Department of Science, Information Technology and Innovation

Land cover change in Queensland 2015–16

Statewide Landcover and Trees Study Report

Queensland Government

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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

- In 2015–16, the total statewide woody vegetation clearing rate was 395 000* hectares per year (ha/year). This represented a 33% increase from the 2014–15 woody vegetation clearing rate of 298 000** ha/year, and is the highest woody vegetation clearing rate since 2003–04 (490 000 ha/year) (Figure 1, below).
- In 2015–16, clearing of remnant woody vegetation increased by 21% to 138 000 ha/year (35% of total statewide woody vegetation clearing) from 114 000 ha/year in 2014–15 (38% of total statewide woody vegetation clearing) (Figure 1, below and Table 4, page 23). Remnant woody vegetation clearing in the state has increased from 22% of total statewide woody vegetation clearing in 2012–13 to 35% of total statewide woody vegetation clearing in 2015–16 (Figure 1, below and Table 4, page 23).
- In 2015–16, the Great Barrier Reef (GBR) catchments had a total woody vegetation clearing rate of 158 000 ha/year. This represented a 45% increase from the woody vegetation clearing rate of 109 000 ha/year in 2014–15, and represented 40% of total statewide woody vegetation clearing for 2015–16 (Table 6, page 24).

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

* * Annual clearing rate for 2014–15 updated using information from the 2015–16 period. See Appendix A for details of this methodology.

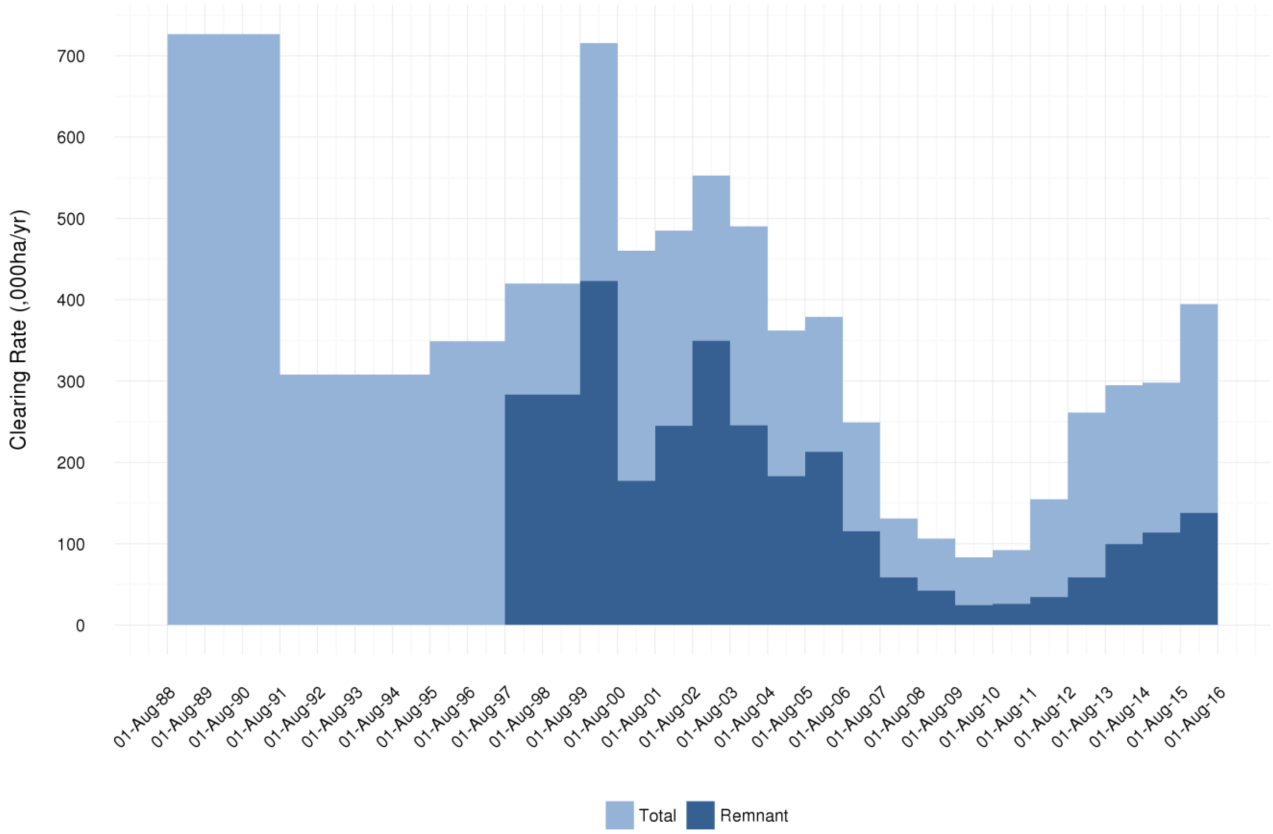


Figure 1: Annual woody vegetation clearing rate in Queensland (1988–2016)[1]

[1] Remnant vegetation mapping is based on regional ecosystems mapping and is available from 1997 onwards. Refer to Table 3, page 17 for details.

- In 2015–16, the biogeographic region with the highest woody vegetation clearing rate was the Brigalow Belt with 207 000 ha/year (Table 8, page 28). This represented a 57% increase from the woody vegetation clearing rate of 132 000 ha/year in 2014–15.
- In 2015–16, the second highest woody vegetation clearing rate occurred in the Mulga Lands biogeographic region with 86 000 ha/year (Table 8, page 28). This represented a 30% increase from the 2014–15 woody vegetation clearing rate of 66 000 ha/year.
- Woody vegetation clearing rates in the Desert Uplands biogeographic region increased by 74% from 19 000 ha/year in 2014–15 to 33 000 ha/year in 2015–16 (Table 8, page 28).
- Woody vegetation clearing rates in the Mitchell Grass Downs biogeographic region decreased by 46% from 26 000 ha/year in 2014–15 to 14 000 ha/year in 2015–16 (Table 8, page 28).
- In 2015–16, the Murray-Darling drainage division had the highest woody vegetation clearing rate of all of the state's major drainage divisions (173 000 ha/year) (Table 9, page 30). This represented a 43% increase from 121 000 ha/year in 2014–15.
- The North East Coast drainage division had the second highest woody vegetation clearing rate of 164 000 ha/year in 2015–16 (Table 9, page 30). This represented a 41% increase from 116 000 ha/year in 2014–15.
- Woody vegetation clearing rates decreased by 22% in the Lake Eyre drainage division from 37 000 ha/year in 2014–15 to 29 000 ha/year in 2015–16 (Table 9, page 30).
- In 2015–16, 34% of the mapped woody vegetation clearing had previously been cleared one or more times since 1988 (Table 10, page 36).
- The dominant replacement land cover class for 2015–16 was pasture (93% of total statewide woody vegetation clearing). The remaining 7% of clearing was attributed to the crop, forestry, mining, infrastructure or settlement replacement land cover classes (Table 5, page 23).

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. 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 (GBR), State of Environment reporting, and biodiversity conservation and planning.

1.1.3 SLATS reporting

SLATS reports are generally produced annually, providing information about the total woody vegetation clearing rate across the state.

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:
  - Great Barrier Reef (GBR) catchments
  - biogeographic regions
  - drainage divisions.

Regional summaries of woody vegetation clearing for local government area, Natural Resource Management regions, catchments and biogeographic sub-regions are published as open data in spreadsheet format (refer to Section 5, page 40 for details about how to access these summaries).

1.1.4 SLATS final report 2015–16

This report comprises the full statewide analysis of annual woody vegetation clearing rates for 2015–16, 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 9 and Section 2.3.1 on page 11, for more detail). Note that this is distinct from the mapping of woody vegetation extent described in the next point.

ii. To derive an estimate of the extent of woody vegetation in different regions. This information provides 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* in Figure 2 on page 9 and Section 2.6.1 on page 17, for more detail). Note that this is distinct from the direct mapping of clearing described in the point above.

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 9 and Section 2.6.1 on page 17, 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 that can be reliably identified and mapped using Landsat satellite imagery and other ancillary information (irrespective of tree/shrub height). Further details about the scope of the mapping undertaken are provided in Section 1.3 (page 6).

This study 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, 2016). Accad *et al*., (2017) provide a comprehensive report for regional ecosystems (woody and non-woody remnant vegetation) from 1997 to 2015. Non-remnant (or regrowth) vegetation is defined as any vegetation that does not fall within the above definition.

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.

This study reports on a category of clearing called 'thinning' that refers to the partial removal of woody vegetation but this does not necessarily align with the VMA definition of thinning. For example, SLATS has mapped areas of partial removal of trees or shrubs where machinery has been used.

The rate of thinning detected for Queensland in 2015–16 is reported separately in Section 3.1.1 on page 21, and is subsequently included in the 'pasture' replacement class.

1.3 Scope

This study detects woody vegetation loss in Queensland that can be reliably mapped, using Landsat satellite imagery and all available ancillary information. 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 21 for discussion on results.

2 Methods

A schematic representation of the SLATS methodology is shown in Figure 2 on page 9. 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 period are selected.
2. A woody vegetation clearing index is calculated to detect areas of change that represent possible clearing of woody vegetation. This model has been calibrated using historic mapping of cleared areas, and highlights most of the possible clearing and omits areas that 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 that are clearing, and ignore areas that 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. For this reason, when Landsat 7 ETM+ was used for SLATS reporting in 2012, a compositing method was developed to infill the missing data in the SLC-off gaps.

The mapping for this report is based on comparison of Landsat 8 OLI imagery for 2015 and 2016 dates at a spatial resolution of 30 metres.

