Department of Science, Information Technology and Innovation

# Land cover change in Queensland 2014–15

## Statewide Landcover and Trees Study Report

Queensland Government

**Prepared by**

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# List of acronyms

| | |
|---|---|
| DERM | Department of Environment and Resource Management |
| DNRM | Department of Natural Resources and Mines |
| DSITI | Department of Science, Information Technology and Innovation |
| ETM+ | Enhanced Thematic Mapper Plus |
| FPC | Foliage Projective Cover |
| GBR | Great Barrier Reef |
| GIS | Geographic Information System |
| HVR | High-Value Regrowth |
| JRSRP | Joint Remote Sensing Research Program |
| LiDAR | Light Detection and Ranging |
| NVIS | National Vegetation Information System |
| OLI | Operational Land Imager |
| RSC | Remote Sensing Centre |
| SLC-off | Scan Line Corrector-off |
| SLATS | Statewide Landcover and Trees Study |
| TM | Thematic Mapper |
| USGS | United States Geological Survey |
| VMA | *Vegetation Management Act 1999* |

# Summary of results

***Statewide woody vegetation clearing for 2014–15***

- In 2014–15, the total statewide woody vegetation clearing rate was 296 000* hectares per year (ha/year), similar to the 2013–14 woody vegetation clearing rate of 295 000 ha/year (Figure 1, below).
- In 2014–15, clearing of remnant woody vegetation increased to 114 000 ha/year (38% of total statewide woody vegetation clearing) from 100 000 ha/year in 2013–14 (34% of total statewide woody vegetation clearing) (Figure 1, below and Table 5, page 21).
- Remnant woody vegetation clearing in the state has increased from 22% of total statewide woody vegetation clearing in 2011–12 to 38% of total statewide woody vegetation clearing in 2014–15 (Figure 1, below and Table 5, page 21).
- In 2014–15, the clearing rate of non-remnant woody vegetation in the state was 182 000 ha/year (Figure 1, below and Table 5, page 21).
- In 2014–15, 29% of the mapped woody vegetation clearing had previously been cleared one or more times since 1988 (Table 10, page 34).

* Clearing rates are rounded to the nearest 1000 ha/year and percentages rounded to the nearest whole percentage.

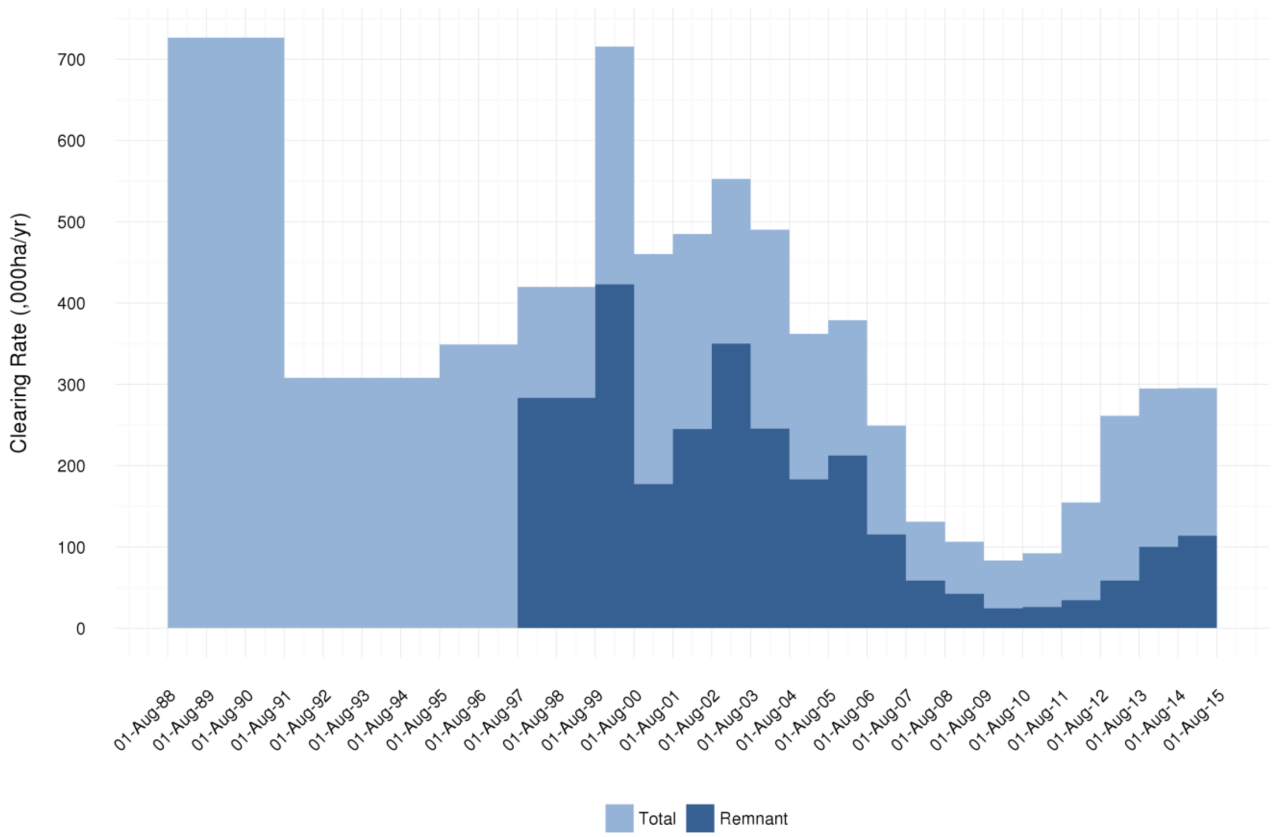



**Figure 1: Annual woody vegetation clearing rate in Queensland (1988–2015)[1]**

[1] Remnant vegetation mapping is based on regional ecosystems mapping and is available from 1997 onwards. Refer to Table 3, page 18 for details.

***Woody vegetation clearing analysis***

- In 2014–15, 91% of the total statewide woody vegetation clearing was replaced with pasture. The remaining 9% was replaced by crop, forestry, mining, infrastructure or settlement (Table 4, page 21).
- In 2014–15, the biogeographic region with the highest woody vegetation clearing rate was the Brigalow Belt with 130 000 ha/year (Table 6, page 23). This compares to a similar woody vegetation clearing rate of 132 000 ha/year in 2013–14.
- In 2014–15, the second highest woody vegetation clearing rate occurred in the Mulga Lands biogeographic region with 65 000 ha/year (Table 6, page 23). This represented a 40% decrease from the 2013–14 woody vegetation clearing rate of 108 000 ha/year.
- Woody vegetation clearing rates changed significantly in the Gulf Plains biogeographic region (18 000 ha/year in 2014–15 compared to 4 000 ha/year in 2013–14), and in the Mitchell Grass Downs biogeographic region (26 000 ha/year in 2014–15 compared to 14 000 ha/year in 2013–14).
- In 2014–15, the Murray-Darling drainage division had the highest woody vegetation clearing rate of all of the state's major drainage divisions (119 000 ha/year) (Table 7, page 25). This represented a 22% decrease from 153 000 ha/year in 2013–14.
- The North East Coast drainage division had the second highest woody vegetation clearing rate of 115 000 ha/year in 2014–15 (Table 7, page 25). This was similar to the woody vegetation clearing rate of 111 000 ha/year in 2013–14.
- Woody vegetation clearing rates changed significantly in the Gulf Rivers drainage division (21 000 ha/year in 2014–15 compared to 7 000 ha/year in 2013–14), and in the Lake Eyre drainage division (38 000 ha/year in 2014–15 compared to 20 000 ha/year in 2013–14).
- In 2014–15, the Great Barrier Reef (GBR) catchments had a total woody vegetation clearing rate of 108 000 ha/year. This was similar to the woody vegetation clearing rate of 105 000 ha/year in 2013–14 (Table 8, page 27). The GBR catchments are a subset of the North East Coast drainage division, indicated by the purple outline in Figure 8 on page 29.
- Since 2011–12, the rate of clearing of woody vegetation in the GBR catchments has increased by 46%, but as a percentage of total statewide woody vegetation clearing, it has fallen from 48% in 2011–12 to 37% in 2014–15 (Table 8, page 27).

# 1 Introduction

## 1.1 Background

The Statewide Landcover and Trees Study (SLATS) is a vegetation monitoring initiative of the Queensland Government, undertaken by the Remote Sensing Centre (RSC) in the Department of Science, Information Technology and Innovation (DSITI). It supports the *Vegetation Management Act 1999* (VMA), which is administered by the Department of Natural Resources and Mines (DNRM).

### 1.1.1 Legislative framework for the Statewide Landcover and Trees Study

The VMA was introduced in 2000 to regulate the clearing of native vegetation in order to conserve remnant vegetation, prevent land degradation and the loss of biodiversity, maintain ecological processes, reduce greenhouse gas emissions and allow for sustainable land use.

In December 2013, the legislative framework for the VMA was amended. The changes that affect the assessable nature of native woody vegetation clearing include:

- removal of the restrictions of clearing high-value regrowth (HVR) on freehold tenures
- creation of a statewide regulated vegetation management map
- introduction of 15 self-assessable vegetation clearing codes to allow landholders to clear vegetation for particular purposes in accordance with the conditions of the code
- introduction of permits for high-value agriculture or irrigated high-value agriculture activities.

### 1.1.2 Objectives of the Statewide Landcover and Trees Study

The study monitors woody vegetation loss using a combination of automated and manual mapping techniques, primarily based on Landsat satellite imagery and supported by ancillary data sources.

The primary objective of the study is to map the location and extent of woody vegetation clearing that is the result of anthropogenic (i.e. human) removal of vegetation across the entire state of Queensland to support the vegetation management framework. These mapping data are used to update regional ecosystem mapping and to assess compliance of land management activities with the vegetation management framework under the VMA, and to inform vegetation management policy formulation.

These data are also used to inform a range of other land management policies and reporting initiatives in Queensland such as protection and management of the Great Barrier Reef, State of Environment reporting, and biodiversity conservation and planning.

### 1.1.3 SLATS reporting

SLATS reports are generally produced annually, providing an analysis of the total woody vegetation clearing rate across the state. To streamline the 2014–15 SLATS report, a number of revisions have been made. For instance, some regional summaries of woody vegetation clearing have been omitted (e.g. local government area, Carnahan class and native pasture communities), as well as the reporting of catchments and biogeographic sub-regions. These summaries will now be published as open data in spreadsheet format (refer to Section 5, page 38 for details about how to access these summaries). Further, analysis and reporting of tenure and HVR has not been provided in this report. These are reported within DNRM’s supplementary report to the 2014–15 SLATS report.

Key reporting statistics included in this report are:

- statewide woody vegetation clearing rates for the reporting period and in the context of historical woody vegetation clearing rates
- statewide woody vegetation clearing rates by:
  - replacement land cover
  - remnant status
- woody vegetation clearing rates summarised for different reporting regions including:
  - biogeographic regions
  - drainage divisions
  - Great Barrier Reef (GBR) catchments

#### 1.1.4 SLATS final report 2014–15

This report comprises the full statewide analysis of annual woody vegetation clearing rates for 2014–15, and is based on the mapping methodology described in Section 2 on page 7. An executive summary also accompanies this report and can be found at http://www.qld.gov.au/environment/land/vegetation/mapping/slats/.

## 1.2 Definitions and terms used in this report

#### 1.2.1 Woody plants

A *woody plant* is a plant that produces wood as its primary structural tissue. Woody plants may be trees, shrubs or lianas and are usually perennial.

#### 1.2.2 Foliage Projective Cover

*Foliage Projective Cover (FPC)* is defined as the fraction of ground covered by the vertical projection of photosynthetic foliage of all strata (Specht, 1983). FPC is a metric that is used in remote sensing (i.e. satellite-based monitoring) as a direct estimate of the foliage (or leaves) on vegetation when viewed (vertically or near-vertically) from above, as is the perspective of the satellite. Herein, FPC refers to the foliage of woody plants only and is expressed as a percentage where: 0% FPC implies there is no woody plant foliage cover; and, 100% FPC implies total or complete woody plant foliage cover.

SLATS uses the FPC metric, applied to Landsat satellite imagery, in three ways:

i. As an input to the woody clearing index to reduce the amount of non-woody changes detected due to fluctuations in herbaceous and grass cover, rather than woody vegetation (refer to *FPC Index* in Figure 2 on page 8 and Section 2.3.1 on page 10, for more detail).

ii. To derive an estimate of the extent of woody vegetation in different regions in order to provide context for the rate of woody vegetation clearing in those regions, relative to the total woody vegetation extent (refer to *Landsat Woody Vegetation Extent – Queensland 2014* in Figure 2 on page 8 and Section 2.6.1 on page 14, for more detail).

iii. To provide an estimate about the ranges of tree and shrub densities that are represented in the mapped woody vegetation clearing (refer to *Landsat Foliage Projective Cover – Queensland 2014* in Figure 2 on page 8 and Section 2.6.1 on page 14, for more detail).

#### 1.2.3 Woody vegetation clearing

*Woody vegetation clearing* refers to the anthropogenic (i.e. human) removal or destruction of woody vegetation. SLATS mapping of woody vegetation clearing is limited to those areas which can be reliably identified and mapped using Landsat satellite imagery and other available information, including field data and high resolution airborne and satellite imagery. Further details about the scope of the mapping undertaken by SLATS are provided in Section 1.3 (page 6).

SLATS maps woody vegetation clearing in the National Vegetation Information System (NVIS) structural formation classes of 'open woodland'/'open shrubland' to 'closed forest'/'closed shrubland' (ESCAVI, 2003) provided the tree/shrub density is sufficient to reliably determine that an observed change was due to woody plant removal (Table 1 below).

**Table 1: Extract from National Vegetation Information System (NVIS) Framework Structural Formation Standards used to classify Australian vegetation by cover and height classes (ESCAVI, 2003). Scarth et al. (2008a) was used to estimate the FPC equivalent of the crown cover classes described by NVIS. SLATS maps woody vegetation clearing in 'open woodland'/'open shrubland' and denser.**

| FPC Equivalent | > 0 | 0 – 3 | < 11 | 11 – 27 | 27 – 45 | > 45 |
|---|---|---|---|---|---|---|
| Tree | Isolated trees | Isolated clumps of trees | Open woodland | Woodland | Open forest | Closed forest |
| Shrub | Isolated shrubs | Isolated clumps of shrubs | Sparse shrubland | Open shrubland | Shrubland | Closed shrubland |

### 1.2.4 Remnant vegetation

The VMA defines remnant vegetation as;

"*vegetation –*

*(a) that is –*

- (i) *an endangered regional ecosystem; or*
- (ii) *an of concern regional ecosystem; or*
- (iii) *a least concern regional ecosystem; and*

*(b) forming the predominant canopy of the vegetation –*

- (i) *covering more than 50% of the undisturbed predominant canopy; and*
- (ii) *averaging more than 70% of the vegetation's undisturbed height; and*
- (iii) *composed of species characteristic of the vegetation's undisturbed predominant canopy."(Vegetation Management Act 1999 p159)*

An undisturbed stratum (or layer) is defined as one that shows no evidence of extensive mechanical or chemical disturbance, such as logging, clearing or poisoning, during field inspections or on the available historical aerial photographic record. This definition of remnant vegetation includes woody vegetation, non-woody vegetation such as grasses, and areas of remnant vegetation as defined by the regional ecosystem mapping (Queensland Herbarium, 2015). Accad and Neldner (2015) provide a comprehensive report for regional ecosystems (woody and non-woody remnant vegetation) from 1997 to 2013.

### 1.2.5 Woody thinning

Under the VMA, thinning is defined as the selective clearing of vegetation at a locality to restore a regional ecosystem to the floristic composition and range of densities typical of the regional ecosystem surrounding that locality. It does not include clearing using a chain or cable linked between two tractors, bulldozers or other vehicles. For the purposes of this report, thinning is simply defined as the partial removal of woody vegetation.

Thinning, as measured by SLATS, is defined as a decrease in FPC. This is where a decrease in the FPC index has occurred, but the pixel is still classified as woody. In reality, the decrease may be at a sub-pixel scale; however, using the SLATS change detection method, thinning can be detected where part of the foliage cover is removed, particularly where there is also soil disturbance or a change in ground cover.

However, using Landsat imagery to map sub-pixel change has limitations. Hence thinning has not been included as a separate class, but included in the total figure for clearing to pasture.

## 1.3 Scope

SLATS monitoring is limited to the detection of woody vegetation loss in Queensland which can be reliably mapped using Landsat satellite imagery and all other available information including field data and high resolution airborne and satellite imagery. Vegetation and land cover changes that are not included in the scope of SLATS are outlined below.

