover were created by joining together 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 last image on top.

In order to calculate annual tree clearing rates, a vector geographic information system (GIS) layer containing the extent and dates of the mosaiced scenes was created. The mosaic raster of cleared areas was intersected with GIS overlays depicting date, tenure type, 30' x 30' grid cell, catchments etc. in order to generate tabular statistics. For the 1988-1991 analysis, many of the new or revised data sets that were used in 1999-2001 analysis were again used. These included, new boundaries for Local Government Areas, biogeographic regions and sub-regions (previously provinces), finer

resolution catchments, regional vegetation management planning boundaries, updated tenure, and EPA Version 3 1999 Regional Ecosystem Mapping.

In some earlier SLATS studies, a one kilometre grid cell resolution was used to intersect these layers with the change analysis. This was appropriate at the time given the scale of most of the input data and the efficiency of computation. However, with the inclusion of data sets such as the finer resolution catchments, it was necessary to increase the resolution used. Therefore a 100 metre grid was used for the 1999-2001 and 1988-1991 analyses. The change in grid resolution to 100 metres will produce slightly different figures for polygon areas and change than the 1 km grid. Differences will be most noticeable where figures are for smaller polygons. Statistics for larger polygons and state figures will not be affected. The periods 1991-1995, 1995-1997 and 1997-1999 were analysed using the one km grid.

There are also differences between this and previous reports due to changes in the statistical reporting themes. There are continual changes to land tenure, biogeographic regions and sub-regions, local authority boundaries and occasional changes to the catchment and sub-catchment divisions. To overcome these problems and the change in grid cell size used in the analysis, all change periods from 1988 to 2001 are being re-analysed using the new boundaries and 100 metre grid resolution and will be provided in spreadsheet form.

The LGA polygon areas in this report differ from previous reports. In previous SLATS reports the areas reported in the tables were administrative areas which included considerable areas of ocean and reef for some coastal LGAs. In this report the areas shown are the land area of LGAs.

Several of the tables have slightly different totals for a given theme of interest. Differences occur when data of differing resolutions are combined and as a result small areas remain unclassified. For example, there will be slightly different clearing area figures for each catchment when comparing the tenure analysis to the biogeographic sub-region for that catchment. These differences are expected given the range in resolution from 1:100,00 to 1:5,000,000 scale. Most of the differences occur along the coastline. For statistical reporting, these differences are insignificant. All SLATS source data and rasters as supplied to clients retain the full data accuracy.

The 1988-1991 analysis also includes the additional cross tabulation figures for tenure by catchment and tenure by biogeographic subregion that were included in the 1999-2001 report. This report also includes woody vegetation cover statistics. These figures are based on the 1991 land cover and vegetation cover mapping described by Kuhnell *et al.* (1998) and Goulevitch *et al.* (2002). The 1991 baseline has been updated to the 1988 woody cover by adding the 1988-1991 change. When calculating woody vegetation cover statistics the unclassified areas were counted as woody areas. They are mostly the result of shadowing and typically occur in steep densely vegetated areas.

It is important to note that all statistics were generated based on an Albers equal-area projection, so clearing rates for different regions could be compared; and 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 now thousands of hectares per year (,000 ha/year) not the km<sup>2</sup>/year used in earlier SLATS reports. The km<sup>2</sup>/year figures in earlier reports can be converted to ,000 ha/year by dividing by 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 some change areas on each scene are checked in the field,

access and cost limit the extent of this checking to a representative sample only. 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 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  $\pm 8$  percent at a 95 percent 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 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 percent confidence level from the NR&M estimates of change for the scene and therefore no Queensland scenes required re-processing for BRS. The 1995-1997, 1997-1999, 1999-2001 and 1988-1991 change analyses were done with similar methods and by many of the same operators so similar accuracy could be expected.

While doing fieldwork to check the 1997-1999 and 1999-2001 change periods, a number of sites identified as being 1988-1991 clearing were checked. Of the 319 sites checked a total of six were incorrectly classified, a two percent misclassification rate. The reasons for misclassification were; images with green pasture, clearing of only understorey vegetation, clearing of sparse vegetation where change was most likely due to change in ground cover.

An extensive amount of work went into ensuring the quality of the change analysis. The satellite imagery was selected at dates which maximise discrimination between the grass and woody layers. Fully documented procedures were developed to analyse the data and these are available to SLATS scientists on the project intranet. Many of the procedures were scripted with error traps to avoid errors and log files to allow errors to be traced. The change detection method used offers the advantage of automated and visual interpretation methods combined with independent checks. Initially, a preliminary change analysis is carried out followed by field checking. Following fieldwork, the incorrect areas are rejected, and if necessary, areas of change are added. When these changes are complete the analysis is then checked by another two team members to ensure a high level of accuracy and consistency.

Potentially, 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 FPC layer are well calibrated to ground vegetation measurements. These ground vegetation measurements and the radiometric correction methods used ensure the FPC layer is well matched across scene boundaries. This process ensures a high level of accuracy and consistency in the change area measurements.

# Statewide Assessment of Woody Vegetation Change

## Woody Vegetation Change by 30'x30' Grid Cell

The average annual clearing rate over the period 1988-1991 was calculated to be 730,000 hectares per year or 0.42 percent of the land area of Queensland per year. In total, the annual clearing rate represents an area of 85 km by 85 km cleared per year.