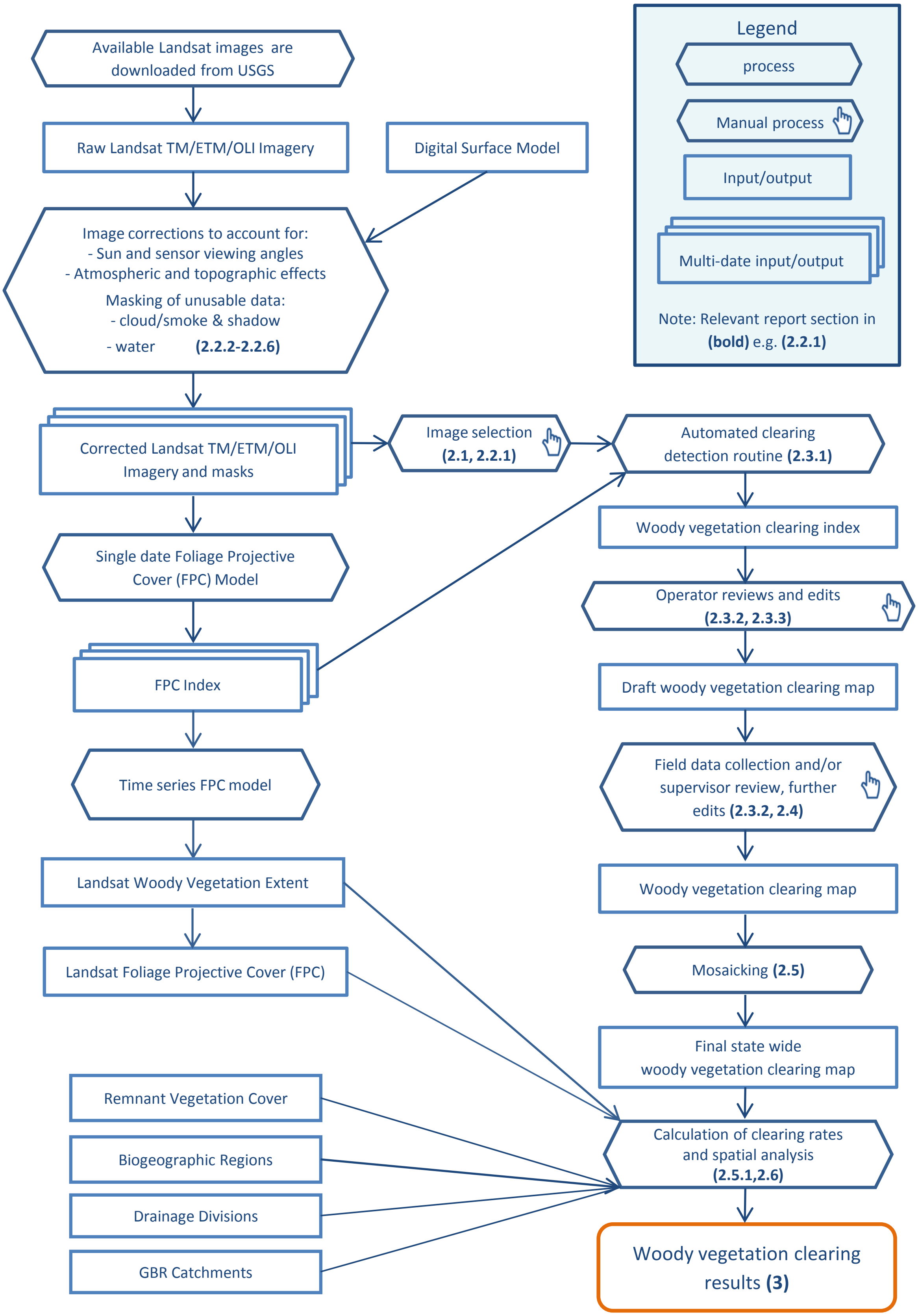


Figure 2: Flowchart of SLATS processes

2.1.2 SLATS mapping period

For this study, a range of satellite overpass dates is acquired in order to capture suitable cloud-free Landsat satellite images for the entire state. The images are typically obtained in the dry winter months between June and October. Suitable imagery for 2015 was obtained between June and September, and, due to persistent widespread rain across the state during 2016, between May and October.

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 about accessing these data is provided in Section 5 on page 40.

2.2 Landsat imagery acquisition and pre-processing for 2015–16

2.2.1 Imagery acquisition

For 2015 and 2016 imagery, geometrically corrected Landsat 8 OLI satellite imagery was downloaded 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 14 scenes for 2015 and 10 scenes for 2016.

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 has previously been undertaken, with appropriate adjustments made to the models by Flood (2014). These adjustments ensure imagery from the two sensors is comparable.

2.2.4 Radiometric standardisation

Radiometric standardisation was applied to the Landsat 8 OLI 2015 and 2016 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 models 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 2015–16 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 that 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 that was fitted to historical mapped clearing data. The model highlights the sorts of changes that are likely to correspond to removal of trees and shrubs, and minimizes the differences that 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 that 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 that *might* have been cleared, but requires manual inspection to distinguish the areas that 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 checking and manually editing the output to ensure a high quality map of woody vegetation clearing is produced.

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 is actually vegetation clearing. Additionally, when visually inspecting the clearing index, remote sensing scientists may identify clearing that has not been detected by the clearing index.

Ancillary data sources also assist in deciding whether the vegetation cover that has been cleared is sufficiently woody to be mapped 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 is only included if the ancillary data are unambiguous.

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, TerraServer and the Queensland Government’s Queensland Globe.
- DSITI’s archive of SPOT4, SPOT5, SPOTMaps and Sentinel-2 MSI 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.

Upon completion of 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 below, 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.

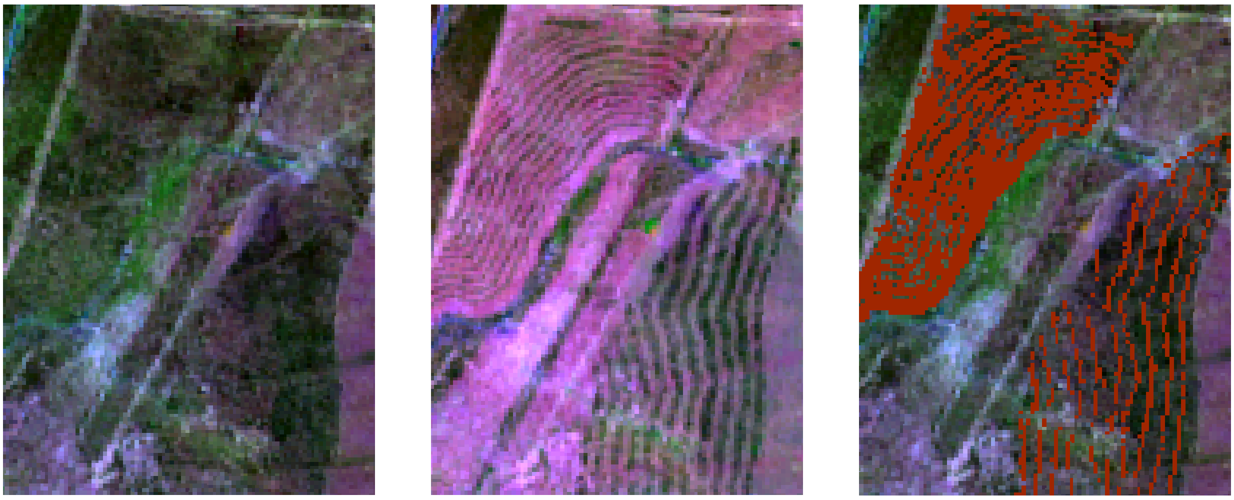
2.3.3 Replacement land cover

During the manual editing stage, each area of woody vegetation clearing is assigned to a replacement land cover class by a remote sensing scientist. This provides an indication of the purpose for which the vegetation was cleared in Table 2 (page 14). The assignment or coding of these classes is primarily based on visual interpretation, with reference to ancillary data sources. In areas where there are many different forms of land use, it can be 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

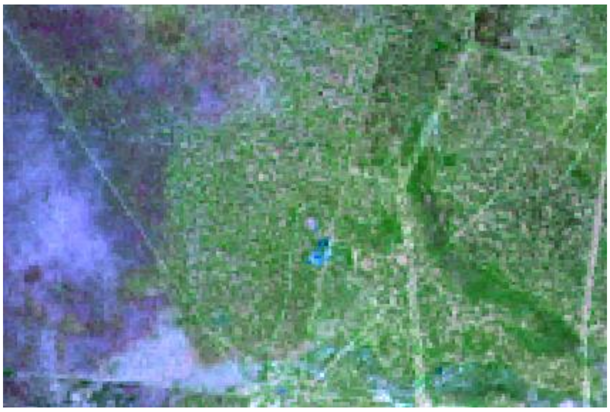
Replacement land cover	Description
Pasture	Grazing and other general land management practices (e.g. this class includes clearing for internal property tracks, fence lines or fire breaks). Areas mapped as thinning are also included in this class.
Crops	Cropping or horticultural purposes.
Forestry	Timber harvesting in state or privately owned native or exotic (e.g. pine) forests or plantations.
Mining	Mining activities (including coal seam gas infrastructure).
Infrastructure	Roads, railways, water storage, pipelines, powerlines etc.
Settlement	Imminent urban development.

As discussed in Section 1.2.5 (page 6), remote sensing scientists can sometimes detect partial removal of trees or shrubs (as shown in Figure 4 below and Figure 5 on page15). This is coded to a 'thinning' class (distinct from the VMA definition of thinning). Ancillary high resolution imagery, where available, can be particularly important in confirming this class. The total amount of thinning detected is reported separately in Section 3.1.1 on page 21, and is subsequently included in the 'pasture' replacement land cover class, as this is the main context in which it occurs.

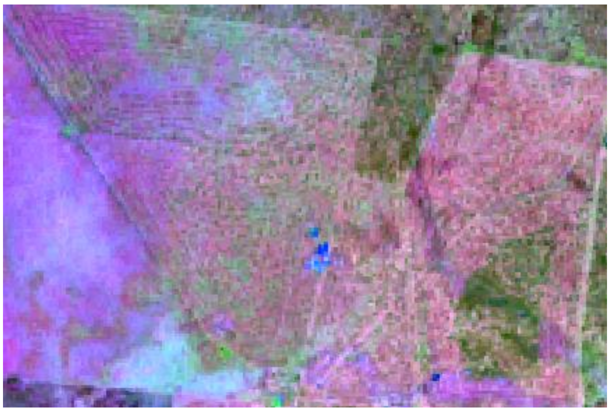


a) Landsat 8 OLI captured in 2015 b) Landsat 8 OLI captured in 2016 c) Woody Vegetation Thinning Map

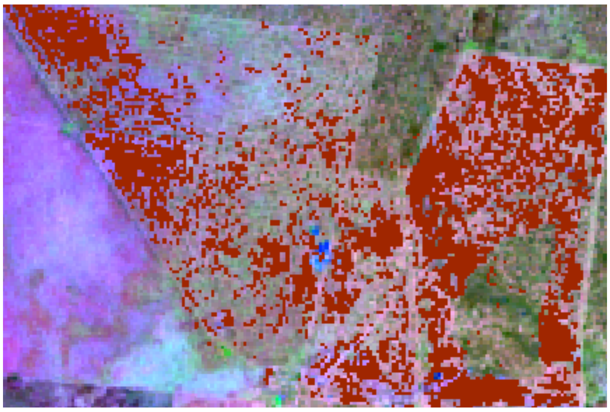
Figure 4: An example of a strip thinning event in south western Queensland as seen in Landsat 8 OLI imagery. a) Landsat 8 OLI captured on 19 July 2015 before the thinning event. b) Landsat 8 OLI captured on 9 October 2016 after the thinning event. c) Woody vegetation thinning map edited by a remote sensing scientist overlaid on imagery in a). Mapped thinning is shown as dark red. This example shows some of the diversity in the areas mapped as strip thinning. Less thinning has occurred in the southern section compared to the northern section. The area in all panels is the same, and is approximately 3 kilometres east to west and 4 kilometres north to south.



a) Landsat 8 OLI captured in 2015



b) Landsat 8 OLI captured in 2016



c) Woody Vegetation Thinning Map

Figure 5: An example of a thinning event in south western Queensland as seen in Landsat 8 OLI imagery. a) Landsat 8 OLI captured on 19 July 2015 before the thinning event. b) Landsat 8 OLI captured on 9 October 2016 after the thinning event. c) Woody vegetation thinning map edited by a remote sensing scientist overlaid on imagery in a). Mapped thinning is shown as dark red. This example shows the partial removal of trees and shrubs across the area, as indicated in the woody vegetation thinning map. The area in all panels is the same, and is approximately 6 kilometres east to west and 4 kilometres north to south.

2.3.4 Limitations

The 30 metre pixel size of Landsat imagery is the main limitation for mapping woody vegetation. The pixel size limits the size of landscape features that can reliably be detected. For example, clearing of narrow riparian strips of woody vegetation cover less than 30 metres wide may sometimes be missed.

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. DSITI remote sensing scientists 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 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 DSITI produces, including those that are inputs to the SLATS clearing index.

In previous SLATS mapping periods, an extensive field program was also undertaken to inform the mapping of woody vegetation clearing, and in particular to clarify areas of uncertainty.

High resolution satellite imagery provides a valuable image interpretation resource, and in many cases provides an alternative to physical field visits. It is especially useful for interpreting and verifying areas that are not physically accessible. For this reason, in the 2015–16 mapping period, fewer field observations of clearing were collected than in previous years.