### 1.3.1 Land use and land use change

Land use and land use change are not mapped by SLATS. SLATS does report on the replacement land cover where woody vegetation clearing has been mapped (refer to Section 2.3.3 on page 13). Comprehensive mapping of land use and land use change in Queensland is undertaken by the Queensland Land Use Mapping Program (QLUMP) (https://www.qld.gov.au/environment/land/vegetation/mapping/qlump/).

### 1.3.2 Fire

SLATS does not map areas affected directly by fire. For the purposes of woody vegetation clearing mapping, fire-affected areas are assumed to be temporary, non-anthropogenic changes in woody vegetation. DSITI maps and publishes annual fire scar mapping composites for Queensland based on Landsat satellite imagery. More information can be found at https://www.qld.gov.au/environment/land/vegetation/mapping/firescar/.

### 1.3.3 Natural tree death and natural disaster damage

SLATS does not include any vegetation loss caused by natural tree death or natural disasters (e.g. cyclone) when calculating woody vegetation clearing rates in this report. Refer to Section 3.1.2 on page 19 for discussion on results.

# 2 Methods

A schematic representation of the SLATS methodology is shown in Figure 2 on page 8. The methodology involves a number of automated and manual processing steps, with quality control checking and review stages. These steps are described in detail in the following sub-sections, and are summarised as follows:

1. Landsat imagery is acquired, corrected for topographic effects and sun and sensor viewing angles, and the most cloud-free images from the dry season images are selected.
2. A woody vegetation clearing index is calculated, to detect areas of change which represent possible clearing of woody vegetation. This model has been calibrated using historic mapping of cleared areas, and highlights all the possible clearing and omits areas which are almost certain not to represent clearing.
3. This initial clearing index is visually inspected, and manually edited by trained remote sensing scientists to confirm areas which are clearing, and remove areas which are not. This manual process makes use of any additional information available to aid decisions.
4. Senior SLATS remote sensing scientists review the manual editing, so that mapped clearing has generally been visually checked and verified by a minimum of two staff.
5. Further edits and quality control checks are undertaken to finalise the woody vegetation clearing mapping.
6. The mapping is compiled, and a statewide mosaic created (i.e. a single statewide map of woody vegetation clearing). Spatial analyses are performed, and the clearing information is summarised for reporting.

## 2.1 Data

### 2.1.1 Landsat satellite imagery

All reporting is based on analysis of imagery acquired by Landsat satellites. The Landsat program is the longest record of earth observation data in history, with the first satellite launched in 1972. Landsat data used by SLATS dates from 1988 to present, and has a spatial resolution of approximately 30 metres (earlier Landsat satellites were of lower spatial resolution). Landsat satellites have a systematic acquisition strategy, with the same place revisited at least once in its 16-day cycle; the entire state of Queensland is imaged every 16 days. The satellites acquire land surface reflectance data at a range of wavelengths including visible and infrared, some of which are useful for distinguishing different land cover features, including woody vegetation. Landsat data are therefore well-suited to statewide and regional monitoring and reporting of land cover change.

SLATS Landsat data includes imagery captured by the Landsat 5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper Plus (ETM+) and Landsat 8 Operational Land Imager (OLI). Landsat 5 TM was launched in 1984 and ceased operation in 2011, while Landsat 7 ETM+ and Landsat 8 OLI remain operational, with the latter launched in 2013. Since 2003, Landsat 7 ETM+ has been capturing imagery in Scan Line Corrector-off (SLC-off) mode when its scan line corrector failed – resulting in strips of lost data along the eastern and western scene margins. While radiometric and geometric quality of the captured images are maintained, approximately 22% of each image is lost due to the SLC-off gaps, with only a 22 kilometre wide strip in the centre of the image being completely unaffected.

The mapping for this report is based on comparison of Landsat 8 OLI imagery for 2014 and 2015 dates at a spatial resolution of 30 metres.

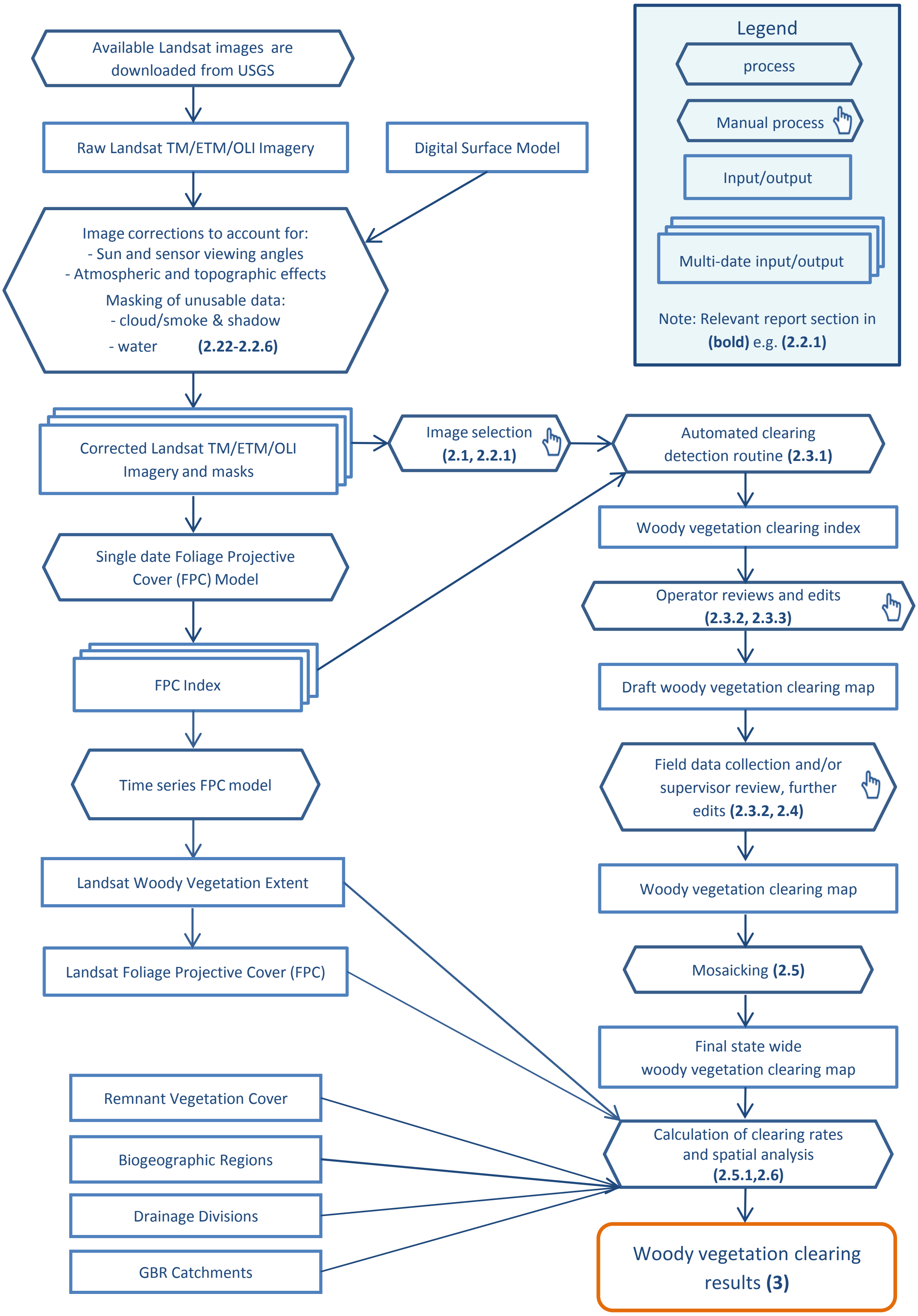



**Figure 2: Flowchart of SLATS processes**

### 2.1.2 SLATS mapping period

A range of satellite overpass dates is acquired in order to capture suitable cloud-free Landsat satellite images for the entire state each year. The images are typically obtained in the dry winter months between June and October. Suitable imagery for 2014 was obtained between June and October, and for 2015, between June and September.

Approximately 99 satellite scenes, or footprints, are incorporated in each SLATS mapping period. Theoretically, in any one year, acquisition dates can differ for each of the 99 satellite scenes. However, every attempt is made to acquire imagery within the dry season period, as close as possible to the same time of year.

The Landsat scene footprint spatial datasets are available for download from the Queensland Government data portal. Information on accessing these data is provided in Section 5 on page 38.

## 2.2 Landsat imagery acquisition and pre-processing for 2014–15

### 2.2.1 Imagery acquisition

For 2014 and 2015 imagery, SLATS downloaded geometrically corrected Landsat 8 OLI satellite imagery from the United States Geological Survey (USGS) website (earthexplorer.usgs.gov).

Preference was given to cloud free, dry season images to align with previous SLATS monitoring periods. A compositing method developed for the 2011–12 period also enabled the infill of pixels obscured by cloud and shadow, which would otherwise be masked. This compositing method was applied to 18 scenes for 2014, and 14 scenes for 2015 with recurrent cloud cover.

It is important to note that the source image date for each pixel used in the composite was recorded in a separate raster image, thus enabling the calculation of the analysis period and woody vegetation clearing rates with the appropriate weighting applied for each pixel.

### 2.2.2 Geometric correction of imagery

All Landsat imagery used has been geometrically corrected by the USGS. Analyses by the USGS suggest that the locational error is below a single pixel (Storey *et al*, 2014). It is therefore quite suitable for use in multi-date studies such as SLATS.

### 2.2.3 Analysis of sensor differences

An analysis of the impact of the sensor differences between Landsat 7 ETM+ and Landsat 8 OLI, on reflectance and FPC models was undertaken, and appropriate adjustments to the models were made by Flood (2014). These adjustments ensure imagery from the two sensors are comparable.

### 2.2.4 Radiometric standardisation

Radiometric standardisation was applied to the Landsat 8 OLI 2014 and 2015 images. Radiometric standardisation allows scene-to-scene matching over space and time. This improves mosaicking and classification. In turn, this improves the accuracy of these data and provides greater certainty in the comparison of the changes in annual rates of woody vegetation clearing. Top-of-atmosphere reflectance is calculated, to correct for solar incidence angle and earth-sun distance, and an empirical radiometric correction was applied to correct for variation in solar azimuth, viewing angle, systematic atmospheric effects, and the effect of bi-directional reflectance distribution function of the surface measured (Danaher, 2002).

### 2.2.5 Topographic corrections

A simple topographic correction to the top-of-atmosphere reflectance imagery was also applied to remove artefacts due to variation in illumination angle on sloping terrain (Dymond and Shepherd, 1999). This correction has the effect of ‘flattening’ the terrain, by estimating the reflectance as if the surface had been horizontal. This correction reduces the effect of hill slope to provide more uniform estimates of top-of-atmosphere reflectance. Classification based on this corrected imagery is therefore more accurate in areas of high slope. This increased accuracy reduces the amount of manual editing required to correct initial misclassification of topographic effects.

### 2.2.6 Other corrections

Cloud, smoke and shadow contamination in the imagery was masked out, to avoid impacts on models for woody extent, FPC and woody vegetation change. To ensure accuracy, these rely on automatic masks generated using the methods of Zhu & Woodcock (2012), combined with manual editing.

## 2.3 Mapping woody vegetation clearing

This section outlines the processes that were undertaken to identify and map woody vegetation clearing for the 2014–15 period.

### 2.3.1 Woody vegetation clearing index

The SLATS method detects change in woody vegetation through an automated process that calculates a multi-component ‘probability of woody vegetation clearing’ index, which is then edited by DSITI remote sensing scientists. This method was first developed for the 2003–04 period (DNR&M, 2006; Scarth *et al*., 2008b).

This woody clearing probability measure is calculated from three components. The most important component is a spectral clearing index, which uses the spectral information from the visible and short wave infra-red bands of the pair of Landsat images (separated by one year). It is similar in principle to creating a difference map, showing the changes in each band. However, this index transforms all of the differences through a model which was fitted to historical mapped clearing data. The model highlights the sorts of changes which are likely to correspond to removal of trees and shrubs, and minimizes the differences which tend to be associated with other sorts of land surface change (e.g. cropping, inundation, pasture response to rainfall).

The second component uses a separate model index which is correlated with the density of tree foliage. This provides a measure of how much foliage cover is present in each pixel, and relates to both the density of the foliage of individual trees, and also the separation between trees within the pixel. While this is not sufficient to perfectly map all tree cover, it does provide a useful indicator. Technically, this is correlated with the FPC, and is known as the FPC index (Armston *et al.*, 2009). The change in this index between the two image dates forms the second component of the clearing probability measure.

The third component is also reliant on the FPC index model, but uses its behaviour over the historic time-series of dry season Landsat imagery (1988–present, one dry season image per year) to obtain a measure of the variability over time. This is used to assist in distinguishing grass (which varies a lot) from trees and shrubs (which are much less variable). This component tries to reduce the amount of false changes identified by the index that is caused by fluctuations in herbaceous vegetation cover and is not due to changes in woody vegetation.

These three components are then combined in a single index, the ‘clearing index’, to give a probability measure that a detected change corresponds to clearing of tree/shrub vegetation (Scarth *et al*., 2008b). This is a useful tool to show the very small amount of the land surface which *might* have been cleared, but requires manual inspection to distinguish which of those areas really do correspond to removal of trees and shrubs. This combined measure forms the basis of the initial classification of possible clearing, ready for manual editing.

The use of dry season imagery is important, because imagery captured during the dry season typically shows the greatest contrast between woody vegetation and grass. Dense green grass in the wet season can become quite similar (spectrally) to sparse tree foliage, making the distinction between open woodland and dense grass more difficult.

### 2.3.2 Image interpretation, manual editing and independent checks

While the clearing index is a good starting point for the classification, considerable time is spent by DSITI remote sensing scientists on checking and manually editing the output to ensure a high quality map.

This is because naturally occurring events can affect vegetation in ways that appear similar to woody vegetation clearing in terms of the spectral and temporal responses observed by the satellite sensor (and used to calculate the clearing index). For example, damage by storms, fire and drought can all cause a reduction in canopy health or cover that can appear similar to a clearing event, and are often detected by the automated clearing index as possible clearing.

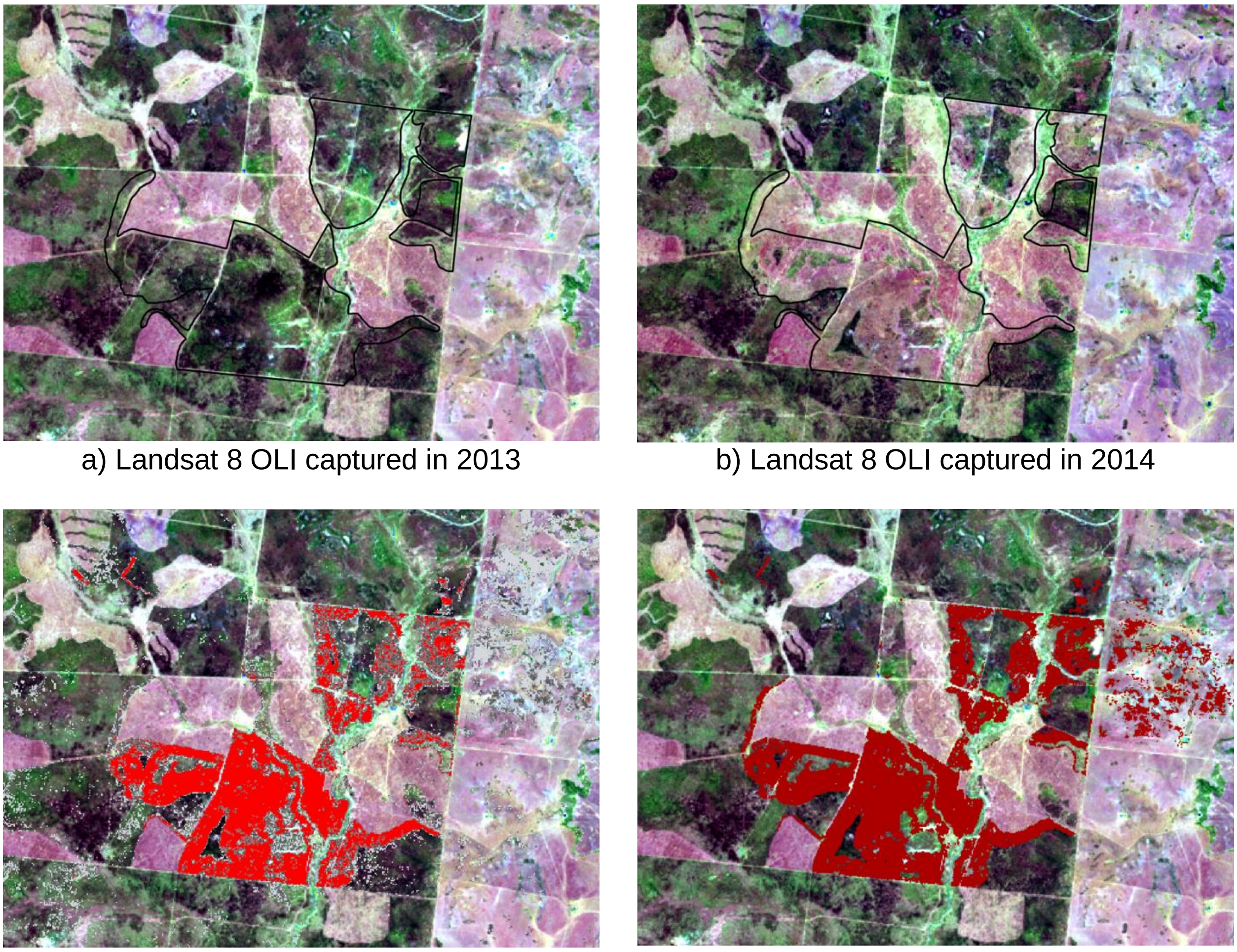
Systematic visual inspection is required to distinguish these cases from anthropogenic clearing. Remote sensing scientists inspect the clearing index, and refer to other image/data sources to assist in confirming whether an area detected as possible clearing by the clearing index is actually woody vegetation clearing. These ancillary data sources also assist in deciding whether the vegetation cover that has been cleared is sufficiently woody to map as woody vegetation clearing. In general, crown cover less than 20% (approximately 11% FPC) has a lower reliability of detection, and woody vegetation clearing in these areas will only be included if the ancillary data are unambiguous, and is in the appropriate NVIS class.

