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Native vegetation regulatory map method statement

Made under the *Local Land Services Act 2013*

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Term	Meaning of term
ACLUMP	Australian Collaborative Land Use and Management Program
ADS	Airborne digital sensor
ALUM	Australian Land Use and Management
CEEC	Critically endangered ecological community
cl.	Clause (of a Regulation)
DEM	Digital elevation model
DPE	Department of Planning and Environment
LLS Act	Local Land Services Act 2013
MGA	Map grid of Australia
NSW	New South Wales
NVR Map	Native vegetation regulatory map
s.	Section (of an Act)
SCD	Seasonal cover disturbance
SDC	Science-Data-Compute
SEED	Sharing and Enabling Environmental Data (data portal)
SLATS	Statewide Landcover and Trees Study
SME	Surface model enhancement
SRTM	Shuttle Radar Topographic Mission

Summary

This *Native Vegetation Regulatory Map Method Statement* describes the science and analytical processes used to develop the native vegetation regulatory map (the NVR Map). The NVR Map underpins the legislative framework for native vegetation clearing in rural areas that is established under the *Local Land Services Act 2013* (LLS Act).

The LLS Act (s. 60G(4)) requires the Environment Agency Head to publish information about the scientific method used to prepare the NVR Map. This method statement has been prepared to meet this requirement, and is also published for transparency, accountability and communication purposes.

The method statement describes the process that is followed to determine whether land meets the criteria under the LLS Act for:

- category 1–exempt land (coloured blue on the map)
- category 2–regulated land (coloured yellow on the map)
- category 2–vulnerable regulated land (coloured orange on the map)
- category 2–sensitive regulated land (coloured pink on the map)
- category 2–regulated land that is both vulnerable and sensitive (coloured brown on the map)
- land that is excluded from the native vegetation regulatory framework (coloured grey on the map).

Broadly, category 1—exempt land is land that was cleared of native vegetation as at 1 January 1990, or land that was lawfully cleared between 1 January 1990 and 25 August 2017 or land that meets other specific category 1 criteria in the legislation. Category 2–regulated land is land that was not cleared as at 1 January 1990, or was unlawfully cleared after 1 January 1990, or is land that meets other specific category 2 criteria in the legislation

Land is mapped to each category on the basis of past clearing or disturbance events, as detected by satellite and aerial imagery, and updated land use data. The LLS Act and Regulation require land that meets other specific criteria to be a certain category, these areas are defined using spatial layers (prescribed layers). Prescribed layers identify land that meets specific criterial outlined in the LLS Act and Regulation (either category 1 or category 2), for example, critically endangered ecological communities (category 2–sensitive) or biodiversity certified land under the *Biodiversity Conservation Act 2016* (category 1–exempt).

Land categorisation based on specific criteria using prescribed layers override any categorisation based on disturbance.

The method statement does not otherwise assess the type, condition or environmental value of vegetation, which remains the subject of site-based assessment.

The native vegetation clearing framework established under the LLS Act is described in Section 1, including information about the transitional, draft and final release phases of the NVR Map.

Developing the native vegetation regulatory map

The method statement outlines the steps needed to develop the NVR Map. Section 2 provides an overview of the method as represented diagrammatically in Figure 1. A detailed order of precedence in the final map formation is described in Section 8.

The following section describes each part of this process, as they are explained in Sections 3 to 9 of the method statement.

Detailed information about scientific and analytical processes, and specific data used to create the map, are included in the separate appendices report: Native Vegetation Regulatory Map Method Statement: Appendices.

Identifying rural areas where the map applies (Section 3)

Section 3 describes the process for compiling data layers that identify land excluded from the operation of the rural native vegetation clearing framework under the LLS Act (i.e. 'excluded land').

Excluded land includes certain local government areas and land use zones (section 3.2.2) and land subject to other legislative frameworks, such as national parks and state forests.

The NVR Map applies to all remaining land (generally, rural land).