2.5 Compilation of statewide data

A large, seamless mosaic of woody vegetation clearing is created by joining all scenes covering the state. Each scene is trimmed to a standard scene template to minimise overlap, and remove areas outside the Queensland state border. When producing the mosaic, the scenes are overlapped in paths from north to south and paths are joined from east to west. The full resolution of these data (30 metre pixel) is preserved.

To ensure that clearing activity related to timber harvesting is not confused with other replacement land cover classes, clearing from known forestry areas is recoded into the forestry replacement land cover class (this does not apply to mining and infrastructure classes within forestry areas). Known forestry areas are obtained from relevant datasets. See Table 3 on page 17.

In recognition of the limited ability to detect clearing at the level of one or two Landsat pixels, a filter is 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 is attributed with the image dates from the compositing process (refer to Section 2.2.1 on page 10).

All statistics are 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) based on a 1st August–1st August period. This conversion makes the results comparable by re-weighting shorter or longer periods, based on the assumption that clearing occurs at a uniform rate throughout the year. A slight adjustment of the woody vegetation clearing rates for the previous period occurs as a result of this rate calculation method.

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

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 21.

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 below provides a list of spatial data sets used in these analyses.

Table 3: Spatial datasets used to summarise woody vegetation clearing

Spatial dataset	Data custodian	Mapping period
Agricultural land audit – current forestry plantations – Queensland (current to 2017)	DNRM	2015–16
Queensland Cadastre (where base tenure is equal to 'State Forest', 'Forest Reserve' or Timber Reserve' - current to April 2015)	DNRM	2015–16
Queensland 1:25000 map sheet key map (current to 2010)	DNRM	2015–16
Landsat Woody Vegetation Extent – Queensland	DSITI	2015–16
Landsat Foliage Projective Cover – Queensland 2014	DSITI	2015–16
Biogeographic Regions – Queensland (version 5.0)	DNRM	2015–16; 2014–15; 2013–14; 2012–13
Drainage Divisions Queensland	DNRM	2015–16; 2014–15; 2013–14; 2012–13
Great Barrier Reef Catchments	DNRM	2015–16; 2014–15; 2013–14; 2012–13
Remnant Vegetation Cover of Queensland (current to 2015)	DSITI	2015–16
Remnant Vegetation Cover of Queensland (current to 2013)[1]	DSITI	2014–15; 2013–14
Remnant Vegetation Cover of Queensland (current to 2011)[1]	DSITI	2012–13; 2011–12
Remnant Vegetation Cover of Queensland (current to 2009)[1]	DSITI	2010–11; 2009–10
Remnant Vegetation Cover of Queensland (current to 2007)[1]	DSITI	2008–09; 2007–08
Remnant Vegetation Cover of Queensland (current to 2006)[1]	DSITI	2006–07
Remnant Vegetation Cover of Queensland (current to 2005)[1]	DSITI	2005–06
Remnant Vegetation Cover of Queensland (current to 2003)[1]	DSITI	2004–05; 2003–04
Remnant Vegetation Cover of Queensland (current to 2001)[1]	DSITI	2002–03; 2001–02
Remnant Vegetation Cover of Queensland (current to 2000)[1]	DSITI	2000–01
Remnant Vegetation Cover of Queensland (current to 1999)[1]	DSITI	1999–00
Remnant Vegetation Cover of Queensland (current to 1997)[1]	DSITI	1997–99

[1]Remnant Vegetation Cover of Queensland (Version 10.0, 2016)

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 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.

1:25 000 Map sheet

The statewide woody vegetation clearing mosaic was intersected with the Queensland 1:25 000 map sheet key map, and clearing rates calculated for each 1:25 000 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 every two years.

For each mapping period from 1997–99 to 2015–16, 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 17). 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 and Landsat Foliage Projective Cover

Previous SLATS reports (e.g. DSITI, 2015) have presented and reported on estimates of woody vegetation density and extent based on published datasets, either *Wooded Extent and Foliage Projective Cover – Queensland*, or the equivalent pair of *Landsat Woody Vegetation Extent – Queensland* and *Landsat Foliage Projective Cover – Queensland*.

These datasets were all produced using the methods 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 that 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* statewide dataset provides an estimate of the extent of woody vegetation across the state. It is a separate product to the SLATS clearing mapping, and is not used to directly map clearing of woody vegetation. It is used in this report only to provide context for the rate of woody vegetation clearing, showing, for any given region (e.g. bioregions, drainage divisions), what percentage of that region is considered ‘woody’, and how that compares to the amount of clearing.

For example, of two regions with a similar rate of woody vegetation clearing, this clearing may represent a greater proportion of the woody vegetation in one region, while only representing a small proportion of the woody vegetation in another.

In this report, a further step has been taken in order to estimate the uncertainty on the woody extent area. As described above, the principle uncertainties arise due to inter-annual variations in sparsely wooded areas, in which a given pixel is sometimes classified as woody, and sometimes not. By using an ensemble of five years of the *Woody Extent* product (2010 to 2014), an estimation was made of the mean percentage of each summary region that was considered ‘woody’, and also the standard deviation of this percentage. This report shows the percentage of the region that was considered ‘woody’ as being the *mean +/- uncertainty*, where the *uncertainty* is 2 standard deviations. This uncertainty applies only to the estimates of woody area, and is not applicable to the reported rates of clearing.

The *Landsat Foliage Projective Cover* dataset provides an estimate of the density (expressed as percentage of FPC) of woody vegetation across the state. The most recent available version of this product is that produced 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%. This allows the reader to answer questions such as ‘given that a certain amount of clearing has occurred, how was this clearing distributed across the range of tree and shrub densities in the state?’ In general, clearing occurs evenly across the range of tree and shrub densities but analyses using the *Landsat Woody Vegetation Extent* and *Landsat Foliage Projective Cover* products can help to indicate if a particular range of vegetation density is over-represented in the woody vegetation clearing mapping.

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:

- GBR catchments
- biogeographic regions
- drainage divisions.

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 remote sensing scientists, but enables any problems to be reliably traced and rectified.

During the manual editing phase, DSITI remote sensing scientists consult regularly with each other, and this combined with a checking process, is intended to maximise consistency.

3 Results and discussion

This section presents the results of the assessment of woody vegetation clearing for the 2015–16 period, at the statewide and regional level, after intersection with various GIS layers described in Section 2.6 on page 16.

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 2015–16 period was 395 000 ha/year, or 0.23% of the land area of Queensland. In total, this woody vegetation clearing rate represents an area of approximately 63 kilometres x 63 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 6 (page 22). 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 2015–16 period, the figure for woody vegetation loss due to thinning was 33 000 ha/year (8% of total statewide woody vegetation clearing), more than double the 2014–15 figure of 16 000 ha/year (4% of total statewide woody vegetation clearing).

3.1.2 Natural tree death and natural disaster damage

- Approximately 1% of total statewide woody vegetation clearing in 2015–16 was mapped as natural tree death. Much of this occurred around the Gulf of Carpentaria where areas of mangrove dieback were mapped.
- No natural disaster damage was mapped during the 2015–16 period.
- Woody vegetation change due to natural tree death or natural disaster damage was not included in the final woody vegetation clearing statistics.

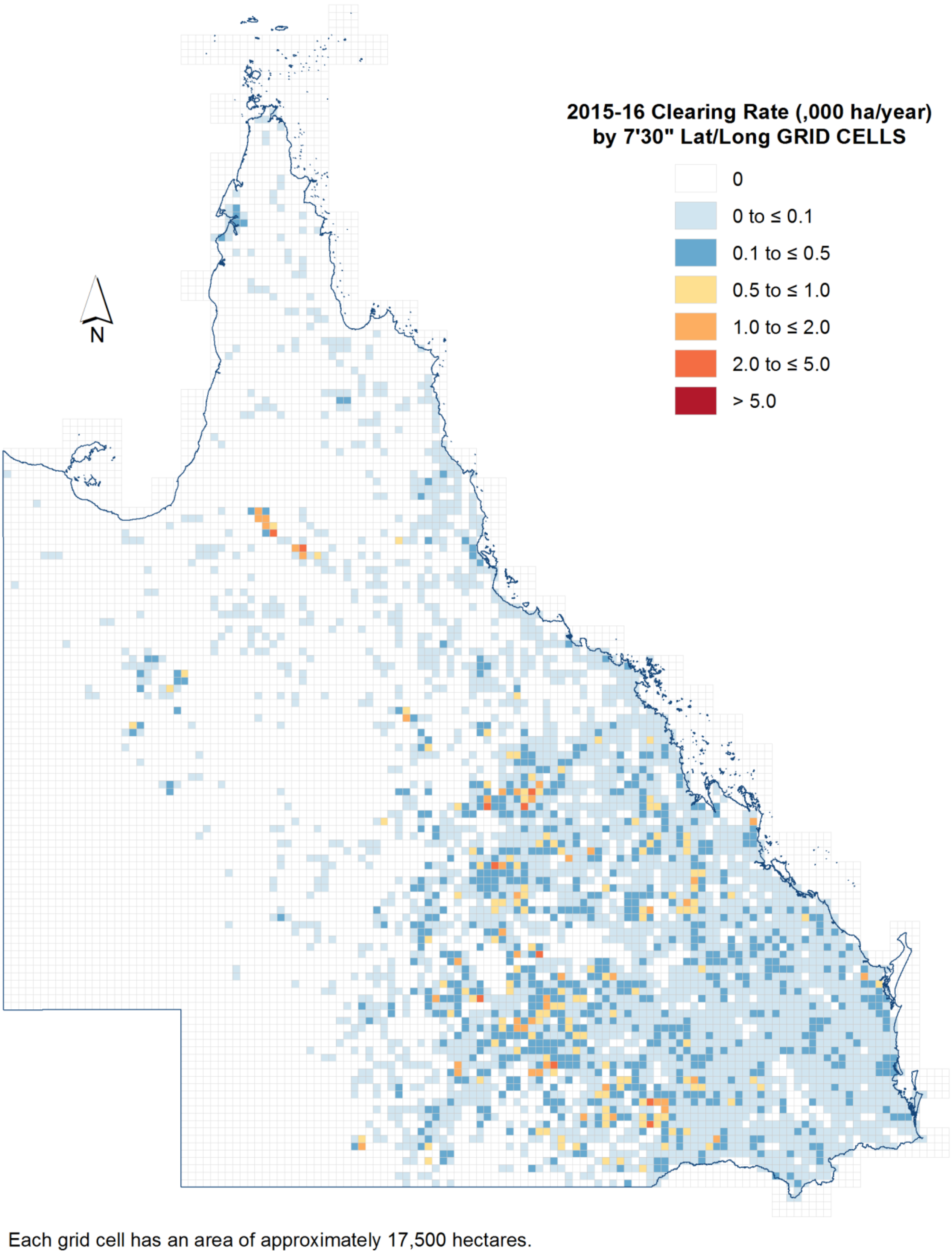


Figure 6: Aggregated annual woody vegetation clearing rate in Queensland for 2015–16

3.2 Woody vegetation clearing by remnant status

To provide a summary of remnant status, SLATS 2015–16 woody vegetation clearing mapping data was intersected with the Remnant Vegetation Cover of Queensland, current to 2015 (Queensland Herbarium, 2016). Clearing figures since 2012–13 are included in Table 4 below for comparison.