Ancillary data sources include, but are not limited to:

- Landsat imagery, both the start and end dates for the mapping period as well as additional images captured before, during and after the period.
- High resolution satellite imagery and aerial photography available through online image services such as Google Earth and the Queensland Government's Queensland Globe.
- DSITI's archive of SPOT4, SPOT5 and SPOTMaps imagery.
- Complementary remote sensing products, for example DSITI's annual fire scar maps, and the Northern Australia Fire Information fire hotspots and fire scar maps.

Remote sensing scientists use this information to edit the clearing index and produce a map of woody vegetation clearing. Upon completion of this visual interpretation and manual editing, the process is repeated by an experienced DSITI remote sensing scientist to provide an independent check and ensure a high level of accuracy and consistency in the final map.

Figure 3 (page 12) shows an example of woody vegetation clearing where Landsat 8 OLI imagery is used to visually inspect the clearing index to create the clearing map.



a) Landsat 8 OLI captured in 2013

b) Landsat 8 OLI captured in 2014

c) Woody Vegetation Clearing Index

d) Woody Vegetation Clearing Map

**Figure 3: An example of a clearing event in south western Queensland as seen in Landsat 8 OLI imagery. a) Landsat 8 OLI captured on 30 August 2013, before the clearing occurred. b) Landsat 8 OLI captured on 1 August 2014 after the clearing occurred. In a) and b), the same black outline is shown to highlight areas of clearing. c) Woody vegetation clearing index overlaid on image in a). Pixels with high probability of being woody vegetation clearing are shown in red, and lower probabilities shown in shades of grey. d) Woody vegetation clearing map edited by a remote sensing scientist overlaid on image in a). Mapped clearing is shown as dark red. The area in all panels is the same, and is approximately 15 kilometres east to west and 12 kilometres north to south.**

### 2.3.3 Replacement land cover

To give an indication of the types of purposes for which vegetation was cleared, during the manual editing stage, each area of woody vegetation clearing was assigned to one of the replacement land cover classes in Table 2 (below) by DSITI remote sensing scientists. The assignment of these classes was primarily based on visual interpretation and reference to other ancillary data sources on Google Maps or Queensland Globe. In areas where there were many different forms of land use, it was sometimes difficult to interpret the final replacement class. For example, land cleared to pasture may later be converted to urban development.

**Table 2: Replacement land cover classes for woody vegetation clearing**

| Replacement land cover | Description |
|---|---|
| Pasture | Cleared for pasture includes: woody vegetation clearing which is generally for grazing. Areas mapped as thinning are also included in this class. |
| Crops | Cleared for cropping or horticultural purposes. |
| Forestry | Cleared for timber harvesting in state or privately owned native or exotic (e.g. pine) forests or plantations. |
| Mining | Cleared for mining activities (including coal seam gas infrastructure). |
| Infrastructure | Cleared for roads, railways, water storage, pipelines, powerlines etc. |
| Settlement | Cleared for imminent urban development. |

### 2.3.4 Limitations

The 30 metre pixel size of Landsat imagery is the main limitation of the SLATS mapping, and this limitation is manifested in a number of ways. Most obviously, the pixel size limits the size of landscape features which can reliably be detected. For example, clearing of narrow riparian strips of woody vegetation cover may sometimes be missed, if they are less than 30 metres wide.

Perhaps more importantly, the pixel size also limits the ability to distinguish open woodland from open grassland, as scattered trees and interspersed grass cover within a pixel are averaged for the whole pixel. This means that reliable detection of clearing in these areas is subject to interpretation by the manual operator. The operator must decide, using all available information, whether a change represents removal of all or most of the trees, or just a change in herbaceous cover.

## 2.4 Field verification

DSITI's RSC maintains a database containing field observations of vegetation cover, gathered throughout the time that Landsat satellites have been operating. These field data are used to calibrate and validate the remote sensing products that RSC produces, including those that are inputs to the SLATS clearing index.

In previous mapping periods, an extensive field program was also undertaken as part of the SLATS program to inform the mapping of woody vegetation clearing, and in particular to clarify areas of uncertainty. These observations were made during the editing process and used to refine the map, rather than as independent validation data.

The increasing spatial coverage and frequency of high resolution satellite imagery captured in recent years provides a valuable image interpretation resource which can be an alternative to physical field visits in many cases. It is especially useful for interpreting and verifying areas that would not be physically accessible. For this reason, in the 2014–15 mapping period, fewer field observations of clearing were collected than in previous years.

## 2.5 Compilation of statewide data

A large, seamless mosaic of 2014–15 woody vegetation clearing was created by joining all scenes covering the state. Each scene was trimmed to a standard scene template to minimise overlap. When producing these mosaics, the scenes were overlapped in paths from north to south and paths were joined from east to west. The full resolution of these data (30 metre pixel) was preserved.

In recognition of the limited ability to detect clearing at the level of one or two Landsat pixels, a filter was applied to the final mosaic to remove clearing of two pixels or less.

In order to calculate annual woody vegetation clearing rates, each pixel identified as woody vegetation clearing was attributed with the image dates from the compositing process (refer to Section 2.2.1 on page 9).

All statistics were generated based on data transformed to an Albers equal-area projection, thus allowing woody vegetation clearing rates for different regions to be comparable.

### 2.5.1 Calculation of woody vegetation clearing rates

Due to the range of overpass dates, the SLATS mapping period is not a precise 365-day period, and this also varies from scene to scene. This means that the area of clearing mapped in a given period is not necessarily comparable to the area mapped in another period; variations in the satellite overpass dates mean that reporting periods can be longer or shorter than a year. Therefore, for reporting, the total area of mapped clearing (hectares) is converted to an annual clearing rate (hectares/year). This conversion makes the results comparable by re-weighting shorter or longer periods, based on the assumption that clearing occurred at a uniform rate throughout the year.

The full detail of how this calculation was performed is available in Appendix A.

The current report uses version 2.0 of this rate calculation. Previous reports have used version 1.0 of the rate calculation method. Version 1.0 used information only from the two dates of each period. For this report, all rates have been calculated using version 2.0, which uses information from the preceding and following periods when available, and includes recalculation of all historic rates of clearing for previous mapping periods. The differences between these methods are described in Appendix A, along with a comparison of the difference in resulting clearing rates derived from each version of the rate calculation.

## 2.6 Spatial analysis and summary of woody vegetation clearing

A number of spatial analyses are performed on the final clearing map, to summarise clearing rates for the state in different ways. These summaries provide information about:

- the types of clearing activities that have occurred
- patterns in clearing rates over time
- the types of vegetation structures that have been cleared
- the geographic distribution of clearing.

The results are presented as maps, graphs and tables in Section 3, commencing on page 19.

The following sections further describe these spatial analyses and the datasets used.

### 2.6.1 Statewide analysis and summary of clearing

This section describes the spatial analyses and summaries at a statewide level.

Table 3 (page 18) provides a list of spatial data sets used in these analyses.

### *Replacement land cover class*

The rates of woody vegetation for the present, and previous three mapping periods were summarised by the replacement land cover classes described in Section 2.3.3 on page 13.

### *Missed clearing*

Since 2001–02, woody vegetation clearing that occurred in a given period but which was not mapped until the subsequent period has been recorded as 'missed clearing'. Previous reporting has shown that the amount of missed clearing in a given period is very low (less than 2%) compared to the total rate of clearing for the state. In general, missed clearing has been more prevalent in wetter periods, when cloud cover, surface moisture, and an increase in herbaceous and grass cover can make identification of woody vegetation clearing more challenging.

Missed clearing is reported by adding the rate for the missed clearing to the total rate of clearing for the period in which it occurred (i.e. not for the period in which it was mapped).

### *1:25 000 Mapsheet*

The statewide woody vegetation clearing mosaic was intersected with the Queensland 1:25000 map sheet key map, and clearing rates calculated for each 1:25000 map sheet. The resulting summary of clearing rates was used to create a choropleth map depicting the spatial distribution and intensity of clearing for the current mapping period.

### *Remnant Vegetation*

DSITI (Queensland Herbarium) produces a map of remnant vegetation cover at two year intervals.

For each mapping period from 1997–99 to 2014–15, statewide woody vegetation clearing mosaics were intersected with the remnant vegetation cover map corresponding to the start of the mapping period (refer to Table 3 on page 18). The rate and proportion of woody vegetation clearing of remnant vegetation for each mapping period were calculated. The rate of woody vegetation clearing of remnant vegetation for each replacement land cover class was also calculated for the current period, and previous three mapping periods.

Remnant vegetation mapping is not available for years prior to 1997, and therefore these analyses and calculations were not performed for mapping periods prior to 1997–99.

### *Repeat clearing events*

The woody vegetation clearing mosaic for each mapping period was overlaid with the mosaics for all previous mapping periods, and the number of times cleared counted for each pixel. This allowed the identification of cleared areas in each period which had been cleared more than once since 1988.

### *Landsat Woody Vegetation Extent – Queensland 2014 and Landsat Foliage Projective Cover – Queensland 2014 datasets*

Previous SLATS reports (e.g. DSITI, 2015) have presented and reported on estimates of woody vegetation density and extent based on the published dataset *Wooded Extent and Foliage Projective Cover – Queensland, Year*. This dataset was based on a combined representation of the estimated extent and FPC of woody vegetation in Queensland.

For reporting herein, and for the publication of these data, this combined representation has been separated into two datasets:

(i) *'Landsat Woody Vegetation Extent – Queensland 2014',* and

(ii) *'Landsat Foliage Projective Cover – Queensland 2014'.*

These datasets have been produced using the same methods outlined in DSITI (2015), which are based on a method described in Armston *et al.,* (2009) and Kitchen *et al*., (2010).

The method includes a series of automated steps and is based on an FPC index which has been calibrated by field observations from a range of vegetation types across the state. The FPC index is applied to annual Landsat satellite imagery to create an FPC index time-series. The time-series is then summarised to create a set of temporal statistics. Thresholds based on these statistics are then used in a decision-tree to provide a prediction of the presence or absence of woody vegetation, per pixel. This prediction forms the basis for the production of the *Landsat Woody Vegetation Extent* dataset. A linear model is fitted to the time-series of FPC indices, and for each pixel classified as woody vegetation, a prediction of FPC is made for the final year in the time series. This estimate of FPC forms the basis for the production of the *Landsat Foliage Projective Cover* dataset. Automated and manual post-processing steps are applied to these data to minimise error due to cloud contamination in the time-series, inundated areas, topographic shadowing, cropped areas and to ensure consistency between each Landsat scene.

The time-series approach used helps to remove some of the noise due to year-to-year variation, and to improve estimates in areas where a disturbance such as fire or clearing has occurred within the time period. However, the estimation of woody vegetation using Landsat satellite imagery can be sensitive to a range of influences including seasonal and inter-annual variability in climate, fire and other landscape changes. Furthermore, the 30 metre spatial resolution of the Landsat satellite imagery limits the accuracy of detection of sparse trees and shrubs and increases its sensitivity to variability in grass and other ground cover below the trees and shrubs. These limitations will result in estimates of woody vegetation extent and FPC varying from year to year for the same location, particularly in areas of sparse tree and/or shrub density and young regrowth. Due to these limitations, these datasets and their predecessors from previous years are not suitable for comparisons to directly derive change in woody vegetation extent, or density change estimates.

The *Landsat Woody Vegetation Extent – Queensland 2014* statewide dataset provides an estimate of the extent of woody vegetation across the state. It is used in this report only to provide context for the rate of woody vegetation clearing, relative to the total woody vegetation extent.

The *Landsat Foliage Projective Cover – Queensland 2014* dataset provides an estimate of the density (expressed as percentage of FPC) of woody vegetation across the state for the year 2014. It is used in this report only to provide information about the ranges of densities of woody plant assemblages that have been cleared across the state. The woody vegetation clearing mapping is summarised for five classes of woody plant density (as estimated by percentage FPC) to report which classes are most represented: 0–19%; 20–39%; 40–59%; 60–79%; and 80–100%.

#### 2.6.2 Regional summaries of woody vegetation clearing

Three spatial datasets were used to calculate breakdowns of woody vegetation clearing by geographic location. Statewide woody vegetation clearing maps for the current, and previous three mapping periods were intersected with these datasets, and woody vegetation clearing rates for each polygon within were calculated. The datasets used were:

- biogeographic regions
- drainage divisions
- GBR catchments.

## 2.7 Quality Control

Procedural consistency throughout the SLATS mapping methodology is maximised through a number of measures. Excepting the manual editing phase, many of the steps involved have been automated with purpose-built programs. Throughout the image processing chain and mapping process, file and program histories are recorded. This not only maximises procedural consistency across many satellite scenes, multiple mapping periods, and staff members, but enables any problems to be reliably traced and rectified.

During the manual editing phase, remote sensing scientists consult regularly within the mapping team, and this combined with a checking process, is intended to maximise consistency between staff.

**Table 3: Spatial datasets used to summarise woody vegetation clearing**

| Spatial dataset | Data custodian | Mapping period |
|---|---|---|
| Queensland 1:25000 map sheet key map (current to 2010) | DNRM | 2014–15 |
| Landsat Woody Vegetation Extent – Queensland 2014 | DSITI | 2014–15 |
| Landsat Foliage Projective Cover – Queensland 2014 | DSITI | 2014–15 |
| Biogeographic Regions – Queensland (version 5.0) | DNRM | 2014–15; 2013–14; 2012–13; 2011–12 |
| Drainage Divisions Queensland | DNRM | 2014–15; 2013–14; 2012–13; 2011–12 |
| Great Barrier Reef Catchments | DNRM | 2014–15; 2013–14; 2012–13; 2011–12 |
| Remnant Vegetation Cover of Queensland (current to 2013) | DSITI | 2014–15; 2013–14 |
| Remnant Vegetation Cover of Queensland (current to 2011) | DSITI | 2012–13; 2011–12 |
| Remnant Vegetation Cover of Queensland (current to 2009) | DSITI | 2010–11; 2009–10 |
| Remnant Vegetation Cover of Queensland (current to 2007) | DSITI | 2008–09; 2007–08 |
| Remnant Vegetation Cover of Queensland (current to 2006) | DSITI | 2006–07 |
| Remnant Vegetation Cover of Queensland (current to 2005) | DSITI | 2005–06 |
| Remnant Vegetation Cover of Queensland (current to 2003) | DSITI | 2004–05; 2003–04 |
| Remnant Vegetation Cover of Queensland (current to 2001) | DSITI | 2002–03; 2001–02 |
| Remnant Vegetation Cover of Queensland (current to 2000) | DSITI | 2000–01 |
| Remnant Vegetation Cover of Queensland (current to 1999) | DSITI | 1999–00 |
| Remnant Vegetation Cover of Queensland (current to 1997) | DSITI | 1997–99 |

# 3 Results and discussion

This section presents the results of the assessment of woody vegetation clearing detected by SLATS in the 2014–15 period, at the statewide and regional level, after intersection with various GIS layers described in Section 2.6 on page 14.

Please note: All clearing rates in this report are rounded to the nearest 1000 ha/year and percentages rounded to the nearest whole percentage.