Using SLATS woody vegetation cover mapping based on 30 metre Landsat TM imagery it was estimated that the area of wooded vegetation in Queensland was 86 million hectares in 1988. Hence, the 1988-1991 annual clearing rate is 0.84 percent of this wooded area per year.

A spatial view of where clearing occurred from 1988-1991 within Queensland is shown in Figure 2 representing the rate of clearing (,000 ha/year) per 30' x 30' (latitude/longitude) grid cell. These 30' x 30' cells are the same size as a 1:100,000 map sheet. Figure 3 shows similar maps for all the time periods where SLATS has analysed vegetation change.

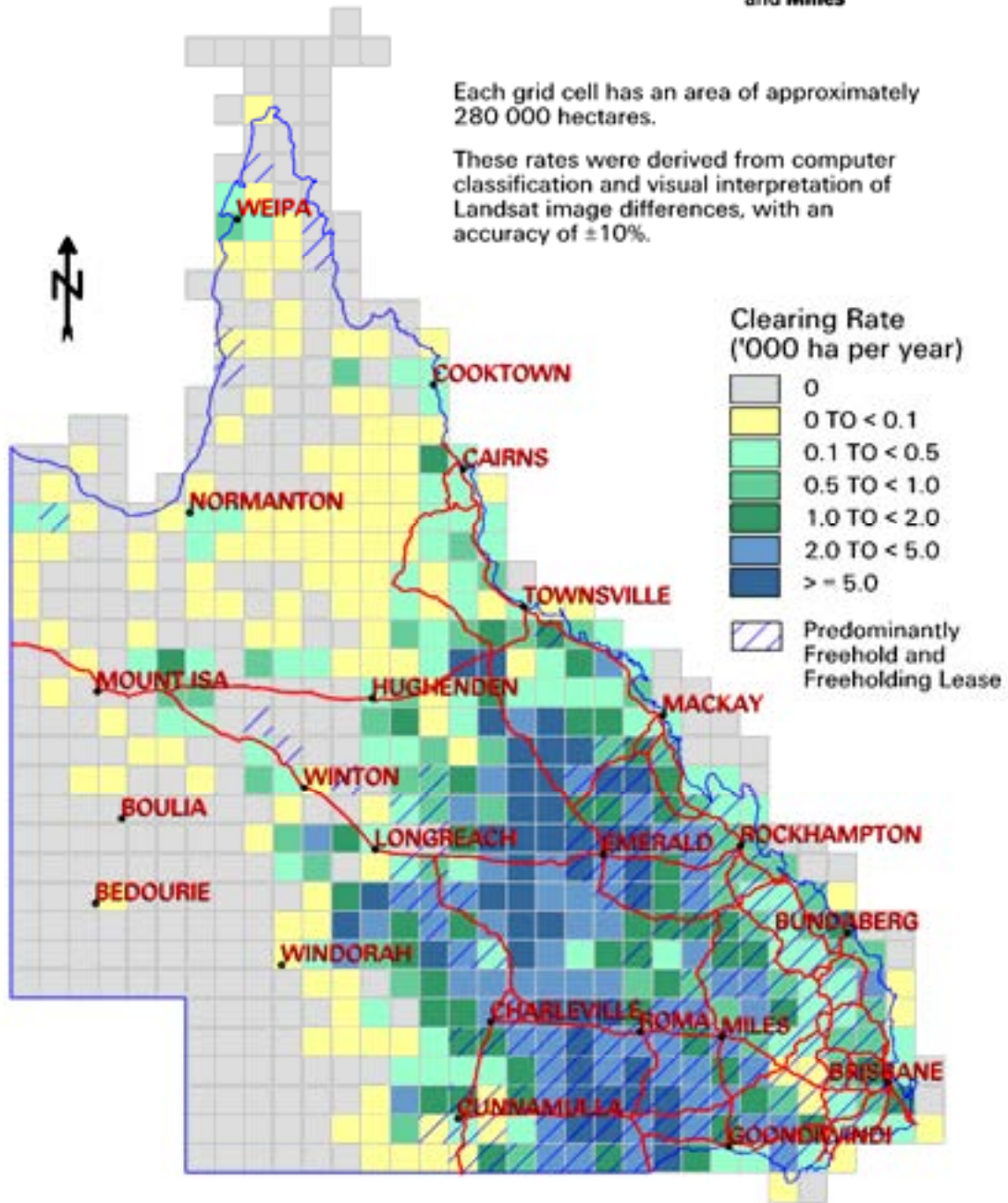
A more detailed map of the distribution of 1988-1991 clearing in Queensland is shown in Figure 4. It shows the clearing rate for each one km by one km grid cell. Due to the scale of this mapping some smaller areas of clearing may not be shown.

The distribution of remaining woody vegetation cover in Queensland at 1991 is shown in Figure 5. This map was created by using the 1991 baseline landcover mapping (Kuhnell *et al.* 1998) produced by SLATS. Please take care when interpreting Figure 5 as the areas mapped as pasture include both natural grasslands and cleared areas. 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.

# QUEENSLAND

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

1988-1991



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Figure 2: Average annual clearing rate (1988–1991)