3.2.1 Results

- The rate of clearing of remnant woody vegetation for 2015–16 was 138 000 ha/year. This compares to 114 000 ha/year of remnant woody vegetation clearing in 2014–15 (Table 4, below). This represented an increase of 21% in the rate of remnant woody vegetation clearing from the previous period.
- Remnant woody vegetation clearing was 22% of total statewide woody vegetation clearing in 2012–13, 38% in 2014–15 and then 35% of the total statewide woody vegetation clearing in 2015–16.
- In 2015–16, the rate of non-remnant woody vegetation clearing was 257 000 ha/year (185 000 in 2014–15) (Table 4, below).

Table 4: Woody vegetation clearing by remnant status (2012–16)

	Rate of woody vegetation clearing (,000 ha/year)[1]		
Period	Remnant	Non-remnant	Total
2012–13	58	203	261
2013–14	100	195	295
2014–15	114	185	298
2015–16	138	257	395

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

3.3 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 2015–16 (and for comparison, results since 2012–13) in Table 5 below.

3.3.1 Results

- The dominant replacement land cover class for 2015–16 was pasture (93% of total statewide woody vegetation clearing). This was consistent with results since 2012–13 (Table 5, below).
- Forestry was the second largest replacement land cover (4% of total statewide woody vegetation clearing), and was consistent with results since 2012–13 (Table 5, below).

Table 5: Woody vegetation clearing by replacement land cover (2012–16)

	Rate of woody vegetation clearing (,000 ha/year)[1]						
Period	Pasture	Crops	Forest	Mining	Infrastructure	Settlement	Total
2012–13	236	2	8	6	7	1	261
2013–14	271	4	9	5	4	1	295
2014–15	271	5	16	3	1	2	298
2015–16	369	4	16	3	2	1	395

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

3.4 Woody vegetation clearing by GBR catchments

The GBR catchments are a subset of the North East Coast drainage division indicated by the blue outline in Figure 8 on page 26.

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 the periods 2012–13 until 2015–16) (Table 6, below)
- woody vegetation clearing rates by replacement land cover, and estimated woody vegetation extent in the GBR catchments (Table 7, below)
- annual woody vegetation clearing rates for the GBR catchments against total statewide woody vegetation clearing rates from 1988–2016 (Figure 7, page 25)
- a map of the spatial distribution and intensity of woody vegetation clearing (,000 ha/year) for the GBR catchments within Queensland (Figure 8, page 26).

3.4.1 Results

- The GBR catchments recorded a woody vegetation clearing rate of 158 000 ha/year in 2015–16. This represented a 45% increase from the woody vegetation clearing rate of 109 000 ha/year in 2014–15 (Table 6, below).
- 40% of the state's total woody vegetation clearing occurred in the GBR catchments in the 2015–16 period.
- The rate of clearing of woody vegetation in the GBR catchments since 2012–13 has increased by 49%, and has been consistently increasing since 2010–11 (Table 6, below and Figure 7, page 25).
- The dominant replacement land cover class in the GBR catchments in 2015–16 was pasture (91%), while 7% was cleared to forestry (Table 7, below). These figures were consistent with results since 2012–13.
- The trend in the woody vegetation clearing rate in the GBR catchments from 1988–2016 against the total statewide woody vegetation clearing rates is shown in (Figure 7, page 25).

Table 6: Woody vegetation clearing in the GBR catchments (2012–16)

Period	Rate of woody vegetation clearing (,000 ha/year)[1]		% of total clearing in QLD
	GBR catchments	Total clearing in QLD	
2012–13	106	261	40
2013–14	105	295	36
2014–15	109	298	37
2015–16	158	395	40

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

Table 7: 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	42313	143	2	11	1	<1	<1	158	67 ± 2

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

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

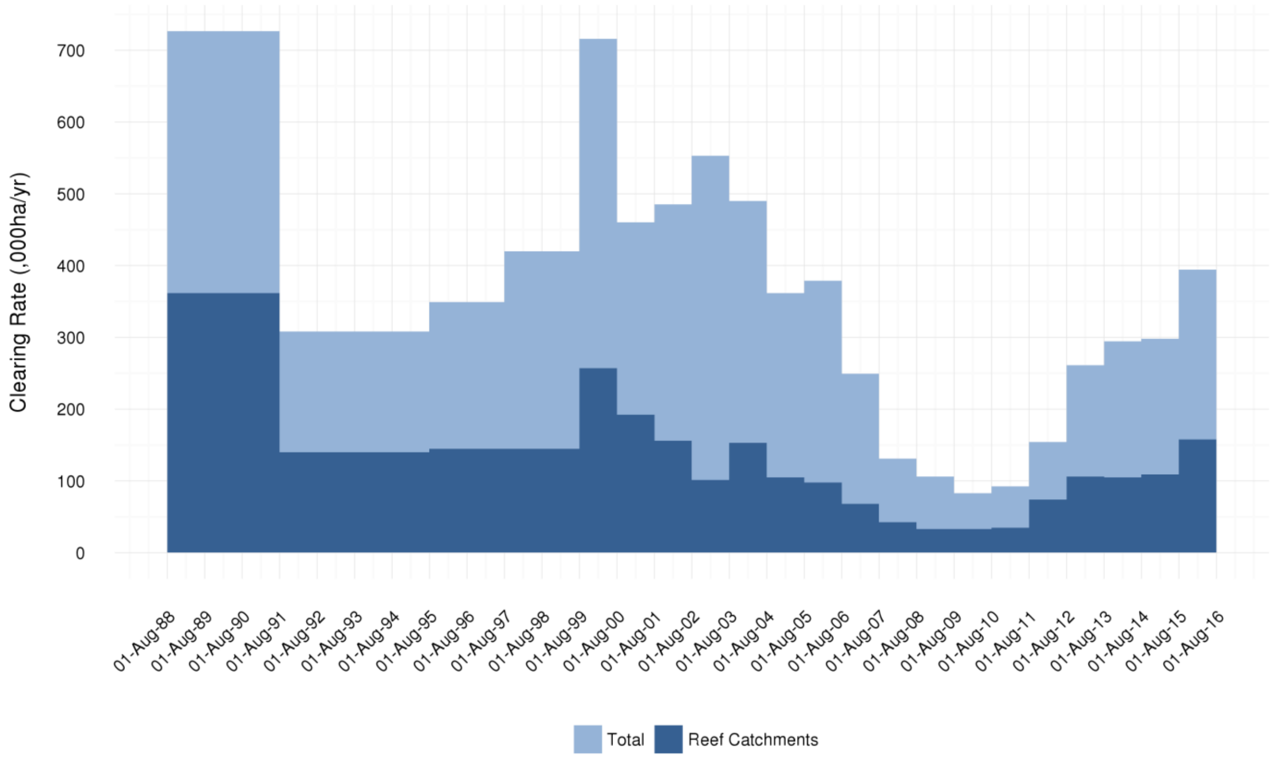


Figure 7: Woody vegetation clearing rates in the GBR catchments (1988–2016)

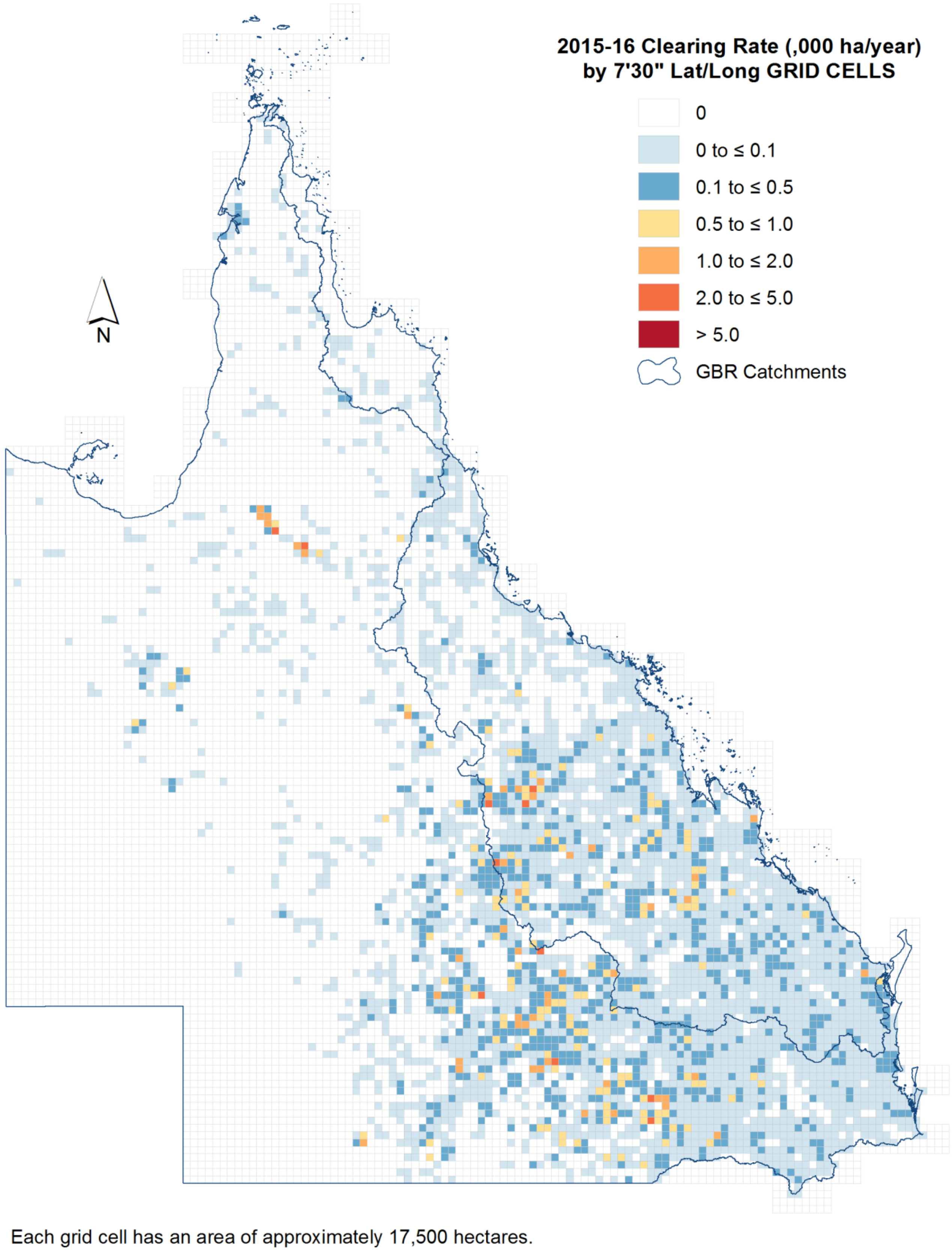


Figure 8: Woody vegetation clearing in Queensland and the GBR catchments for 2015–16

3.5 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 (Neldner *et al*., 2017).

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 class, and the clearing rate for each biogeographic region as a percentage of total statewide woody vegetation clearing (Table 8, page 28)
- a map of the spatial distribution and intensity of woody vegetation clearing (,000 ha/year) for biogeographic regions within Queensland (Figure 9, page 29)
- an estimated woody vegetation extent for each biogeographic region (Table 8, page 28).

3.5.1 Results

- The Brigalow Belt biogeographic region had the highest woody vegetation clearing rate with 207 000 ha/year (52% of total statewide woody vegetation clearing) for 2015–16 (Table 8, page 28). This represented a 57% increase from the woody vegetation clearing rate of 132 000 ha/year in 2014–15.
- The second highest woody vegetation clearing rate occurred in the Mulga Lands biogeographic region with 86 000 ha/year (22% of total statewide woody vegetation clearing) for 2015–16 (Table 8, page 28). This represented a 30% increase from the 2014–15 woody vegetation clearing rate of 66 000 ha/year.
- Woody vegetation clearing rates in the Desert Uplands biogeographic region increased by 74% from 19 000 ha/year in 2014–15 to 33 000 ha/year in 2015–16 (Table 8, page 28).
- Woody vegetation clearing rates in the Mitchell Grass Downs biogeographic region decreased by 46% from 26 000 ha/year in 2014–15 to 14 000 ha/year in 2015–16 (Table 8, page 28).
- The dominant land cover replacement class was pasture in most biogeographic regions. The exception was in Southeast Queensland and Wet Tropics where forestry was the dominant land cover replacement class (Table 8, page 28).