## 3.1 Woody vegetation clearing

The statewide woody vegetation clearing rate in the 2014–15 period was 296 000 ha/year, or 0.17% of the land area of Queensland. In total, this woody vegetation clearing rate represents an area of approximately 54 kilometres x 54 kilometres cleared per year.

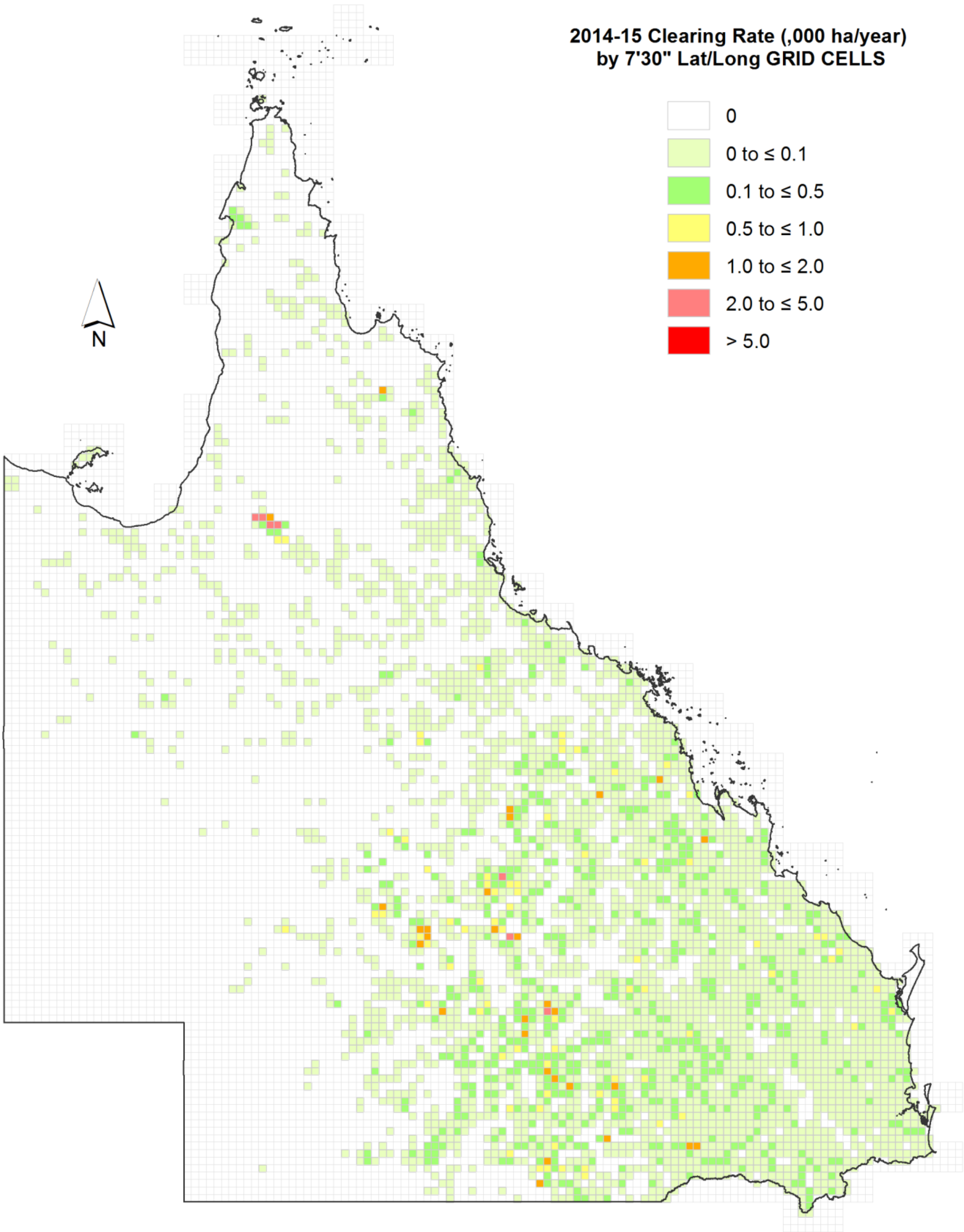
A spatial view of the distribution and intensity of the rate of woody vegetation clearing (,000 ha/year) within Queensland, aggregated to 7´30˝ x 7´30˝ (latitude/longitude) grid cells, is shown in Figure 4 (page 20) for 2014–15. These cells are the same size as a 1:25 000 map sheet – approximately 14 kilometres x 14 kilometres.

### 3.1.1 Thinning

- For the 2014–15 period, the figure for woody vegetation loss due to thinning was 15 000 ha/year (5% of total statewide woody vegetation clearing). Woody vegetation loss due to thinning was included in the ‘pasture’ replacement land cover class for the final woody vegetation clearing statistics in this report.

### 3.1.2 Natural tree death and natural disaster damage

- Little natural tree death was detected during 2014–15 (less than 0.005% of total statewide woody vegetation clearing).
- Natural disaster damage of 5 000 ha/year of woody vegetation was identified that predominantly related to damage caused by Cyclone Marcia on the central Queensland coast in February 2015. Woody vegetation change due to natural tree death or natural disaster damage was not included in the final woody vegetation clearing statistics.




Each grid cell has an area of approximately 17,500 hectares.

**Figure 4: Aggregated annual woody vegetation clearing rate in Queensland for 2014–15**

## 3.2 Woody vegetation clearing by replacement land cover class

In this section, the rate of woody vegetation clearing has been summarised by replacement land cover for 2014–15 (and for comparison, results since 2011–12) in Table 4 below.

### 3.2.1 Results

- The majority of woody vegetation clearing for 2014–15 was for conversion to pasture for grazing purposes (91% of total statewide woody vegetation clearing). This is consistent with results since 2011–12 (Table 4 below).
- Forestry was the second largest replacement land cover (5% of total statewide woody vegetation clearing), and is consistent with results since 2011–12 (Table 4 below).

**Table 4: Woody vegetation clearing by replacement land cover (2011–15)**

| | Rate of woody vegetation clearing (,000 ha/year)[1] | | | | | | |
|---|---|---|---|---|---|---|---|
| Period | Pasture | Crops | Forest | Mining | Infrastructure | Settlement | Total |
| 2011–12 | 135 | <1 | 7 | 6 | 5 | 1 | 155 |
| 2012–13 | 236 | 2 | 8 | 6 | 7 | 1 | 261 |
| 2013–14 | 271 | 4 | 9 | 5 | 4 | 1 | 295 |
| 2014–15 | 269 | 5 | 16 | 3 | 1 | 2 | 296 |

[1] Rates are rounded to nearest 1000 ha/year.

## 3.3 Woody vegetation clearing by remnant status

In this section, SLATS 2014–15 woody vegetation clearing mapping data were intersected with the Remnant Vegetation Cover of Queensland, current to 2013 (Queensland Herbarium, 2015) to provide a summary of remnant status (and for comparison, results since 2011–12) (Table 5 below).

### 3.3.1 Results

- The rate of clearing of remnant woody vegetation for 2014–15 was 114 000 ha/year, or 38% of total statewide woody vegetation clearing. This compares to 100 000 ha/year of remnant woody vegetation clearing in 2013–14 (34% of total statewide woody vegetation clearing) (Table 5 below).
- Remnant woody vegetation clearing has increased from 22% of total statewide woody vegetation clearing in 2011–12 to 38% of total statewide woody vegetation clearing in 2014–15.
- In 2014–15, the rate of non-remnant woody vegetation clearing was 182 000 ha/year (195 000 in 2013–14) (Table 5 below).

**Table 5: Woody vegetation clearing by remnant status (2011–15)**

| | Rate of woody vegetation clearing (,000 ha/year)[1] | | |
|---|---|---|---|
| Period | Remnant | Non-remnant | Total |
| 2011–12 | 34 | 120 | 155 |
| 2012–13 | 58 | 203 | 261 |
| 2013–14 | 100 | 195 | 295 |
| 2014–15 | 114 | 182 | 296 |

[1] Rates are rounded to nearest 1000 ha/year.

## 3.4 Woody vegetation clearing by biogeographic region

Queensland is divided into 13 biogeographic regions with native vegetation occurring across many different environments – from spinifex grasslands in western regions to tall eucalypts in south east Queensland and rainforest in the wet tropics.

An analysis of woody vegetation clearing rates for each biogeographic region in Queensland is provided in this section. The information presented includes:

- woody vegetation clearing rates by replacement land cover, and the clearing rate for each biogeographic region as a percentage of total statewide woody vegetation clearing (Table 6, page 23)
- a map of the spatial distribution and intensity of woody vegetation clearing (,000 ha/year) for biogeographic regions within Queensland (Figure 5, page 24)
- estimated woody vegetation extent for each biogeographic region (Table 6, page 23) that provides contextual information about distribution across different regions.

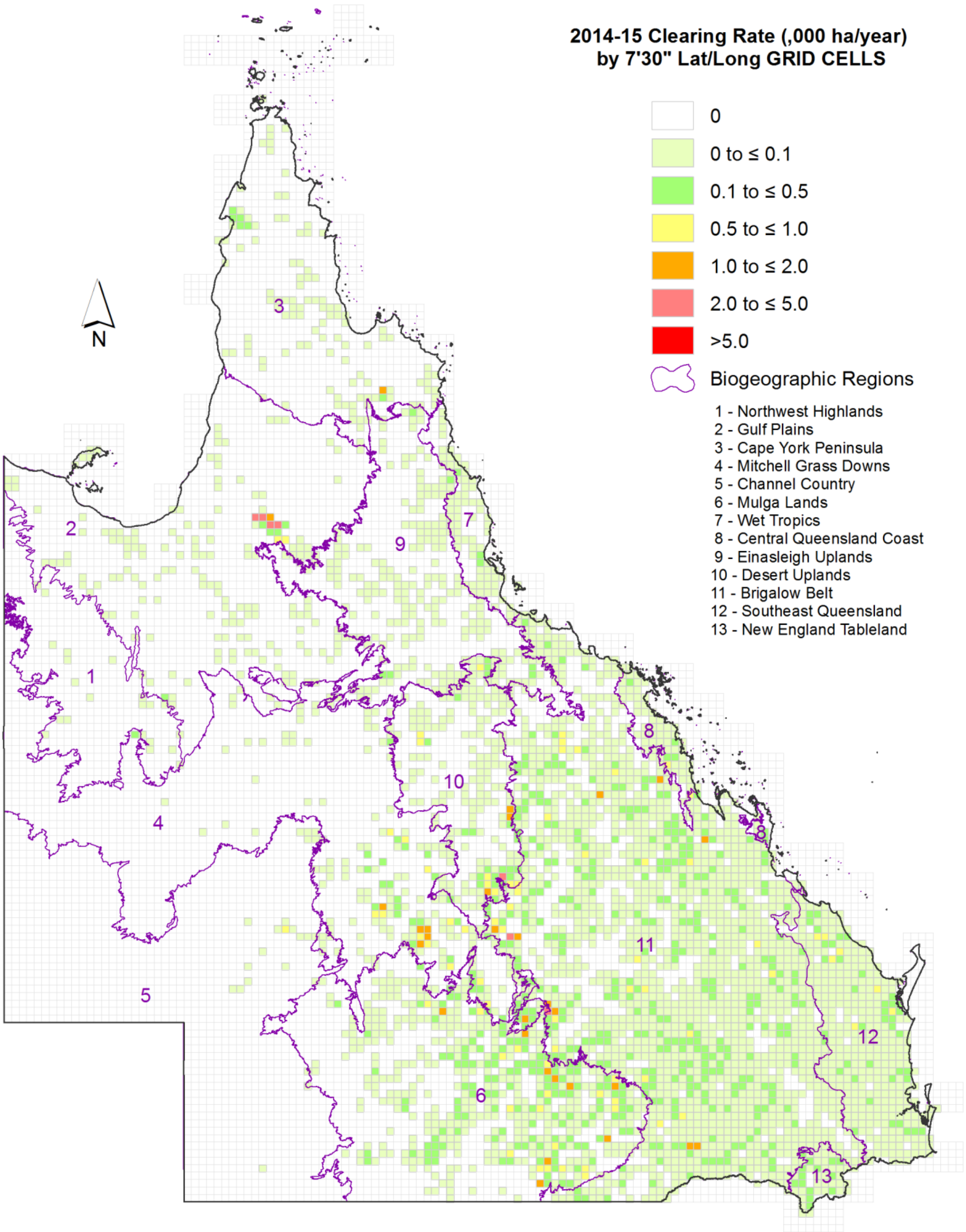
### 3.4.1 Results

- The Brigalow Belt biogeographic region had the highest woody vegetation clearing rate with 130 000 ha/year (44% of total statewide woody vegetation clearing) for 2014–15 (Table 6, page 23). This result was similar to the 132 000 ha/year cleared in 2013–14.
- The second highest woody vegetation clearing rate occurred in the Mulga Lands biogeographic region (65 000 ha/year for 2014–15) (Table 6, page 23). This represented a decrease of 40% from 2013–14 (108 000 ha/year).
- Significant changes in woody vegetation clearing rates occurred in the Gulf Plains biogeographic region (18 000 ha/year in 2014–15 compared to 4 000 ha/year in 2013–14), and in the Mitchell Grass Downs biogeographic region (26 000 ha/year in 2014–15 compared to 14 000 ha/year in 2013–14).
- Clearing of woody vegetation to pasture was dominant in most biogeographic regions. The exception was in Southeast Queensland where forestry was dominant (Table 6, page 23).

**Table 6: Woody vegetation clearing by replacement land cover by biogeographic region (2014–15)**

| Bio-geographic region | Total area (,000 ha) | Rate of woody vegetation clearing (,000 ha/year)[1] | | | | | | | % total clearing in QLD | Estimated extent of woody vegetation in region[2] (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Pasture | Crops | Forest | Mining | Infra-structure | Settle-ment | Total | | |
| Brigalow Belt | 36528 | 120 | 4 | 3 | 2 | 1 | <1 | 130 | 44 | 51 |
| Cape York Peninsula | 12305 | 2 | <1 | 0 | 1 | <1 | <1 | 3 | 1 | 95 |
| Central Queensland Coast | 1484 | 2 | <1 | 1 | <1 | <1 | <1 | 3 | 1 | 79 |
| Channel Country | 23217 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | <1 | 11 |
| Desert Uplands | 6941 | 19 | 0 | 0 | <1 | <1 | 0 | 19 | 6 | 63 |
| Einasleigh Uplands | 11626 | 2 | <1 | 0 | <1 | <1 | <1 | 3 | 1 | 87 |
| Gulf Plains | 21911 | 18 | 0 | 0 | <1 | <1 | <1 | 18 | 6 | 73 |
| Mitchell Grass Downs | 24162 | 26 | 0 | 0 | 0 | <1 | 0 | 26 | 9 | 13 |
| Mulga Lands | 18606 | 65 | <1 | <1 | 0 | <1 | <1 | 65 | 22 | 44 |
| New England Tableland | 775 | 4 | <1 | <1 | <1 | <1 | <1 | 4 | 1 | 62 |
| Northwest Highlands | 7344 | <1 | 0 | 0 | <1 | 0 | 0 | <1 | <1 | 61 |
| Southeast Queensland | 6248 | 8 | 1 | 11 | <1 | <1 | 1 | 21 | 7 | 76 |
| Wet Tropics | 1993 | <1 | <1 | 1 | <1 | <1 | <1 | 1 | <1 | 85 |

[1] Rates are rounded to nearest 1000 ha/year. Percentages are rounded to nearest whole percentage.
[2] Based on the 'Landsat woody extent – Queensland 2014' dataset




Each grid cell has an area of approximately 17,500 hectares.

**Figure 5: Woody vegetation clearing in Queensland for 2014–15 showing biogeographic regions**

## 3.5 Woody vegetation clearing by drainage division

An analysis of woody vegetation clearing rates for Queensland's drainage divisions is provided in this section. The information presented includes:

- woody vegetation clearing rates by replacement land cover, and the clearing rate for each drainage division as a percentage of total statewide woody vegetation clearing (Table 7 below)
- map of the spatial distribution and intensity of woody vegetation clearing (,000 ha/year) for drainage divisions within Queensland (Figure 6, page 26)
- estimated woody vegetation extent for each drainage division (Table 7 below) that provides contextual information about distribution across different divisions.