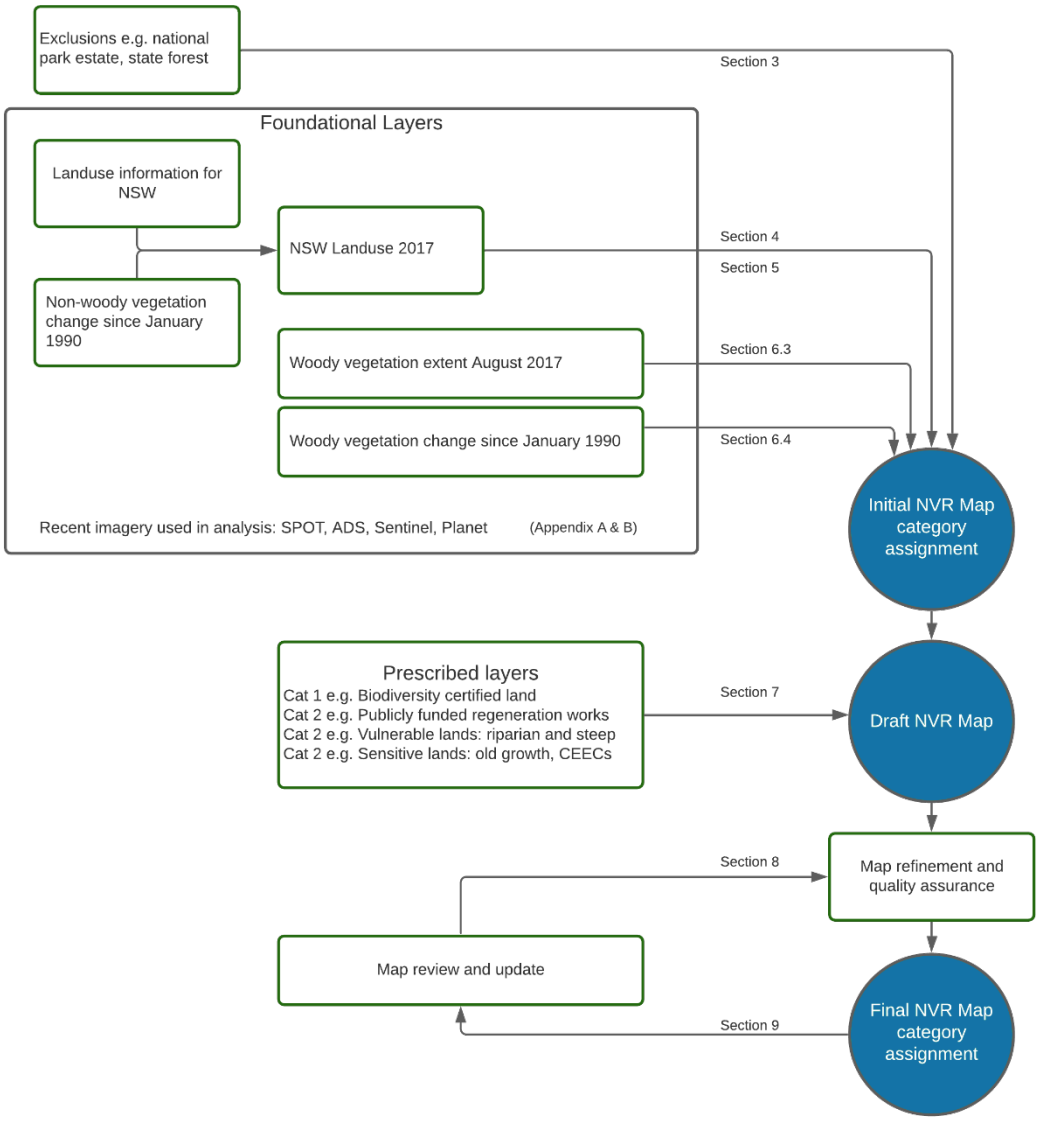


Figure 1 Overview of the process to create the native vegetation regulatory map (NVR Map)

Mapping existing land use (Section 4)

The history of agricultural land use provides an initial indicator of where native vegetation is likely to have been cleared. It is the first step in the analytical process to identify land that has been cleared (i.e. 'woody vegetation' that has been cleared) or significantly disturbed or modified (including 'non-woody vegetation' that has been significantly disturbed or modified at or since 1 January 1990 [as per LLS Act section (s.) 60J(2)]).