Table 8: Woody vegetation clearing by replacement land cover by biogeographic region (2015–16)

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	198	4	3	1	1	<1	207	52	52 ± 1
Cape York Peninsula	12305	1	<1	0	1	<1	<1	2	1	95 ± 2
Central Queensland Coast	1484	2	<1	2	<1	<1	<1	4	1	80 ± 2
Channel Country	23217	<1	0	0	0	<1	0	<1	<1	11 ± 1
Desert Uplands	6941	33	<1	0	0	<1	<1	33	8	64 ± 2
Einasleigh Uplands	11626	4	<1	0	<1	<1	0	4	1	87 ± 1
Gulf Plains	21911	20	0	<1	<1	<1	<1	20	5	72 ± 1
Mitchell Grass Downs	24162	14	0	0	0	<1	0	14	4	13 ± 1
Mulga Lands	18606	85	<1	<1	0	<1	0	86	22	47 ± 4
New England Tableland	775	2	<1	<1	<1	<1	0	3	1	62 ± 2
Northwest Highlands	7344	<1	0	0	<1	<1	0	<1	<1	61 ± 1
Southeast Queensland	6248	9	<1	10	<1	<1	1	20	5	74 ± 5
Wet Tropics	1993	<1	<1	1	0	<1	<1	2	<1	85 ± 1

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

[2] Based on the *'Landsat Woody Vegetation Extent* – Queensland' dataset

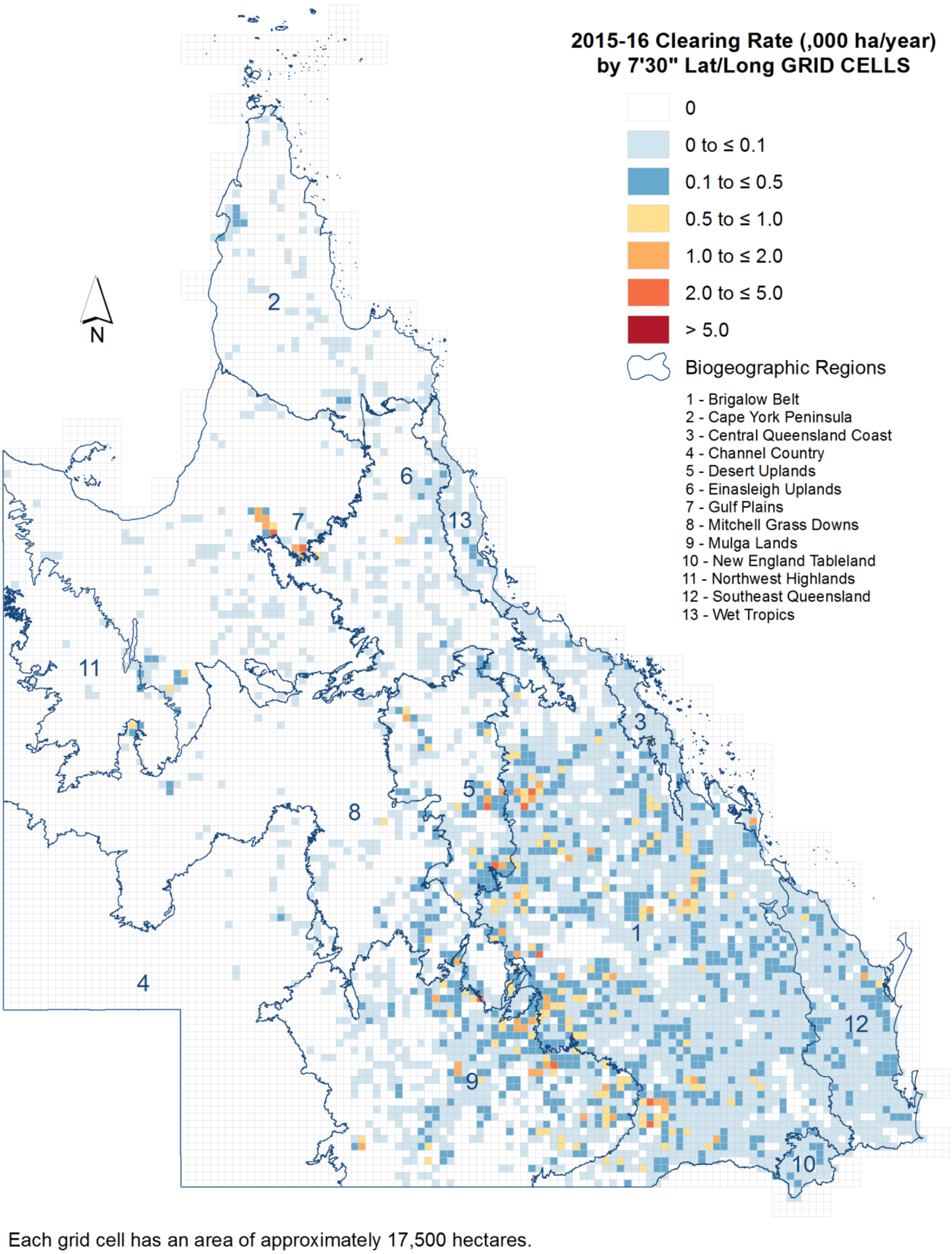


Figure 9: Woody vegetation clearing in Queensland for 2015–16 showing biogeographic regions

3.6 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 class, and the clearing rate for each drainage division as a percentage of total statewide woody vegetation clearing (Table 9 below)
- a map of the spatial distribution and intensity of woody vegetation clearing (,000 ha/year) for drainage divisions (Figure 10, page 31)
- an estimated woody vegetation extent for each drainage division (Table 9 below).

3.6.1 Results

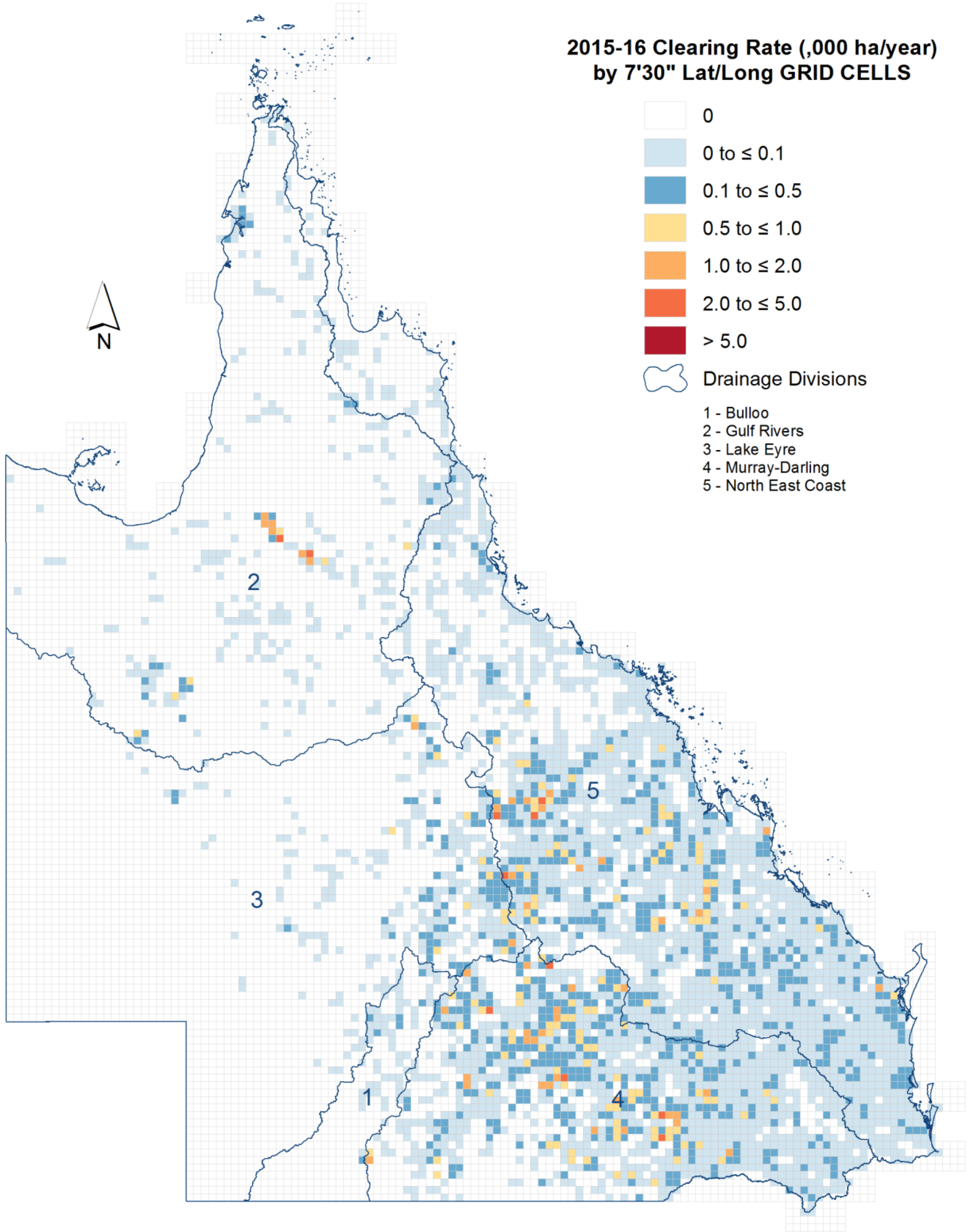
- In 2015–16, the Murray-Darling drainage division recorded the highest woody vegetation clearing rate with 173 000 ha/year (44% of total statewide woody vegetation clearing) (Table 9 below). This represented a 43% increase from 121 000 ha/year in 2014–15.
- The second highest woody vegetation clearing rate was recorded in the North East Coast drainage division with 164 000 ha/year (42% of total statewide woody vegetation clearing) (Table 9 below). This represented a 41% increase from 116 000 ha/year in 2014–15.
- Woody vegetation clearing rates decreased by 22% in the Lake Eyre drainage division from 37 000 ha/year in 2014–15 to 29 000 ha/year in 2015–16 (Table 9 below).
- The dominant land cover replacement class in all drainage divisions was pasture (greater than 95%), except in the North East Coast division where 9% of clearing was attributed to the forestry land cover replacement class, and 88% to the pasture replacement land cover class (Table 9 below).