### 3.5.1 Results

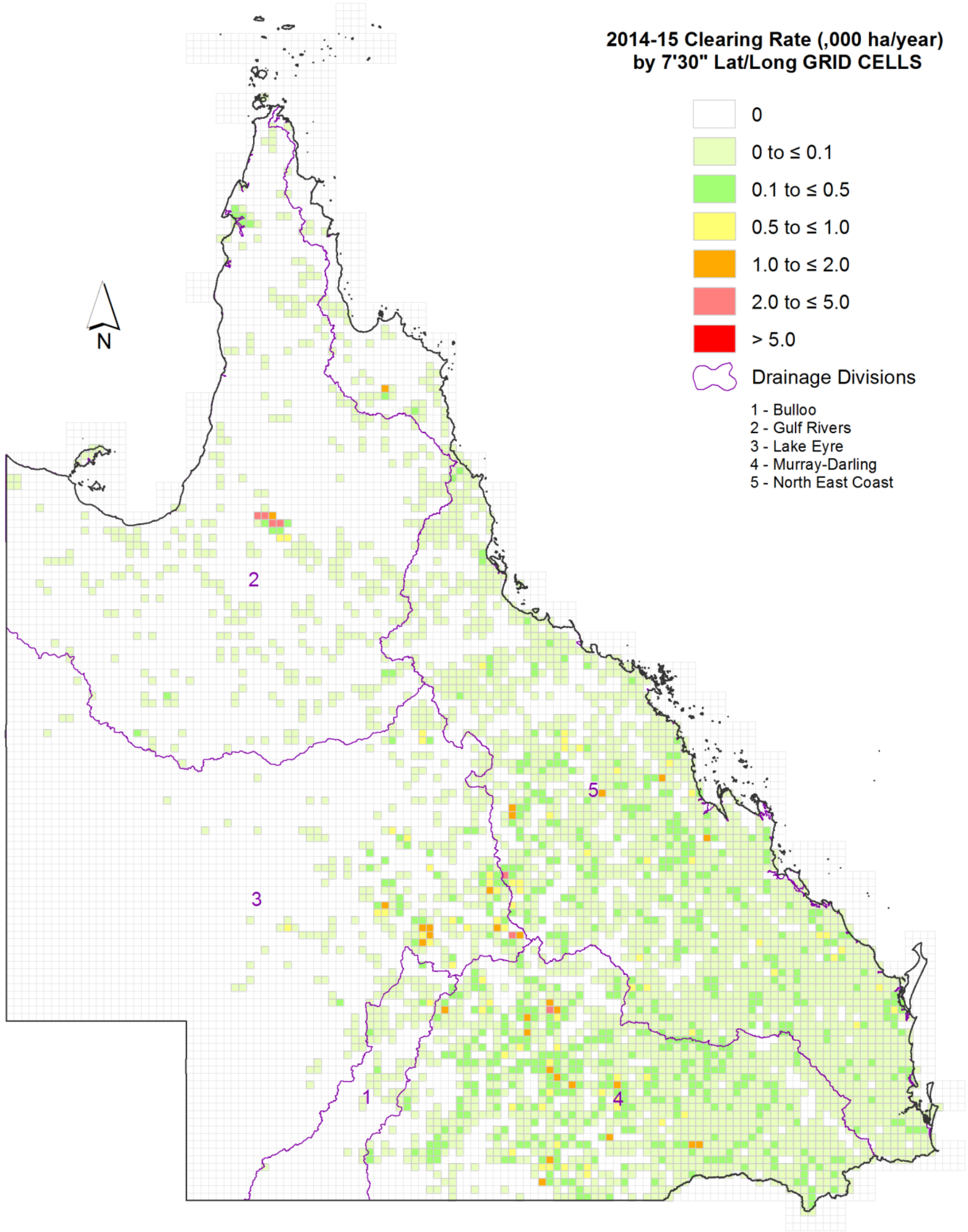
- In 2014–15, the Murray-Darling drainage division recorded the highest woody vegetation clearing rate with 119 000 ha/year (40% of total statewide woody vegetation clearing) (Table 7 below). This represented a 22% decrease from 153 000 ha/year in 2013–14.
- The second highest woody vegetation clearing rate was recorded in the North East Coast drainage division with 115 000 ha/year (Table 7 below). This clearing rate is similar to 111 000 ha/year in 2013–14.
- Woody vegetation clearing rates changed significantly in the Gulf Rivers drainage division (21 000 ha/year in 2014–15 compared to 7 000 ha/year in 2013–14), and in the Lake Eyre drainage division (38 000 ha/year in 2014–15 compared to 20 000 ha/year in 2013–14).
- Clearing to pasture was the dominant land cover replacement in all drainage divisions (greater than 95%), except in the North East Coast division where 13% of clearing was for forestry and 82% for pasture (Table 7 below).

**Table 7: Woody vegetation clearing by replacement land cover by drainage division (2014–15)**

| Drainage division | Total area (,000 ha) | Rate of woody vegetation clearing (,000 ha/year)[1] | | | | | | | % total clearing in QLD | Estimated extent of woody vegetation in division[2] (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Pasture | Crops | Forest | Mining | Infra-structure | Settle-ment | Total | | |
| Bulloo | 5185 | 3 | 0 | 0 | 0 | <1 | 0 | 3 | 1 | 30 |
| Gulf Rivers | 45307 | 20 | <1 | 0 | 1 | <1 | <1 | 21 | 7 | 74 |
| Lake Eyre | 51014 | 38 | 0 | 0 | 0 | <1 | 0 | 38 | 13 | 19 |
| Murray-Darling | 26253 | 114 | 3 | 1 | <1 | 1 | <1 | 119 | 40 | 45 |
| North East Coast | 45026 | 94 | 2 | 15 | 2 | 1 | 2 | 115 | 39 | 67 |

[1] Rates are rounded to nearest 1000 ha/year. Percentages are rounded to nearest whole percentage.

[2] Based on the 'Landsat woody extent – Queensland 2014' dataset




Each grid cell has an area of approximately 17,500 hectares.

**Figure 6: Woody vegetation clearing in Queensland for 2014–15 showing drainage divisions**

## 3.6 Woody vegetation clearing by GBR catchments

The GBR catchments are a subset of the North East Coast drainage division indicated by the purple outline in Figure 8 on page 29.

An analysis of woody vegetation clearing rates in the GBR catchments is provided in this section. The information presented includes:

- woody vegetation clearing rates as a percentage of total statewide woody vegetation clearing for the GBR catchments for 2014–15 (and for comparison, results since 2011–12) (Table 8 below)
- woody vegetation clearing rates by replacement land cover, and estimated woody vegetation extent in the GBR catchments (Table 9, page 28)
- trend of annual woody vegetation clearing rates for the GBR catchments against total statewide woody vegetation clearing rates from 1988–2015 (Figure 7, page 28)
- map of the spatial distribution and intensity of woody vegetation clearing (,000 ha/year) for the GBR catchments within Queensland (Figure 8, page 29).

### 3.6.1 Results

- The GBR catchments recorded a woody vegetation clearing rate of 108 000 ha/year in 2014–15 (37% of the state's total woody vegetation clearing), slightly more than the 105 000 ha/year in 2013–14 (Table 8, page 27).
- Since 2011–12, the rate of clearing of woody vegetation in the GBR catchments has increased by 46%, but as a percentage of total statewide woody vegetation clearing, it has fallen from 48% in 2011–12 to 37% in 2014–15 (Table 8, page 27).
- The percentage of clearing of woody vegetation to pasture remained the dominant land cover replacement in the GBR catchments in 2014–15 with 85%, while 11% was cleared to forestry (Table 9, page 28). These figures are consistent with results since 2011–12.
- The trend in woody vegetation clearing rate in the GBR catchments from 1988–2015 generally follows the total statewide woody vegetation clearing rate from 1988–2015 (Figure 7, page 28).

**Table 8: Woody vegetation clearing in the GBR catchments (2011–15)**

| Period | Rate of woody vegetation clearing (,000 ha/year)[1] | | % of total clearing in QLD |
|---|---|---|---|
| | GBR catchments | Total clearing in QLD | |
| 2011–12 | 74 | 155 | 48 |
| 2012–13 | 106 | 261 | 40 |
| 2013–14 | 105 | 295 | 36 |
| 2014–15 | 108 | 296 | 37 |

[1] Rates are rounded to nearest 1000 ha/year. Percentages are rounded to nearest whole percentage.

**Table 9: Woody vegetation clearing in the GBR catchments by replacement land cover**

| Drainage division | Total area (,000 ha) | Rate of woody vegetation clearing (,000 ha/year)[1] | | | | | | | Estimated extent of woody vegetation in GBR catchments[2] (%) |
|---|---|---|---|---|---|---|---|---|---|
| | | Pasture | Crops | Forest | Mining | Infra-structure | Settle-ment | Total | |
| GBR catchments | 42311 | 92 | 2 | 12 | 2 | 1 | <1 | 108 | 67 |

[1] Rates are rounded to nearest 1000 ha/year. Percentages are rounded to nearest whole percentage.
[2] Based on the ‘Landsat woody extent – Queensland 2014’ dataset

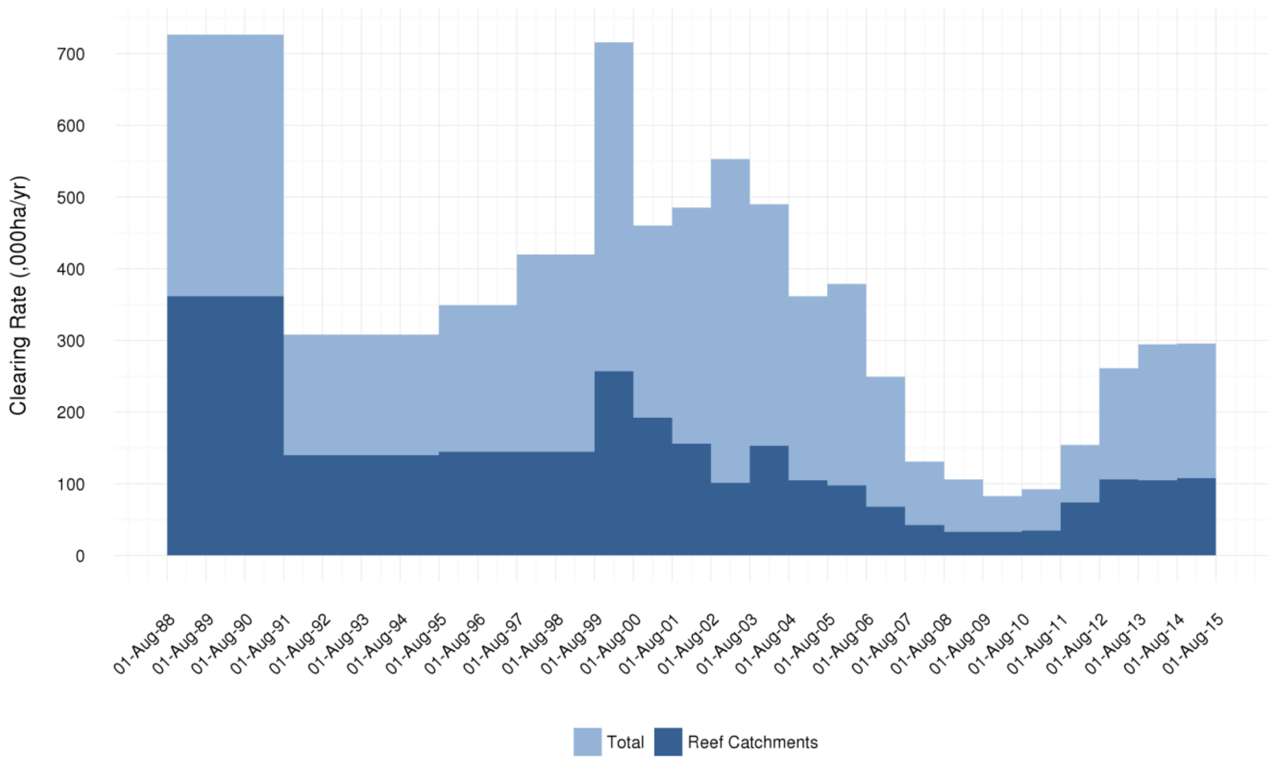
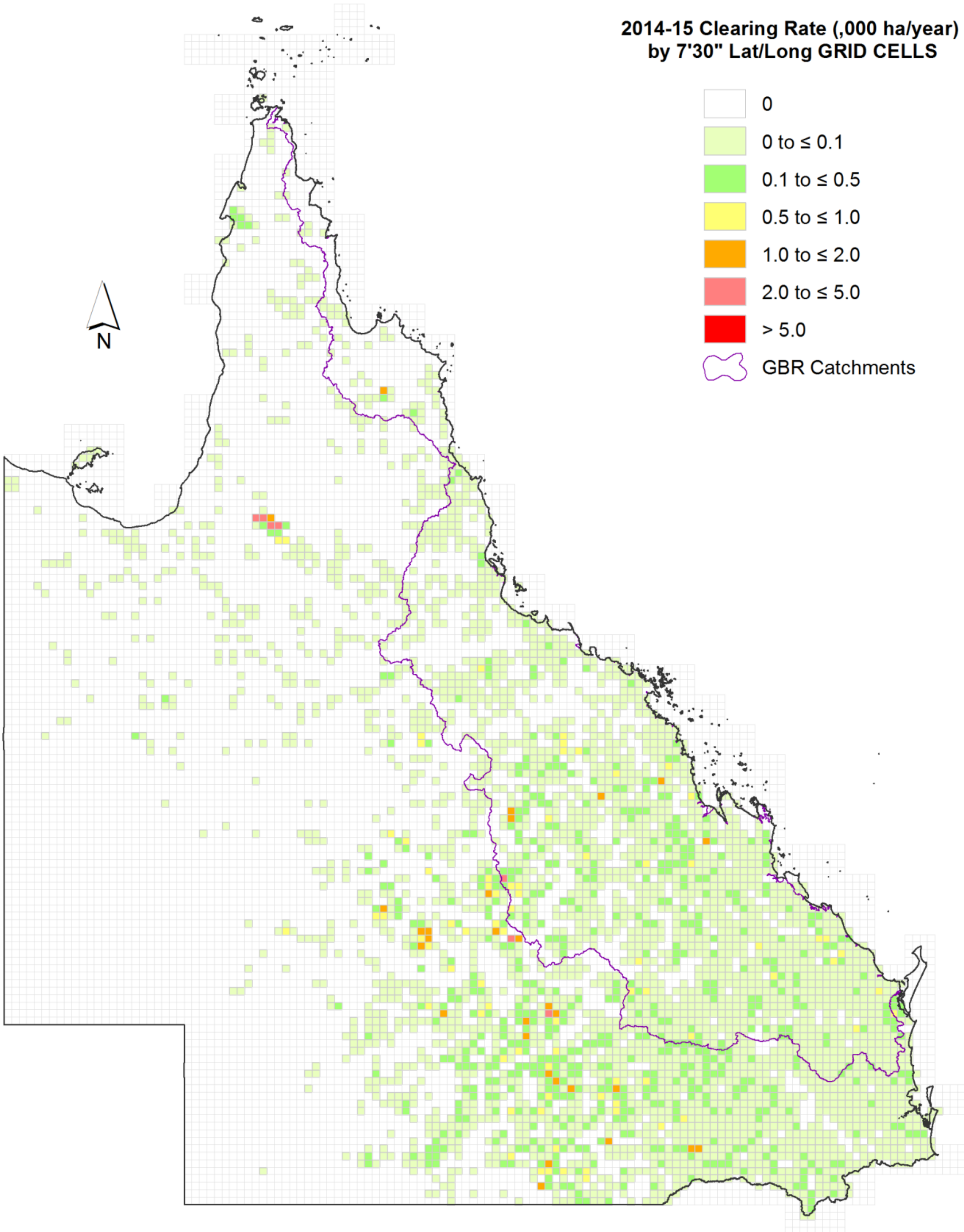



**Figure 7: Woody vegetation clearing rates in the GBR catchments (1988–2015)**




Each grid cell has an area of approximately 17,500 hectares.

**Figure 8: Woody vegetation clearing in Queensland for 2014–15 showing the GBR catchments**

## 3.7 Woody vegetation clearing by woody vegetation extent and foliage projective cover

Figure 9 on page 31 is a map of the state which shows the woody vegetation extent as estimated by the *Landsat Woody Vegetation Extent – Queensland 2014.* The map shows that the northern and eastern parts of the state have extensive areas of woody vegetation estimated. The central, southern and western parts of the state are generally patchier in woody vegetation cover and have large areas which are estimated to be non-woody vegetation. It is important to note that this map does not distinguish the structure or density of woody vegetation cover, or the type of woody vegetation cover present. This information can be derived from other datasets; for example, the *Landsat Foliage Projective Cover – Queensland 2014* and regional ecosystems mapping.