Table 9: Woody vegetation clearing by replacement land cover by drainage division (2015–16)

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	0	0	3	1	30 ± 1
Gulf Rivers	45315	24	<1	<1	1	<1	<1	26	7	73 ± 1
Lake Eyre	51013	29	<1	0	0	<1	<1	29	7	20 ± 1
Murray-Darling	26252	168	2	2	<1	<1	<1	173	44	48 ± 3
North East Coast	45028	145	2	14	1	1	1	164	42	67 ± 2

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

[2] Based on the *'Landsat Woody Vegetation Extent – Queensland'* dataset



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

Figure 10: Woody vegetation clearing in Queensland’s drainage divisions for 2015–16

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

Figure 11 on page 33 is a map of the state that shows the woody vegetation extent (as estimated by the *Landsat Woody Vegetation Extent – Queensland dataset).* The map shows that the northern and eastern parts of the state have extensive areas of estimated woody vegetation. The central, southern and western parts of the state are generally patchier in woody vegetation cover and have large areas that are estimated to be non-woody vegetation. It is important to note that this map does not distinguish the structure, height 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 12 on page 34 is a map of the state that 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, typifying 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 that 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 that 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

- It was estimated that between 50 and 51% of the total area of the state had woody vegetation present at Landsat scale (Figure 11, page 33). The total area of woody vegetation clearing mapped in 2015–16 was therefore a small percentage of the estimated total area of woody vegetation across the state (approximately 0.23% of the state, or 0.45% of the area of woody vegetation). 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 2015–16, 47% of all woody vegetation clearing for the state occurred in the FPC range 0–19% (Figure 13, page 35). 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.
- 43% of all woody vegetation clearing occurred in the FPC range 20–39% (23% of the total area of the state is in this range of FPC).

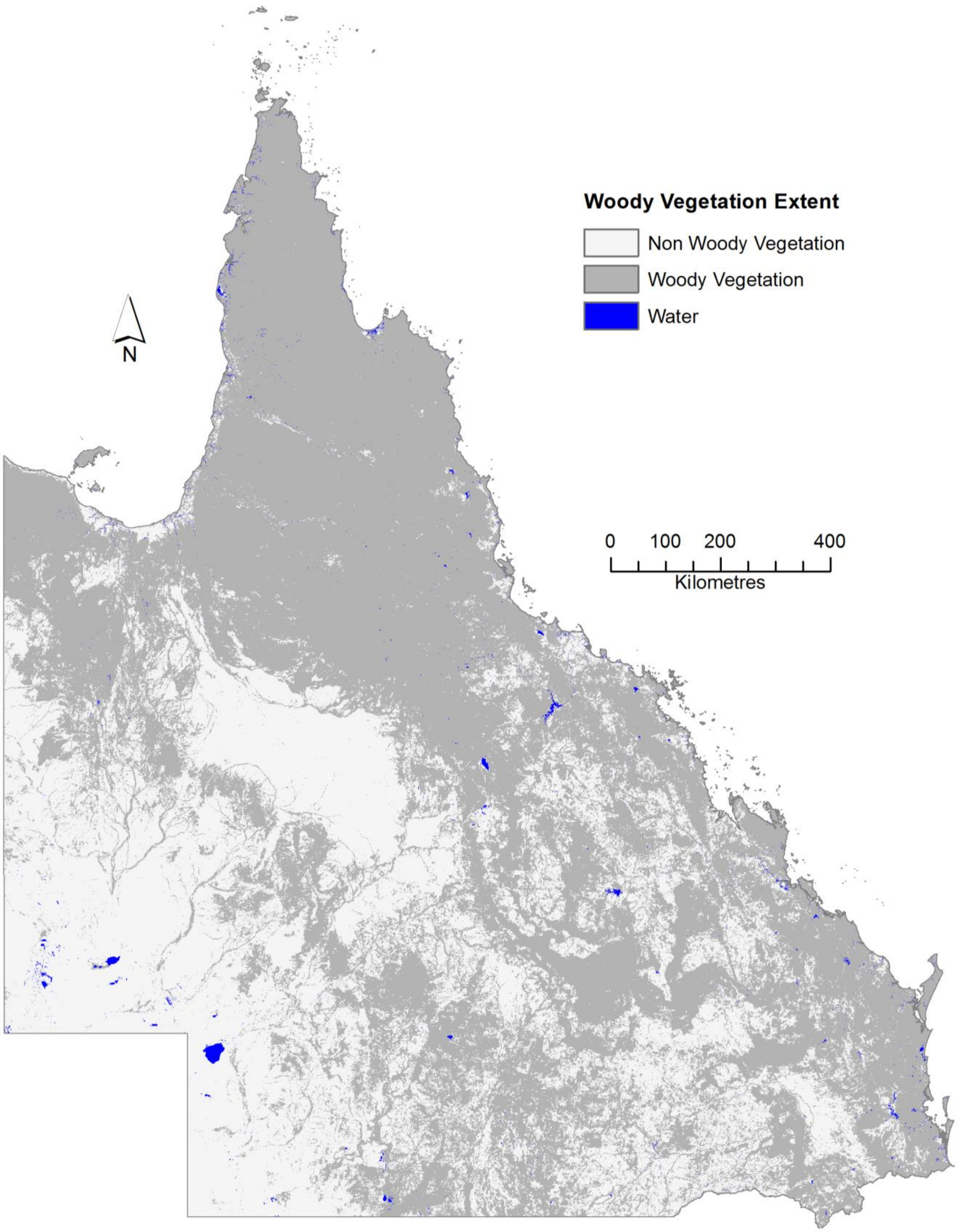


Figure 11: A map of Queensland showing the distribution and extent of woody vegetation across the state as estimated by the *Landsat Woody Vegetation Extent – Queensland* dataset. This map is an estimate of woody vegetation only, and does not distinguish the structure, height, density or type of woody vegetation present at any given location. Note that this is *not* used to directly map clearing.

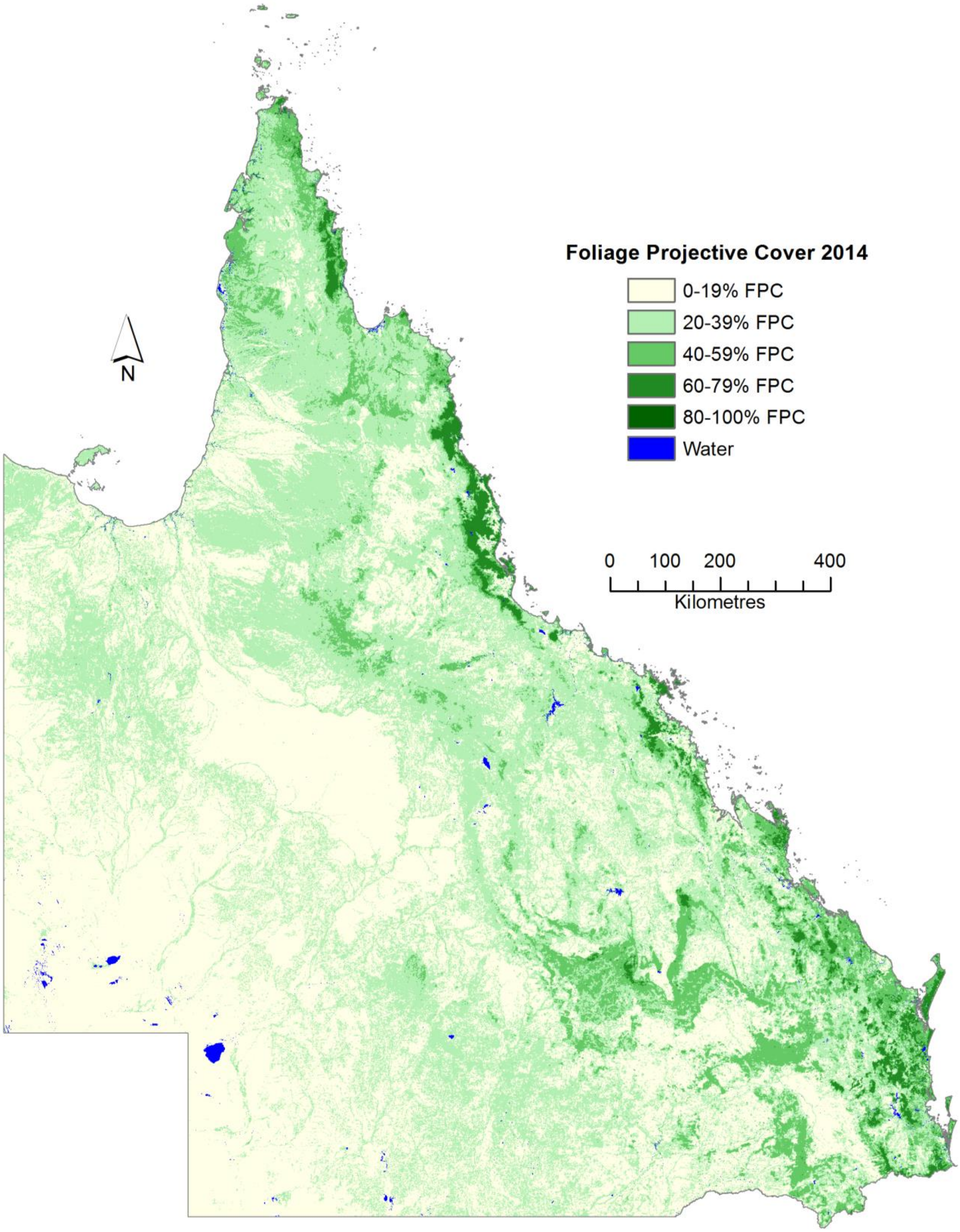


Figure 12: A map of Queensland showing the ranges of FPC across the state as estimated by the *Landsat Foliage Projective Cover – Queensland 2014* dataset. This dataset is indicative of the density of woody vegetation present at any given location. Five ranges of FPC of woody vegetation (expressed as percentage FPC) are shown. Most of the state's woody vegetation occurs in the ranges 0–19% and 20–39%.

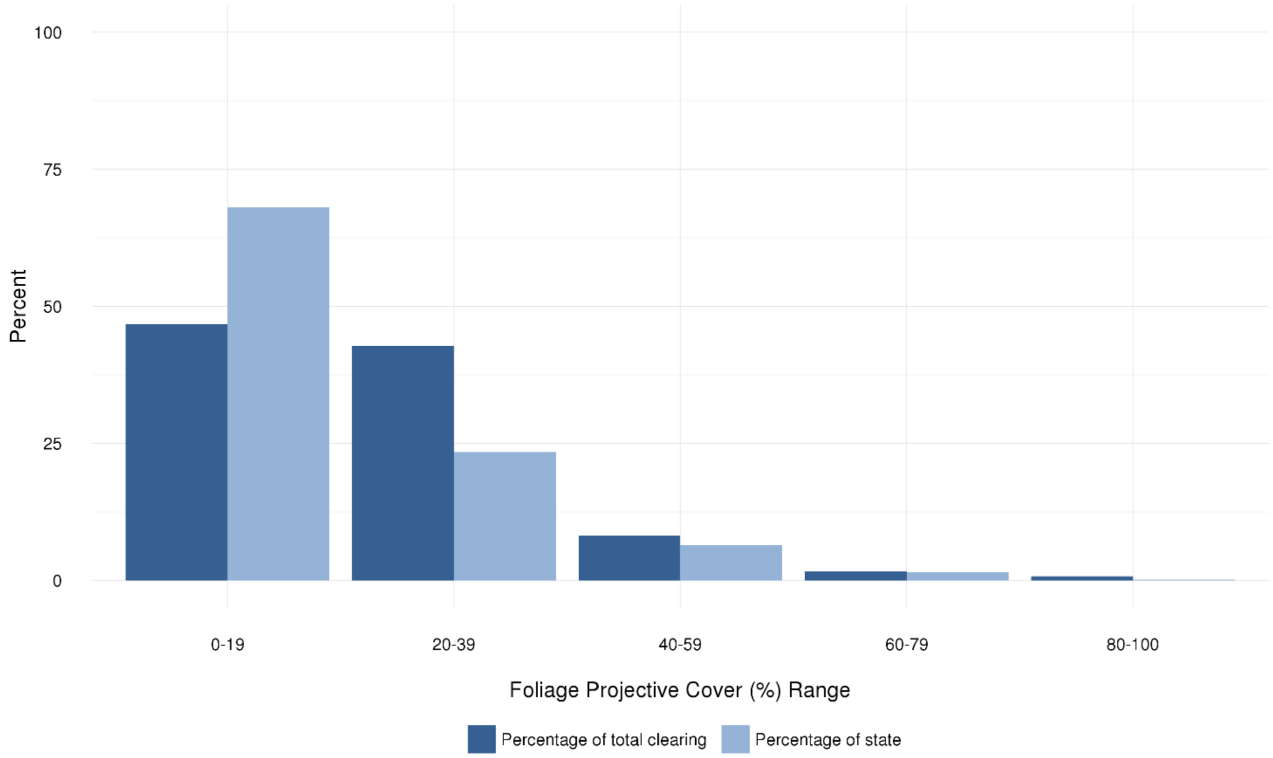


Figure 13: The percentage of the total of all woody vegetation clearing for 2015–16 for five ranges of FPC (dark blue bars). 90% of all woody vegetation clearing occurred in the FPC ranges 0–19% and 20–39%. The percentage of the total area of the state is also shown for each of the five FPC ranges (light 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 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 14 (page 36) 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 2012–13 in Table 10 (page 36).

3.8.1 Results

- In 2015–16, 34% of the mapped woody vegetation clearing had previously been cleared one or more times since 1988 (Table 10, page 36).

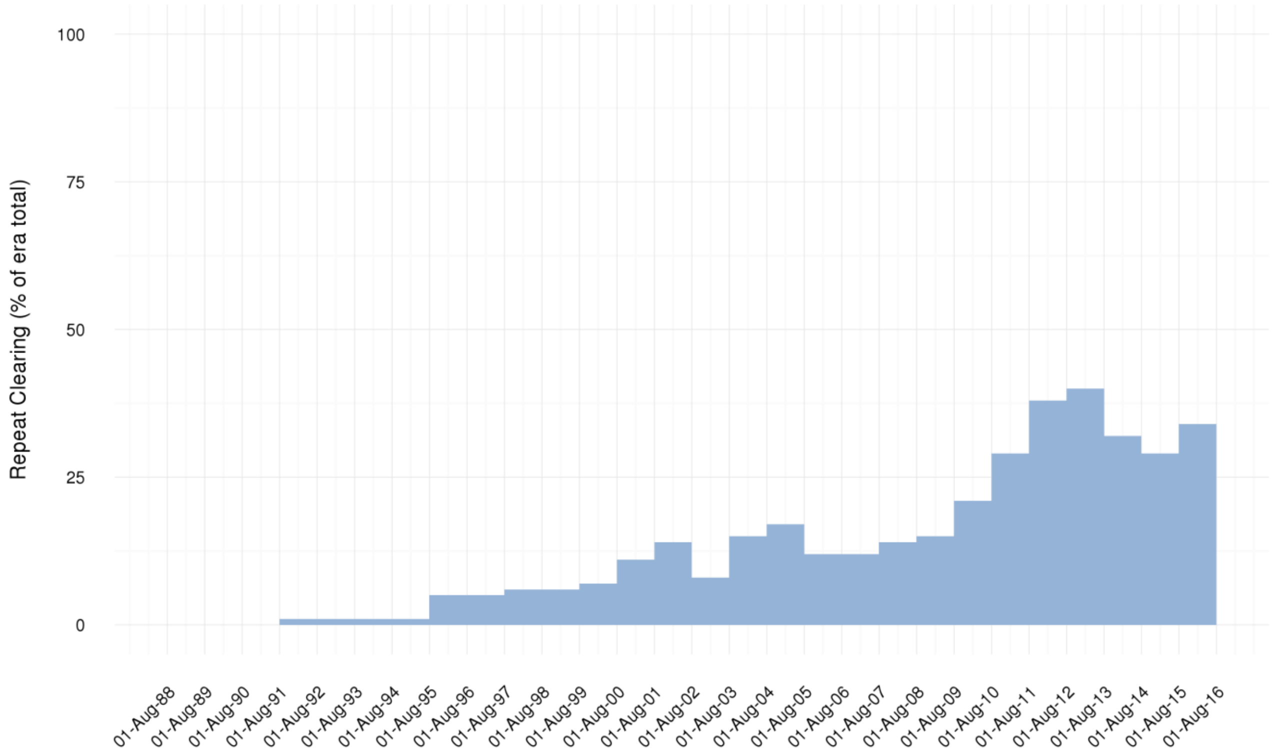


Figure 14: Repeat woody vegetation clearing as a percentage of total woody vegetation cleared for each period (1988–2016)

Table 10: Repeat woody vegetation clearing as a percentage of total woody vegetation cleared for each period (2012–16)

Period	Percentage[1] of woody vegetation clearing previously detected as cleared (repeat clearing)
2012–13	40
2013–14	32
2014–15	29
2015–16	34

[1] Percentages are rounded to nearest whole percentage.

3.9 Missed woody vegetation clearing

For each period since 2001–02, woody vegetation clearing that has been missed in a previous mapping period is identified in the subsequent period. 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 2015–16 analysis, less than 1% of total woody vegetation clearing was identified as missed woody vegetation clearing in the 2014–15 period (Figure 15, page 37).

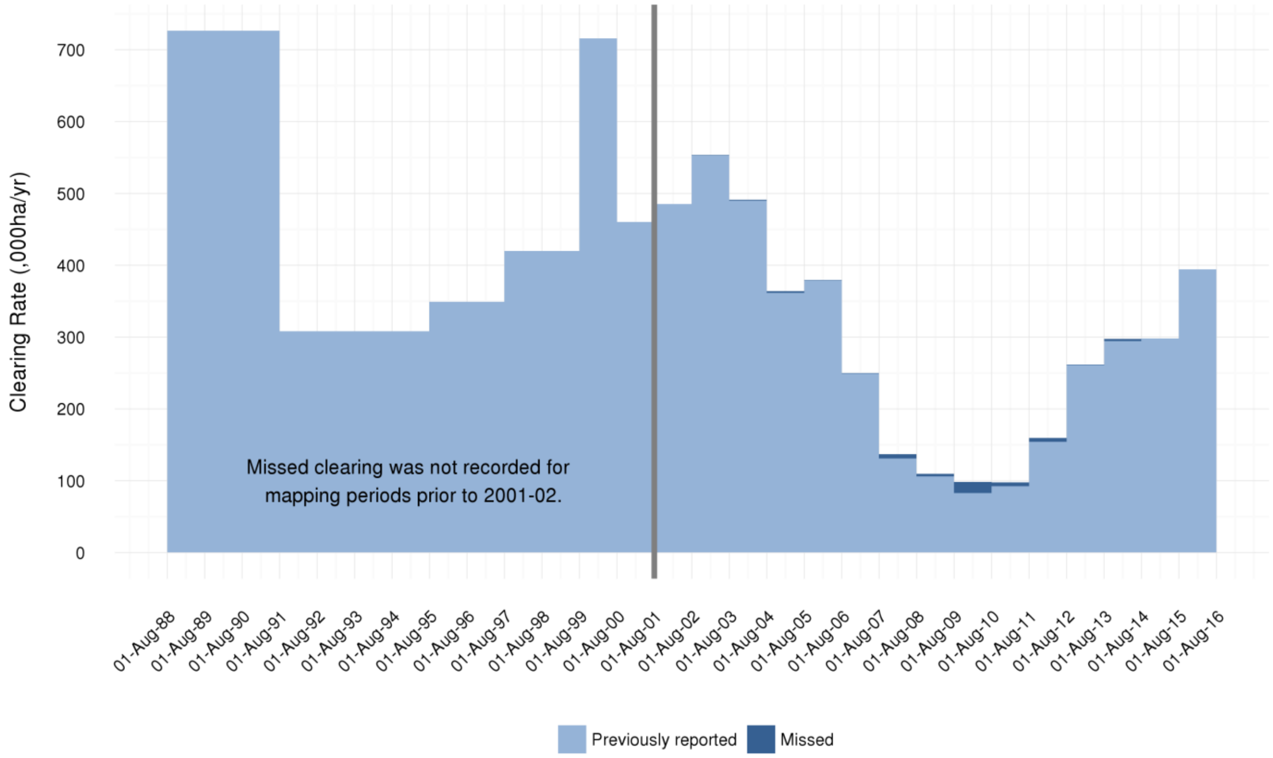


Figure 15: Annual woody vegetation clearing rate in Queensland (1988–2016) showing the effect on the clearing rate of missed woody vegetation clearing identified in the subsequent period

4 Conclusion

4.1 Woody vegetation clearing in Queensland in 2015–16

SLATS is an initiative of DSITI’s Remote Sensing Centre 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 2015–16. This map represents one of a series of maps of woody vegetation clearing produced between 1988 and 2016. 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 2015–16, the woody vegetation clearing rate was 395 000 ha/year. This was significantly higher than 2012–13 (261 000 ha/year), 2013–14 (295 000 ha/year) and 2014–15 (298 000 ha/year), and the highest rate of clearing since 2003–04 (490 000 ha/year). The 2015–16 rate of clearing is similar to 2005–06 (379 000 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 84 000 ha/year and 92 000 ha/year, respectively.

In 2015–16, remnant woody vegetation clearing increased by 24 000 ha/year to 138 000 ha/year compared with the 2014–15 period, when 114 000 ha/year of remnant woody vegetation clearing was mapped. In 2013–14 the remnant woody vegetation clearing rate was 100 000 ha /year.

The GBR catchments had a total woody vegetation clearing rate of 158 000 ha/year. This was a 45% increase from the 2014–15 period (109 000 ha/year). Since 2012–13, the rate of woody vegetation clearing in the GBR catchments has increased by 49%.

The woody vegetation clearing rate increased by 57% in the Brigalow Belt biogeographic region from 132 000 ha/year in 2014–15 to 207 000 ha/year in 2015–16. The woody vegetation clearing rate increased by 30% in the Mulga Lands biogeographic region from 66 000 ha/year in 2014–15 to 86 000 ha/year in 2015–16. Historically, these biogeographic regions have represented the highest rates of clearing of all of the biogeographic regions across the state.

Woody vegetation clearing rates in the Desert Uplands biogeographic region increased by 74% from 19 000 ha/year in 2014–15 to 33 000 ha/year in 2015–16, while in the Mitchell Grass Downs biogeographic region the woody vegetation clearing rates decreased by 46% from 26 000 ha/year in 2014–15 to 14 000 ha/year in 2015–16.

The Brigalow Belt and Mulga Lands biogeographic regions represent a large part of the Murray-Darling drainage division, and it had the highest rate of woody vegetation clearing of all of the state’s major drainage divisions at 173 000 ha/year, a 43% increase from 121 000 ha/year in 2014–15. The North East Coast drainage division woody vegetation clearing rate also showed an increase of 41% from 116 000 ha/year in 2014–15 to 164 000 ha/year in 2015–16. Woody vegetation clearing rates decreased by 22% in the Lake Eyre drainage division from 37 000 ha/year in 2014–15 to 29 000 ha/year in 2015–16.

Based on previous mapping, 34% of the woody vegetation clearing mapped in 2015–16 had been previously cleared one or more times since 1988.

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 includes enhancing RSC's processing framework to incorporate Sentinel-2 earth observation mission data from the European Space Agency's Copernicus Programme into woody vegetation change detection and other operational products, and to assess the effect of moving to the finer resolution Sentinel-2 data for future reporting periods. RSC has embedded Open Data as a business as usual activity consistent with the Queensland Government Open Data Strategy. As woody change data are released they are made available on the Queensland Government Open Data Portal.

5 Related products and information

Information about 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 2015–16 SLATS woody vegetation clearing figures 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/.