Figure 10 on page 32 is a map of the state which shows the spatial distribution of the ranges of FPC as estimated by the *Landsat Foliage Projective Cover – Queensland 2014* dataset*.* Areas of the state with higher FPC ranges are generally along the east coast and central ranges, with very high FPC in the closed forest which typifies the tropical rainforest areas of the north-eastern coastal areas of the Wet Tropics and Cape York biogeographic regions. The central and western parts of the state are dominated by large areas which are in the very low to medium FPC ranges (0–19% and 20–39%). These include the Gulf Plains, Brigalow Belt, Mulga Lands, Mitchell Grass Downs and Channel Country biogeographic regions. These areas are characterised by the open woodlands, woodlands and open forests which are common of the extensive rangeland and savannah ecosystems of Queensland. In parts of these areas, there is very low or no FPC estimated, such as in the Mitchell Grass Downs biogeographic region. These areas can have sparse or isolated trees or shrubs or may be devoid of woody vegetation entirely. The estimation of FPC by the *Landsat Foliage Projective Cover – Queensland 2014* dataset in these lower ranges is at the lower limits of the detection capability of the Landsat satellite.

### 3.7.1 Results

- In 2014, it is estimated that approximately 51% of the total area of the state had woody vegetation present at Landsat scale (Figure 9, page 31). The total area of woody vegetation clearing mapped in 2014–15 is therefore a small percentage of the estimated total area of woody vegetation across the state (approximately 0.3%). However, it is important to consider the location, density and type of woody vegetation that has been cleared when drawing conclusions about rates of woody vegetation clearing in Queensland.
- For 2014–15, 45% of all woody vegetation clearing for the state occurred in the FPC range 0–19% (Figure 11, page 33). A large proportion of the state is in this range of FPC (68% of the total area of the state), noting that it includes areas where very low or no FPC has been estimated. The FPC range 20–39% has the next greatest representation of all woody clearing, with 43% of all woody vegetation clearing occurring in this range. 23% of the total area of the state is in this range of FPC.

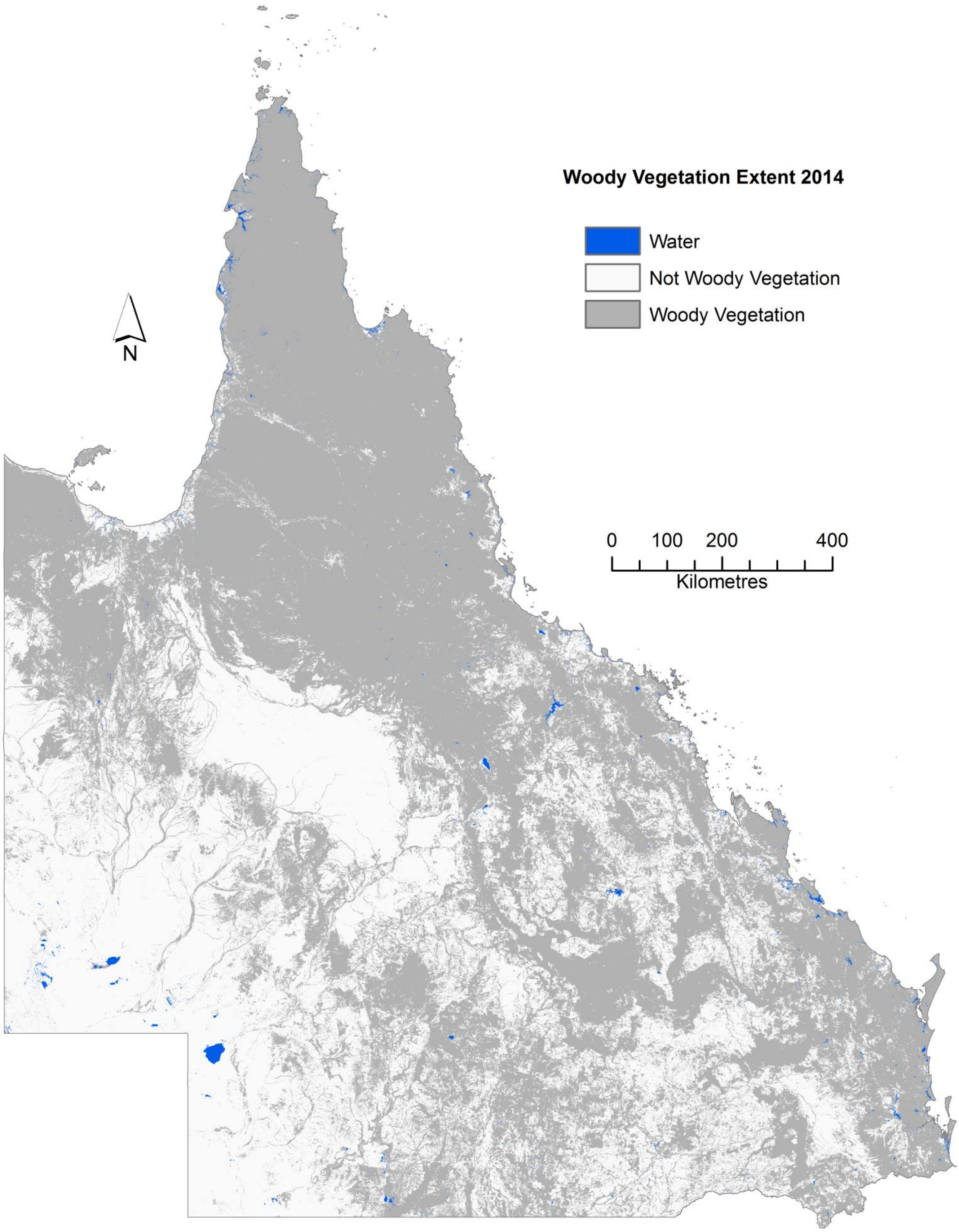



**Figure 9: A map of Queensland showing the distribution and extent of woody vegetation across the state as estimated by the *Landsat Woody Vegetation Extent – Queensland 2014* dataset. This map is an estimate of woody vegetation only, and does not distinguish the structure, density or type of woody vegetation present at any given location.**

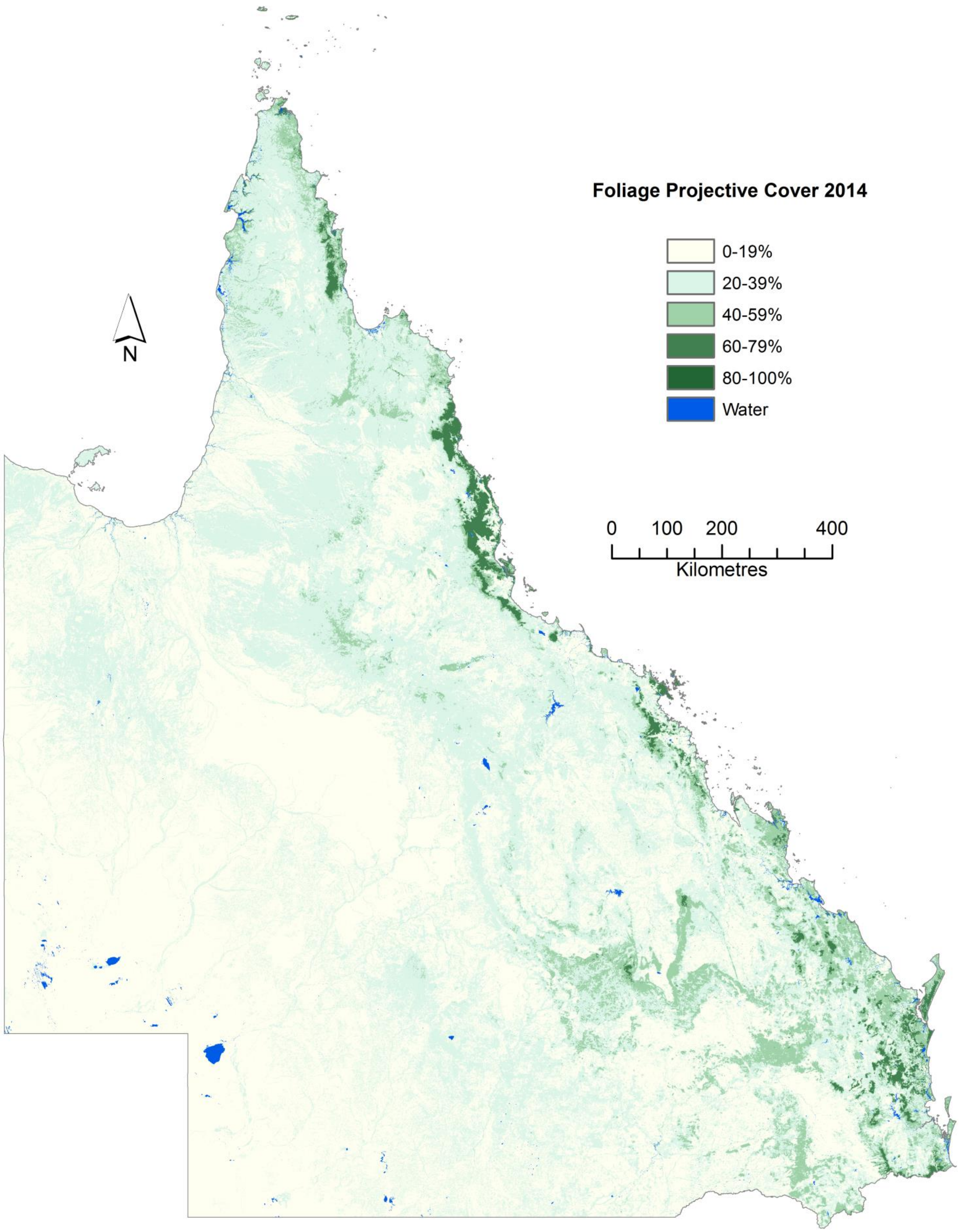



**Figure 10: A map of Queensland showing the ranges of FPC across the state as estimated by the *Landsat Foliage Projective Cover – Queensland 2014* dataset. This dataset is indicative of the density of woody vegetation present at any given location. Five ranges of FPC of woody vegetation (expressed as percentage FPC) are shown. Most of the state's woody vegetation occurs in the ranges 0–19% and 20–29%.**

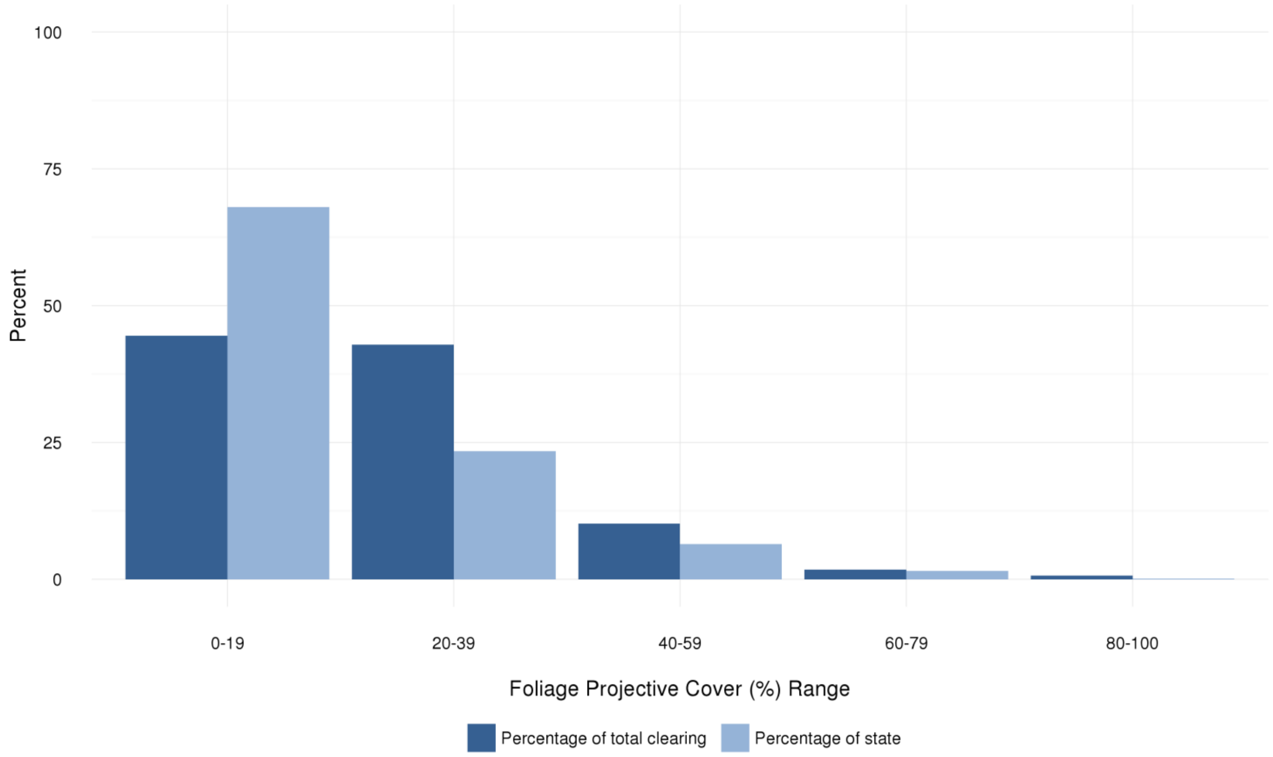



**Figure 11: The percentage of the total of all woody vegetation clearing for 2014–15 for five ranges of FPC (dark blue bars). 88% of all woody vegetation clearing occurred in the FPC ranges 0–19% and 20–39%. The percentage of the total area of the state is also shown for each of the five FPC ranges (light blue bars). Note that the FPC range 0–19% includes areas where very low or no FPC has been estimated by the *Landsat Foliage Projective Cover – Queensland 2014* dataset.**

## 3.8 Repeat woody vegetation clearing

All maps of woody vegetation clearing produced by SLATS from 1988 to present were combined to assess how much of the clearing mapped in each period had been previously mapped as clearing one or more times; referred to herein as 'repeat clearing'.

Figure 12 (page 34) graphically illustrates repeat clearing as a percentage of total woody vegetation clearing for each period since 1988, and the same data are provided in tabular form since 2011–12 in Table 10 (page 34).

### 3.8.1 Results

- In 2014–15, 29% of the mapped woody vegetation clearing had previously been cleared one or more times since 1988. The percentage of repeat clearing has declined since the 2012–13 period (Table 10, page 34).

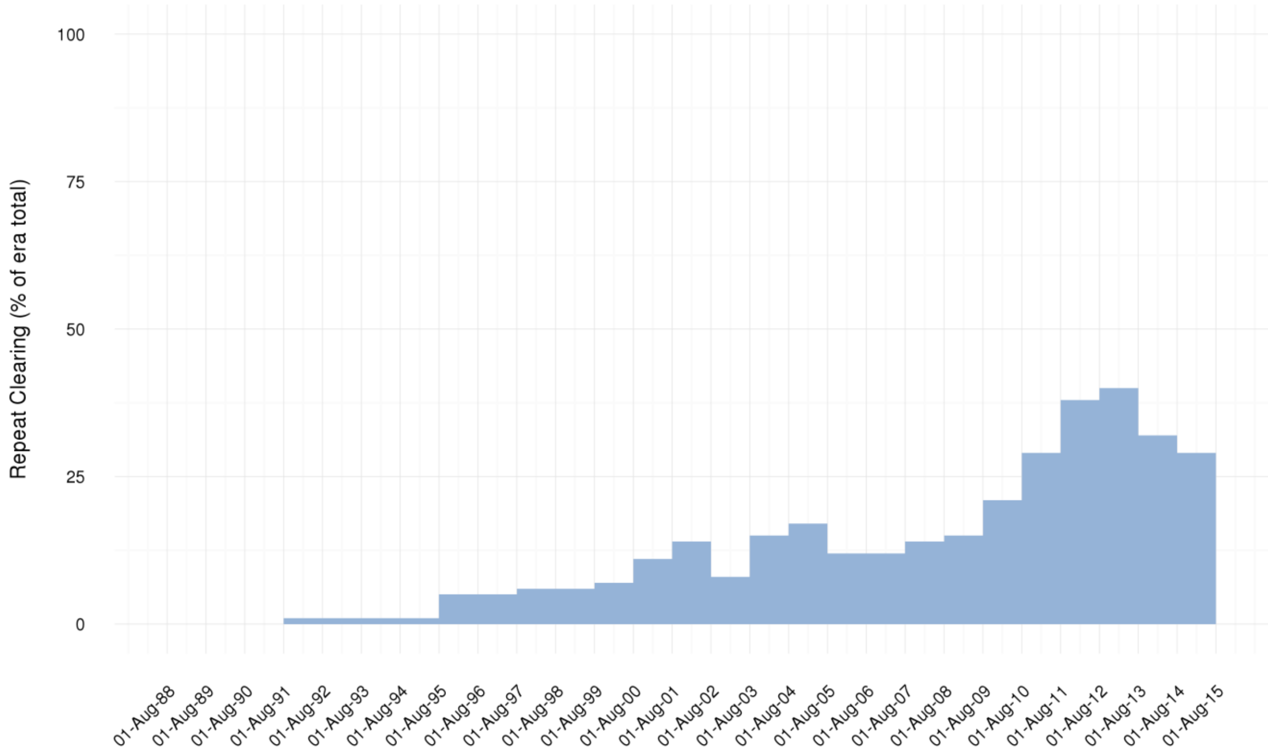



**Figure 12: Repeat woody vegetation clearing as a percentage of total woody vegetation cleared for each period (1988–2015)**

**Table 10: Repeat woody vegetation clearing as a percentage of total woody vegetation cleared for each period (2011–15)**

| Period | Percentage[1] of woody vegetation clearing previously detected as cleared (repeat clearing) |
|---|---|
| **2011–12** | 38 |
| **2012–13** | 40 |
| **2013–14** | 32 |
| **2014–15** | 29 |

[1] Percentages are rounded to nearest whole percentage.