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SLATS is dependent on access to high performance computing facilities, Australia’s high speed Academic and Research Network, and a satellite imagery archive. These 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) was established in the mid–1990s and has been mapping the amount of woody vegetation clearing in Queensland back to 1988 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 since 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 II defines what we mean by a woody vegetation clearing rate, and the assumptions required. Section III discusses in detail the sources of variation in period length, and how it has been distributed historically. Sections IV and V discuss the spatial and temporal calculations needed to estimate the annual woody vegetation clearing rate as robustly as possible.

Finally, section VI 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 since 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 III).

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 three years, with imagery only available for the start and end dates of the period. The next period mapped was a nominal four year period, from 1991 to 1995. After that, mapping was carried out in two 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 i 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.

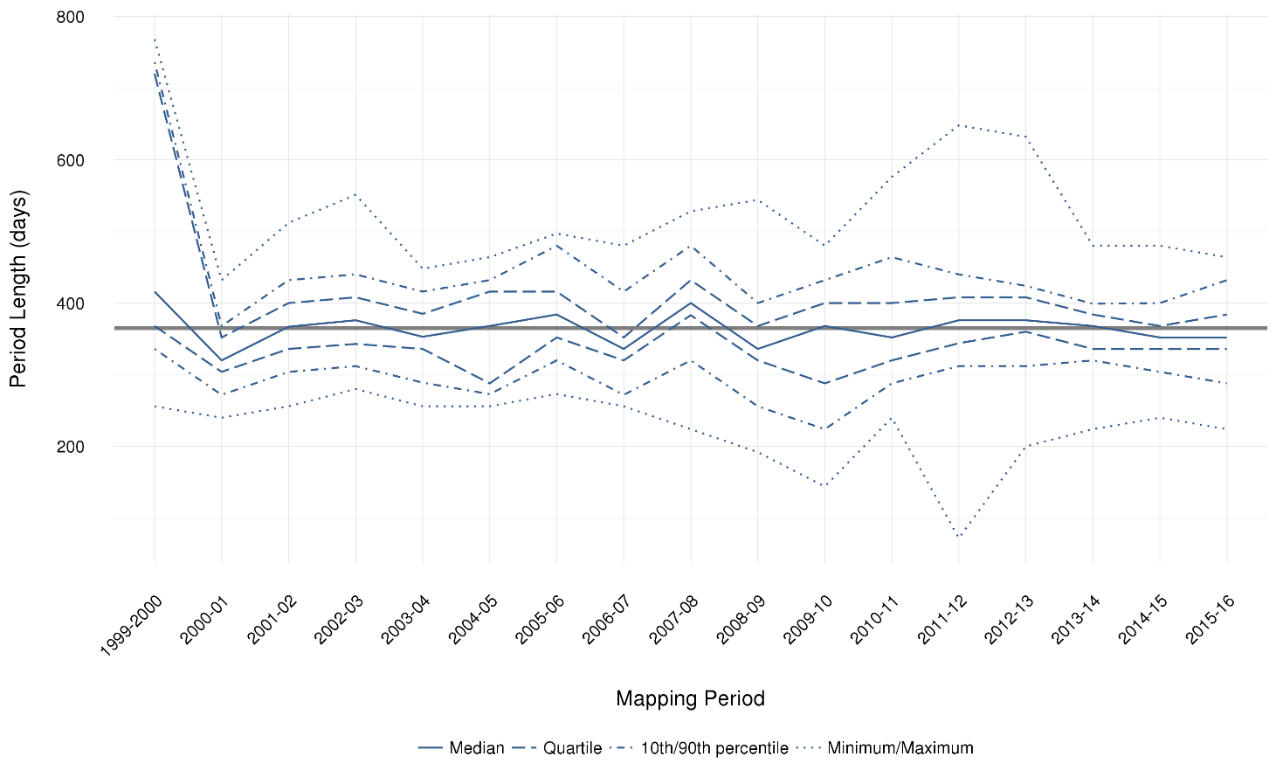

Figure i: Variation in SLATS period length since 1999. Solid blue line is the median period length, over all pixels, for each period. Solid grey line is 365 days, i.e. 1 standard year. For each period, 50% of pixels have a period length between the two quartile lines (blue dashes).

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 the fact that the 2012 imagery was composited from multiple images, as a result of 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 (DSITIA, 2014). It resulted in a much larger range of dates being required to allow coverage of all pixels.

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 two 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 i 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 IV.

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 IV 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 ii 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, 31 October 2000 and 20 June 2001. 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 1 August of 2000 and 2001. The annual woody vegetation clearing rate is thus the difference between these two estimates.

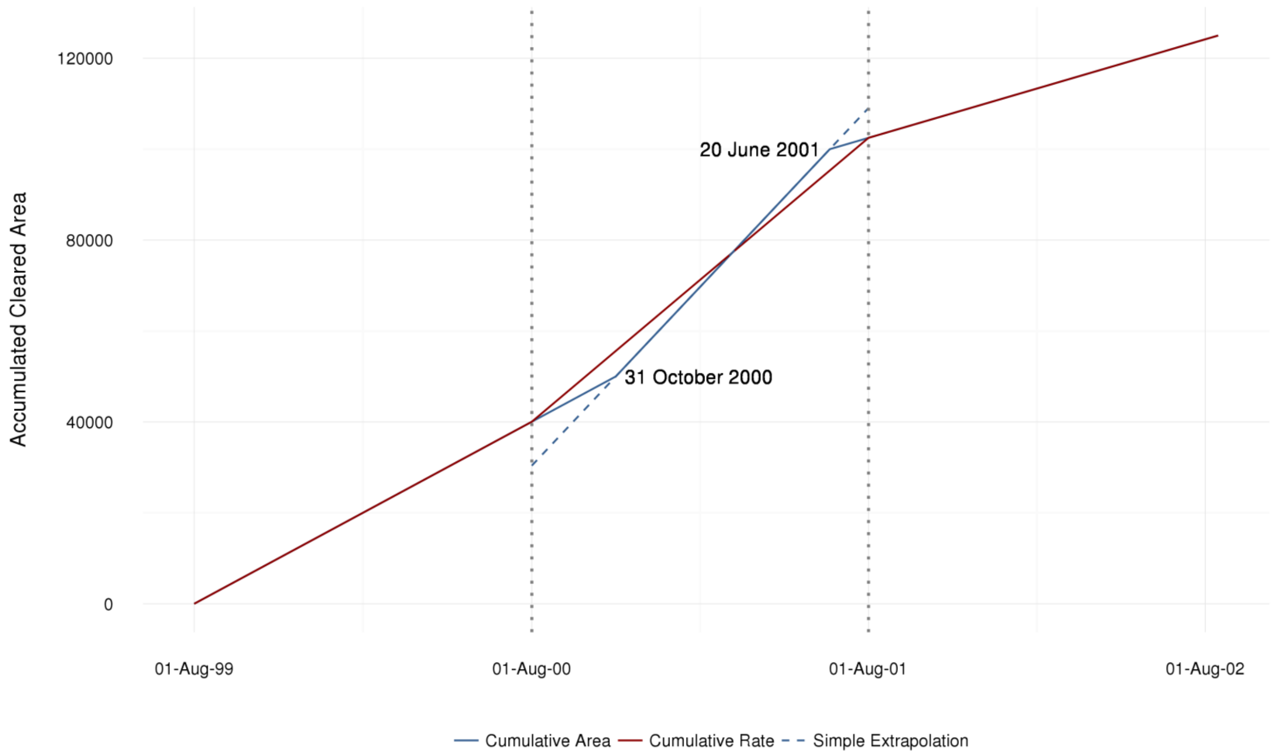

Figure ii: Example calculation of clearing rate from clearing area, for a single Landsat scene. The solid blue line shows the cumulative area cleared, over time. The area of clearing is observed on 31 October 2000 and 20 June 2001. Solid red line shows accumulated annual clearing rate, observed on 1 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 1 August, 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 VI. From the 2014–15 reporting period onwards, the estimation of rates from the areas and dates is carried out after the spatial averaging described in Section IV, 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 been improved and used since 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 IV and V (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 "non-clearing" 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 ii. 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 V. 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 and 2015–16 reports, 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 iii shows the whole time series of annual woody vegetation clearing rates for Queensland, from 1988 until 2014, calculated using the old and new methodologies.

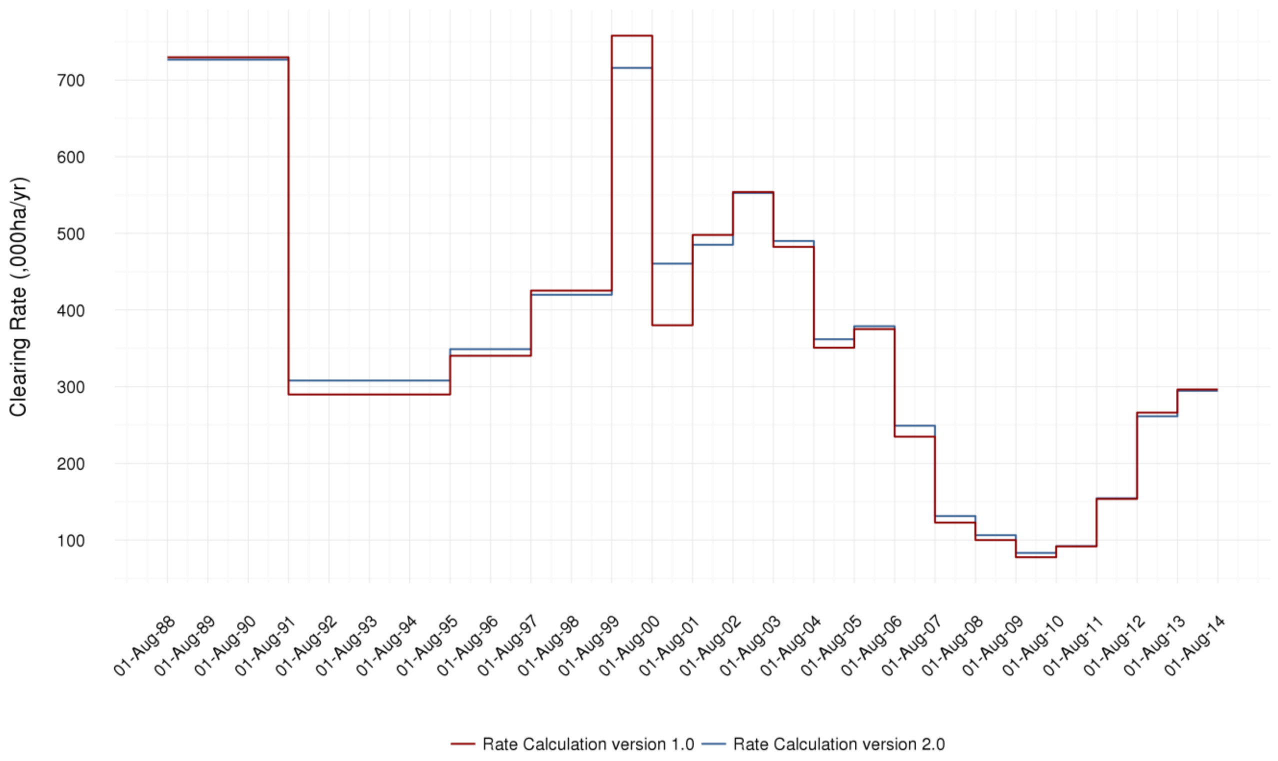

Figure iii: Annual clearing rates using the version 1.0 (red line) and version 2.0 (blue line) methodologies.

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 two year period followed by a period of zero length. This point is discussed in Section III. 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.