## 3.9 Missed woody vegetation clearing

For each period since 2001–02, SLATS has identified woody vegetation clearing that has been missed when the previous period was mapped. Historically, missed clearing identified from the previous period is less than 2% of the total woody vegetation clearing rate in that period.

### 3.9.1 Results

- During the 2014–15 analysis, approximately 1% of total woody vegetation clearing was identified as missed woody vegetation clearing in the previous period (2013–14) (Figure 13, page 35).

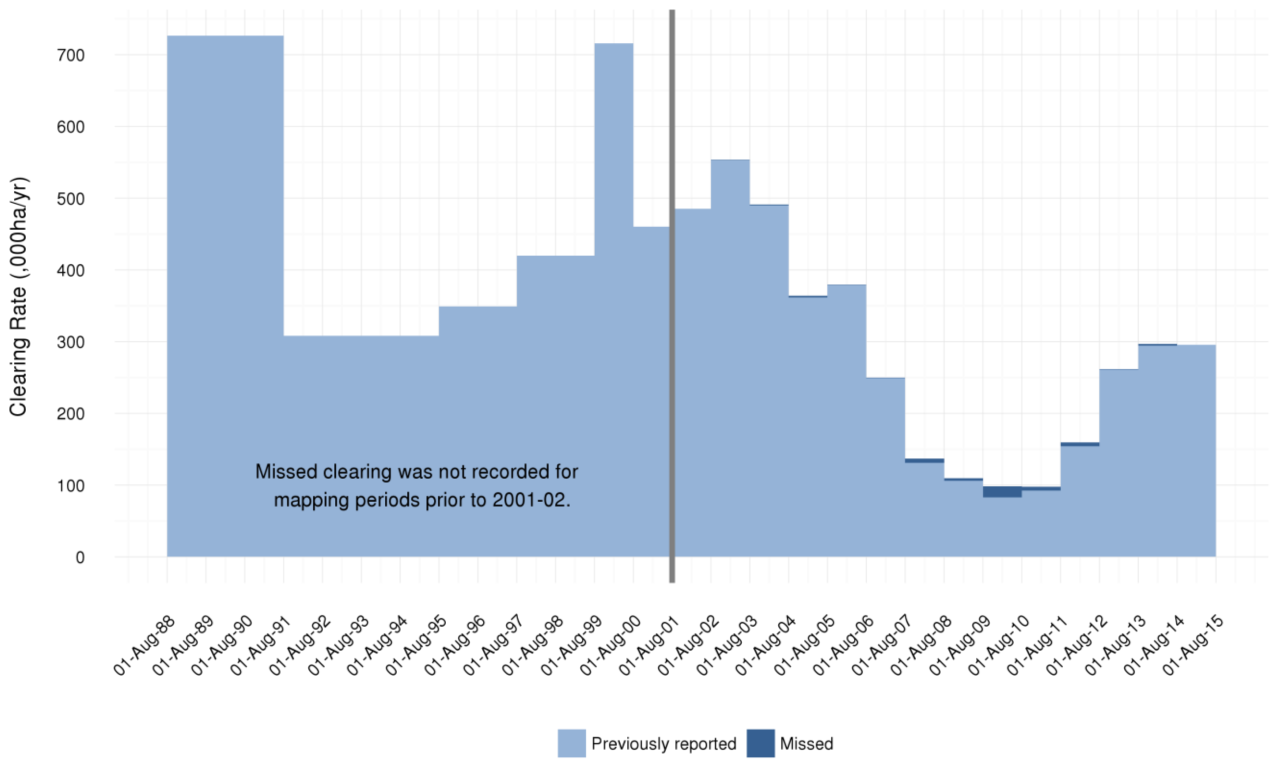



**Figure 13: Annual woody vegetation clearing rate in Queensland (1988–2015) showing the effect on the clearing rate of missed woody vegetation clearing identified in the subsequent period**

# 4 Conclusion

## 4.1 Woody vegetation clearing in Queensland in 2014–15

SLATS is an initiative of DSITI's RSC, in partnership with DNRM. For this report, SLATS used Landsat satellite imagery selected from dry season dates along with automated and manual classification and mapping methods to complete a comprehensive map of woody vegetation clearing for the state of Queensland for the period 2014–15. This map represents one of a series of maps of woody vegetation clearing produced by SLATS between 1988 and 2015. The maps are produced to support the vegetation management framework and to inform a range of other land management policy and planning initiatives, including the protection and management of the GBR.

In 2014–15, the woody vegetation clearing rate was 296 000 ha/year. This was similar to 2012–13 (261 000 ha/year) and 2013–14 (295 000 ha/year) and significantly higher than 2011–12 (155 000 ha/year). The present rate of clearing was also similar to 2006–07 (249 000 ha/year), after which there was a steady decline in the rate of clearing to 2009–10 and 2010–11 when the rates were at the lowest in the SLATS record at 83 000 ha/year and 92 000 ha/year, respectively.

In 2014–15, there has been a 14 000 ha/year increase in remnant woody vegetation clearing compared with the previous period for 2013–14 when 100 000 ha/year of remnant woody vegetation clearing was mapped by SLATS. In 2012–13 the remnant woody vegetation clearing rate was 58 000 ha /year. Based on previous mapping by SLATS, 29% of the woody vegetation clearing mapped in 2014–15 had been previously cleared one or more times since 1988.

The 2014–15 woody vegetation clearing rate remained steady in the Brigalow Belt biogeographic region compared to the previous period for 2013–14, and the rate decreased by 40% in the Mulga Lands biogeographic region. Historically, these biogeographic regions have represented the highest rates of clearing of all of the biogeographic regions across the state. The Gulf Plains biogeographic region recorded a woody vegetation clearing rate of 18 000 ha/year, with much of this clearing localised in one area; this was an almost five-fold increase from the 2013–14 period which was 4 000 ha/year. The Brigalow Belt and Mulga Lands biogeographic regions represent a large part of the Murray-Darling drainage division, and therefore it had the highest rate of woody vegetation clearing of all of the state's major drainage divisions at 119 000 ha/year, a 22% decrease from 153 000 ha/year in 2013–14.

The GBR catchments had a total woody vegetation clearing rate of 108 000 ha/year. This was similar to the 2013–14 period (105 000 ha/year). Since 2011–12, the rate of woody vegetation clearing in the GBR catchments has increased by 46%.

## 4.2 Continuing research and improvement for SLATS

RSC is working with partners in the Joint Remote Sensing Research Program (JRSRP) (https://www.gpem.uq.edu.au/jrsrp) to continually evaluate and improve the quality, accuracy and timeliness of remotely sensed native vegetation products. This currently includes enhancing RSC's processing framework to incorporate Sentinel-2 earth observation mission data from the European Space Agency's Copernicus Programme into operational products including FPC and woody change detection. The Sentinel-2 mission currently includes two planned platforms with a potential revisit time of 5 days and a pixel size of between 10 and 20 metres.

RSC is also working with partners across multiple state agencies to establish a representative database of field FPC observations and airborne LiDAR observations that is being used to assess and refine the current FPC and woody extent products and to report on the effect of moving to the finer resolution Sentinel-2 data in future reporting periods.

RSC has embedded Open Data as a business as usual activity consistent with the Queensland Government Open Data Strategy. As FPC and woody change data are released they are made available on the Queensland Government Open Data Portal. Additionally, a partnership with Terrestrial Ecosystem Research Network-AusCover enables the use and access of these field-verified remote sensing data products for accurate and precise mapping and monitoring of Australian ecosystems by the Australian public and the global research community.

# 5 Related products and information

Information about DSITI's RSC products such as land cover change, Landsat image date footprints, Landsat woody vegetation extent and Landsat Foliage Projective Cover spatial data can be downloaded from the QSpatial data portal: (http://qldspatial.information.qld.gov.au/catalogue/custom/index.page).

Excel spreadsheets to allow further analysis of the 2014–15 SLATS woody vegetation clearing figures by stakeholders can be accessed here: http://www.qld.gov.au/environment/land/vegetation/mapping/slats/.

Landsat imagery is also free to download from the USGS website earthexplorer.usgs.gov.

More information about SLATS can be found at: http://www.qld.gov.au/environment/land/vegetation/mapping/slats/.

Phone: 13QGOV (13 74 68)

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SLATS is dependent on access to high performance computing facilities, Australia's high speed Academic and Research Network, and satellite imagery archive which are serviced and managed through a partnership between DSITI, JRSRP and DNRM. The dedicated support provided by Lindsay Brebber (DNRM) and Neil Flood (JRSRP), in particular, for the operational management of these high technology systems is acknowledged.

SLATS is also dependent on the good will of the United States Geological Survey and the United States National Aeronautics and Space Administration in making the Landsat archive freely available for the development of cost-effective, public-good earth observation products. The benefit derived by Queensland from this extensive archive past, present, and future, is immeasurable. Their continued efforts are gratefully acknowledged.

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# Appendix A Calculation of Woody Vegetation Clearing Rates

## I. Introduction

The Statewide Landcover and Trees Study (SLATS) has been mapping the amount of woody vegetation clearing in Queensland since the mid–1990s, using Landsat satellite imagery. This work has been described in a series of reports, available from the Queensland Government website. The mapping has been based on annual or multi-annual snapshots of the state, which are compared in order to map the areas where woody vegetation cover has been removed, i.e. cleared. One of the main products of this study is an estimation of the area cleared on an annual basis. The earliest versions of this study operated on more limited data, with one snapshot every few years, but since 1999 comparison between pairs of images separated by approximately one year has been possible. These dates are always chosen to be in the dry season (most commonly in the months of August and September). Imagery from these drier months has greater likelihood of being cloud-free, and there is usually greater contrast between tree cover and grass cover under these conditions.

The Landsat satellite passes over any given area in Queensland once every 16 days, scanning a path 185 kilometres wide. Sometimes the resulting images are cloud-affected–at times the images can be completely covered by cloud. In these cases, the imagery is of little value for the detection of land cover change features, including woody vegetation clearing. Therefore, it is not always possible to monitor at exactly the desired date. In some years, the occurrence of two or more cloud-affected images in a row can result in a significant time lag between acquisition of a useful image and the desired monitoring date.

For SLATS, woody vegetation clearing is mapped directly from these available images. However, this means that the total amount of clearing mapped can correspond to a shorter or longer period than one year. If the figures are to be compared between years, this discrepancy must be accounted for. For example, if this is not taken into account, an apparent increase in the mapped area of woody vegetation clearing could be evident, partially due to mapping over a longer period in some areas.

To date, the area of mapped woody vegetation clearing has been used to estimate a woody vegetation clearing rate, in hectares/year, for the region under study. This figure is an estimate of the amount of woody vegetation clearing which would take place in the region during one ideal year (i.e. 365.25 days). These woody vegetation clearing rate figures have been calculated in this manner to enable direct comparison from one year to another. This was particularly important in the earlier years of the SLATS study, when the study periods covered multiple years. Even for the later periods (up until 2013–14), which were nominally annual, the variation could be significant, and so conversion to an annual rate was still necessary to enable comparisons between years.

This document describes the methodology used for the 2014–15 period to estimate the annual clearing rate from the area mapped by SLATS, detailing the assumptions and limitations of this estimate. Section 2 defines what we mean by a woody vegetation clearing rate, and the assumptions required. Section 3 discusses in detail the sources of variation in period length, and how it has been distributed historically. Sections 4 and 5 discuss the spatial and temporal calculations needed to estimate the annual woody vegetation clearing rate as robustly as possible. Finally, section 6 discusses the previous rates calculation method (version 1.0) used prior to the 2014-15 period, and the reasons for changing to the current (version 2.0) methodology.

# II. Clearing rates

Woody vegetation clearing is mapped by comparing imagery from two dates. Thus, the exact date of a clearing event is not known, only that it occurred at some time between the two imagery dates. To estimate the amount of woody vegetation clearing in exactly one year, an assumption must be made about the rate at which woody vegetation clearing is occurring. The simplest assumption is that woody vegetation clearing occurs at a constant rate during the period monitored, and use that constant rate to estimate the area of clearing for exactly one year. For example, if there are two dates which are 1½ years apart, it seems reasonable to assume that the woody vegetation clearing occurred at a constant rate over that period, and that therefore 2/3 of that woody vegetation clearing would have occurred in 1 year (1 year is 2/3 of 1½ years). As discussed in the following sections, there are reasons for making this calculation slightly more complicated, but this is the general idea.

It is important to note that this assumption is only valid when making estimates of the amount of woody vegetation clearing which would occur over one year in a given region. It is not possible to derive exactly which locations would be cleared, only that within a given region, it is likely that a certain amount of clearing would occur in any 365 day period. In addition, it should be noted that the smaller the region in question, the less valid the assumption. For example, if the region were the size of a single small property, it is likely that a landholder might clear a certain stand of woody vegetation in a single event, perhaps over a few days, and it is therefore not valid to assume that the woody vegetation clearing would occur at the same rate throughout the year. It is only when aggregating over much larger regions that is can be assumed that clearing is occurring at a fairly constant rate in that region. Furthermore, it is also not valid to assume that woody vegetation clearing occurs at a constant rate over the whole of Queensland, because different amounts of woody vegetation cover are available for clearing in different regions and there are different imperatives that would drive activity in different regions. For example, woody vegetation clearing occurs at a much lower rate in the Mitchell Grass Downs, where there are very few trees, than in the Mulga Lands, where there are many more trees and shrubs, and other land management requirements.

The size of the region in question should be large enough such that the area being cleared is very small compared to the total size of the region, but small enough to assume that there are the same drivers for woody vegetation clearing, and thus the same rate of woody vegetation clearing occurring over the region. Therefore, larger regions should be disaggregated, and smaller regions aggregated. For reporting in 2014–15, SLATS has disaggregated larger regions to the Landsat scene size (approximately 160km x 160km, or 2.5 million ha, after removing overlaps between scenes), and the smallest regions are sub-catchments on the order of 10000 ha. The Landsat scene is also a suitable unit because this is how the imagery is acquired, and so dates are notionally constant over a single scene (although in some cases images are composited together from multiple dates – see Section 3).

Currently, there are little or no data on how the rate of woody vegetation clearing might vary throughout the year. As outlined above, an assumption is made that woody vegetation clearing occurs at a constant rate through the year, given that SLATS only monitors woody vegetation clearing once per year. It is possible that woody vegetation clearing follows seasonal patterns, and is more common at certain times of year, but to date there are little data available to substantiate this.

# III. Variation in period length

The first SLATS period mapped, was from 1988 to 1991, approximately 3 years, with imagery only available for the start and end dates of the period. The next period mapped was a nominal 4 year period, from 1991 to 1995. After that, mapping was carried out in 2 year periods 1995–97 and 1997–99, and from then on, annual imagery was acquired, so mapping was notionally performed on an annual basis.

For the periods from 1999 onwards, Figure 1 summarizes how the period length has varied over time, across Queensland. The solid line is the median length for each period (in days). This is generally around 365 days. The other lines show how much variability there is in period length across Queensland, for each period. The dashed lines show the upper and lower quartiles, which means that the period length of 50% of pixels lies between these two lines. The dot-dashed lines show the 10th and 90th percentile of the period length, which means that the period lengths of 80% of pixels lie between those two lines. The outer lines are the extremes, and probably represent only a small percentage of these data.

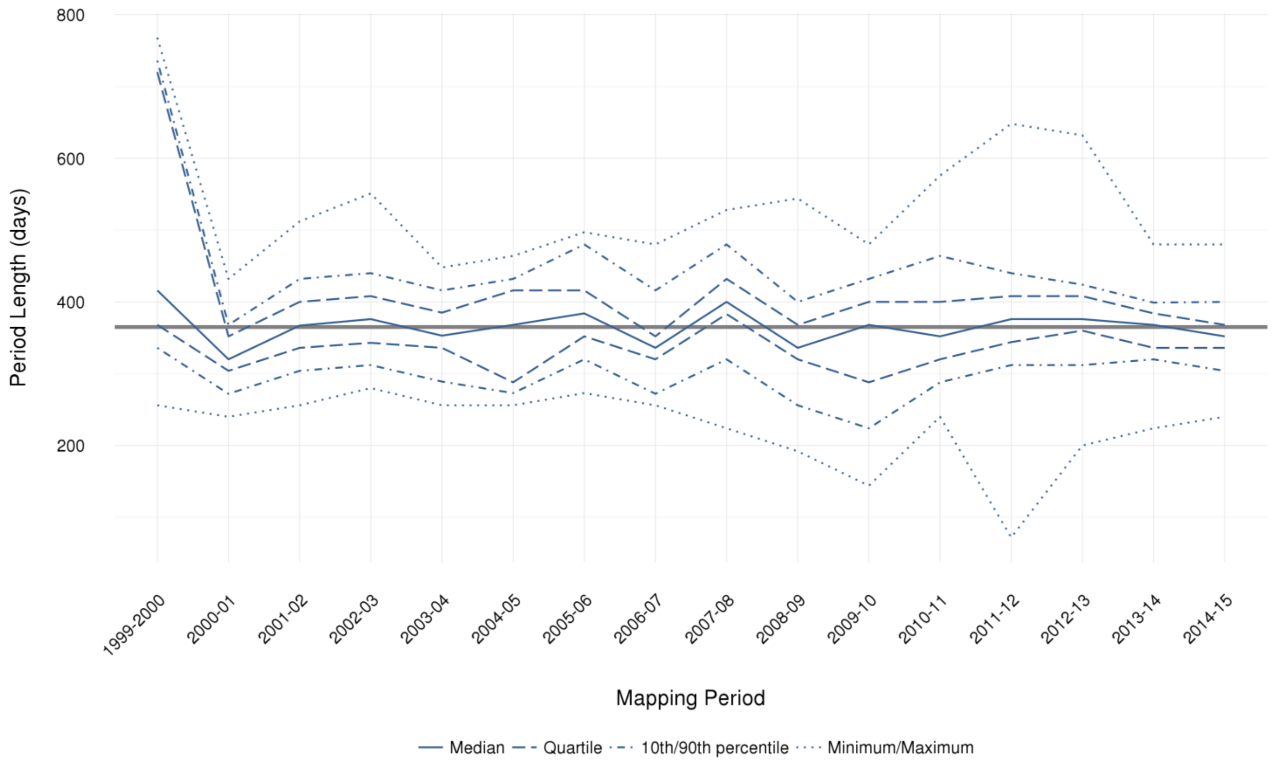


**Figure 1: Variation in SLATS period length since 1999. Solid blue line is the median period length, over all pixels, for each period. Solid grey line is 365 days, i.e. 1 standard year. For each period, 50% of pixels have a period length between the two quartile lines (blue dashes).**

The 2011–12 and 2012–13 periods, both of which include the imagery for 2012, show wider variation in the extremes. This is due to that fact that the 2012 imagery was composited from multiple images, due to the use of Landsat-7 SLC-off imagery. The Landsat 7 SLC-off is a result of a partial failure on board the satellite and results in gaps (i.e. no data) in the imagery. Further details of this are explained in the 2011–12 SLATS report (DSITI 2014). It resulted in a much larger range of dates being required to cover every pixel.

The 1999–2000 period shows a small percentage of very long periods. This is due to the fact that for a number of scenes, no cloud-free imagery was available for the year 2000, and so in effect those scenes were mapped as 2-year periods, from 1999 to 2001.

After 2012, imagery was also composited in some cases (about 25% of scenes), to create a cloud-free image where none was available during the target period. This resulted in a narrower range of dates for most locations, because, for example, two consecutive partly cloudy images could be used to produce a single cloud-free image. This shows up in Figure 1 as a narrowing of the 10th/90th percentile lines for 2013–14 and 2014–15 periods, with a greater proportion of pixels having a period length closer to 365 days.

The use of image compositing from 2012 onwards has required systems to track the dates of every pixel, instead of just the dates of each scene, as was done previously. While this is somewhat more complex, the general principles are the same when considering the calculation of the woody vegetation clearing rate. However, when calculating the annual woody vegetation clearing rate across any group of pixels which do not all have the same start and end dates, some allowance must be made for this. The current method of accounting for this is described in Section 4.

## IV. Summarizing clearing area and period length over a polygon

In order to calculate the annual woody vegetation clearing rate over a given polygon (e.g. a biogeographic region or a drainage division), we need to know the area of woody vegetation clearing actually detected in that polygon, and the length of time for which that polygon was monitored, i.e. the period length for that polygon.

The actual area mapped is given by the total area of all pixels which were mapped as woody vegetation clearing for the period. However, given that the period length varies spatially (i.e. from pixel to pixel), there may be no single value for period length for a given polygon. To account for this, the period length for the polygon is approximated by the average value of the period lengths for each pixel contained within the polygon (based on pixel centre coordinates). All pixels in the polygon are considered, carrying equal weight. This provides an appropriate weighting for different parts of the polygon and different period lengths for pixels within the polygon.

Note that both of these computations are carried out with pixels projected in Albers Equal Area projection, so that areas carry their correct relative weighting, regardless of location.

## V. Estimating clearing rate over time

When estimating the woody vegetation clearing rate for a single period, the only information available is the area cleared in that period, and the period length. However, when there is a time series of clearing areas and image dates over a number of years, there is more information available about how the rate of clearing has varied over time. If the assumption is made that we are estimating the annual woody vegetation clearing rate for a specific 12 month period, explicit use can be made of the clearing area and image dates from the adjacent periods to refine the estimate of clearing rates in any given period.

This can be illustrated by considering the accumulated area cleared over time, for a single Landsat scene which has not been composited. Using a single Landsat scene means the spatial distribution considerations discussed in Section 4 can be ignored, as the period length is constant over the scene. Woody vegetation clearing actually occurs as a series of small events, throughout the year. However, the totals are only observed at the selected imagery dates, once per year. By plotting these once-per-year observations as cumulative values, it can be shown how these single snapshots are representative of an ongoing process. Figure 2 is an illustrative example of this for a single Landsat scene. The solid blue line shows the actual area of woody vegetation clearing mapped, as it accumulates over multiple years. This accumulation has been observed on two dates, 2000-10-31 and 2001-06-20. An estimate of the annual woody vegetation clearing in this period is based on not only the clearing which occurred between these two dates, but also our knowledge of how much clearing was occurring in the periods prior to, and following those dates. The solid red line shows how we would estimate the cumulative woody vegetation clearing rate on the 1st of August of 2000 and 2001. The annual woody vegetation clearing rate is thus the difference between these two estimates.

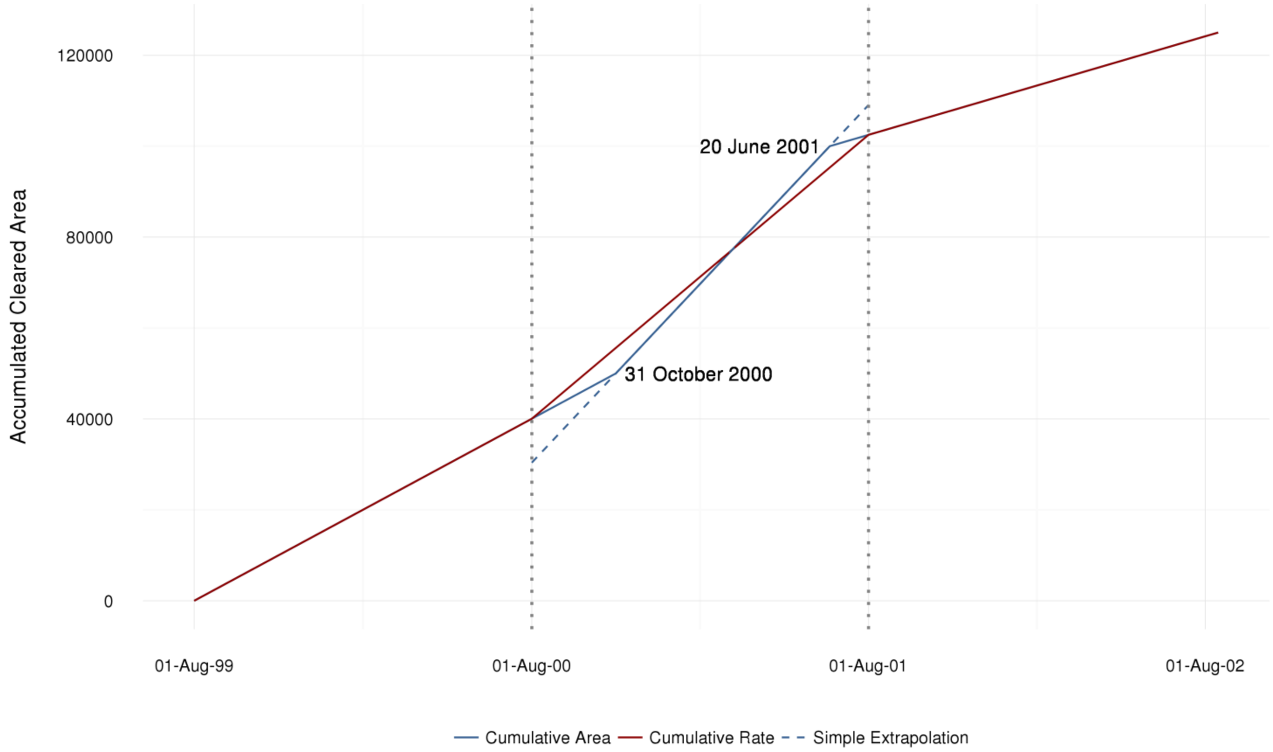


**Figure 2: Example calculation of clearing rate from clearing area, for a single Landsat scene. The solid blue line shows the cumulative area cleared, over time. The area of clearing is observed on 31 October 2000 and 20 June 2001. Solid red line shows accumulated annual clearing rate, observed on the 1st of August each year. Dashed blue line uses a simple extrapolation to estimate change in cumulative clearing, without using known clearing area from preceding and following periods. Annual clearing rate is the difference between the cumulative values on 1st Aug, and this shows the benefit of using the surrounding periods (red line), instead of just the period in question (dashed blue line).**

The dashed blue line demonstrates what would happen if the clearing from the previous and following periods was not taken into account. The measured clearing rate for the period would simply be extrapolated between the two observation dates, extending it out to occupy a full year. In this particular case, this would result in a slightly higher estimate of the annual clearing rate. It should be noted however, that a different set of numbers and dates could give a lower estimate. This is discussed further in Section 6. For 2014–15 reporting, the estimation of rates from the areas and dates is carried out after the spatial averaging described in Section 4, i.e. it happens for each polygon of interest.

## VI. Comparison with version 1.0 method

Prior to the 2014–15 period, a different method was used for calculating annual woody vegetation clearing rate. This method (version 1.0) was initially used at the start of the SLATS program, and was suitable for the computing hardware and software of the time. It was preserved over subsequent reporting periods in order to maintain comparability with previous reporting. However, the methodology has improved for the 2014–15 reporting to better account for the spatial and temporal distribution of woody vegetation clearing and period length variation, resulting in the method described in Sections 4 and 5 (version 2.0). This has also been made possible by a significant improvement in computational hardware and software in recent years.

Version 1.0 differed in two ways. Firstly, the period lengths were only attached to the clearing pixels, rather than to all pixels, and so pixels which were not mapped as clearing were not explicitly weighted. This relied on the implicit assumption that the distribution of period lengths over “nonclearing" pixels was the same as over "clearing". In principle this is a reasonable assumption, as there are no systematic reasons to the contrary, however, it may be less valid in smaller regions where random chance can have more impact. By changing to the newer method, the period length of pixels which are not mapped as woody vegetation clearing is explicitly taken into account, and therefore the period length estimation for each polygon will be more robust against random chance. Version 1.0 was originally chosen as it was more feasible with the available software and hardware, but these limitations no longer apply.

Secondly, version 1.0 estimated the annual rate using only the dates of each period, and without taking account of the clearing mapped in a prior period. This corresponds to the dashed blue line shown in Figure 2. During the first SLATS period, this was the only method available, since there were no prior mapped periods. In subsequent periods, the same methodology was retained for consistency. However, given that there are now many years of woody vegetation clearing data available, as well as improved computational capacity, it is now possible to provide a more robust estimate of the rate of clearing using the multi-date method of version 2.0, as outlined in Section 5. This method also has the advantage that it preserves the cumulative total area cleared, whereas the previous, simpler method relied on the assumption that the over-estimates and under-estimates will, on average, cancel out. It should be noted however, that for completeness, the adoption of this new method implies that when the next period is mapped, the clearing rate estimate for the previous period should be revised, in light of the newly available data. This is the technique used in the 2014-15 report, and so all figures in the whole historic time series have been re-calculated on a consistent basis to allow for comparisons between periods.

In practice, these changes in woody vegetation clearing rate estimation methods make only small differences to the final figures. To demonstrate this, Figure 3 shows the whole time series of annual woody vegetation clearing rates for Queensland, from 1988 onwards, calculated using the old and new methodologies.

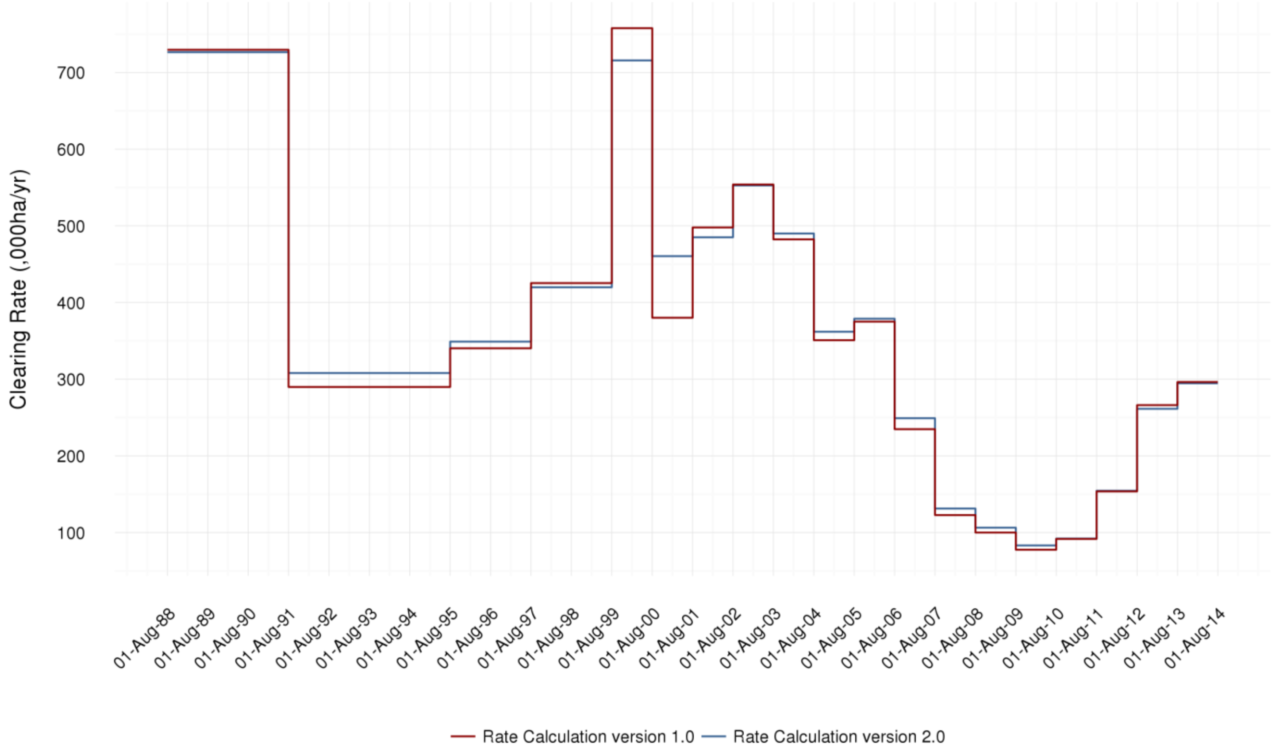


**Figure 3: Annual clearing rates using the version 1.0 (red line) and version 2.0 (blue line) methodologies.**

The red line is the annual woody vegetation clearing rate estimates as they have been given in past SLATS reports. The blue line is the estimates calculated using the version 2.0 methods described in this appendix. In almost all periods the difference is very small. The main exception is in the periods 1999–2000 and 2000–01. The reason for this is that the 1999–2000 period included a number of scenes for which cloud-free imagery was unavailable in 2000, and so they are, in effect, mapped as a 2-year period followed by a period of zero length. This point is discussed in Section 3. By taking account of the known clearing area in the prior and following periods, the estimate of the annual woody vegetation clearing rates are now more robust against these variations in actual period length.