Section 4 describes how analysts use very high-resolution aerial and satellite imagery to identify patterns or evidence of agricultural land uses. These areas are then assigned a code using the Australian Land Use and Management (ALUM) classification system (ABARES 2011, 2015), which then guides an initial designation of land as either category 1–exempt land or category 2–regulated land.

Where the effects of past land use cannot be seen in current imagery, a range of seasonal cover disturbance image (SCDI) products (i.e. SCDImage and SCDIndex) based on a time series of satellite imagery from 1990 onward are used to find evidence of past modification such as cultivation or pasture improvement. The SCDI products are described in Section 5.

Mapping non-woody and woody vegetation cover and change (Sections 5 and 6)

Sections 5 and 6 outline how non-woody and woody vegetation cover and change are mapped to update the land use and woody extent layers. This creates an overall picture of vegetation extent across the State.

Woody vegetation means plants that typically have defined woody stems and are over 2 metres tall, such as trees.

Non-woody vegetation is everything else, such as grasses, shrubs, small trees or seedlings.

Non-woody vegetation change (Section 5)

To assist in determining change in non-woody vegetation (e.g. grasslands, shrubs and other groundcover), analysts use the SCDI products which reflect the entire 26-year archive of Landsat satellite imagery. The combined (composite) time-series image shows the pattern of change in vegetation cover over multiple seasons and across multiple years.

The composite image is primarily used to refine interpretation of existing land use, by helping analysts to identify areas of cultivation as well as improved or modified pastures. This information, in combination with reviewing other satellite and aerial photography, assists analysts to identify areas that have been significantly disturbed or modified, back to 1 January 1990, which can be mapped as category 1.

Woody vegetation change (Section 6)

Using high-resolution satellite imagery (SPOT 5) from 2007 to 2011, analysts have prepared a woody vegetation extent map that shows the location, extent and foliage cover of woody vegetation across New South Wales at a resolution of 5 x 5 metres. This map is updated to account for changes in woody vegetation cover since 2011, using analysts' interpretation of current aerial and satellite imagery.

Mapping of vegetation cover change has been carried out annually for nearly 10 years under the NSW Statewide Landcover and Trees Study (SLATS) mapping program. Clearing is identified by comparing satellite imagery at the same location but captured on 2 different dates, approximately 12 months apart. Analysts then determine whether the woody vegetation loss was caused by changes in agriculture, infrastructure, forestry, fire or natural processes.

The updated woody vegetation extent map and the SLATS mapping are combined to differentiate areas of woody vegetation lawfully cleared by agriculture, infrastructure or forestry (category 1), and areas that have not been cleared since 1 January 1990 (category 2).

Incorporating prescribed layers (Section 7)

Section 7 describes the process of identifying additional legislative requirements that affect the category of land. The LLS Act and the Local Land Services Regulation 2014 (LLS Regulation) specify certain criteria requiring land to be mapped as category 1 or category 2. These criteria will generally 'override' any previous analysis of disturbance that would otherwise identify the land as a different category. Each of the specific criteria defined by the LLS Act and Regulation have been sourced as 'prescribed layers' for incorporation into the NVR Map

For example, LLS Act s. 60I(2)(c) states 'land subject to a private land conservation agreement under the *Biodiversity Conservation Act 2016*' must be mapped as category 2. Therefore, if land subject to a conservation agreement was initially mapped as category 1 due to being identified as legally cleared since 1990, it would subsequently be categorised as category 2–sensitive regulated land due to the conservation agreement.

Section 7 also includes information on how clearing is determined to be lawful or unlawful for the purposes of the NVR Map. Any clearing that is identified as 'unlawful' since 1 January 1990 is to be included as category 2.

Reviewing and finalising the map (Section 8)

Section 8 describes the process for assembling the final map product.

The final map layers are reviewed for accuracy and all the map layers and additional datasets are combined in accordance with criteria in the LLS Act to create a single native vegetation regulatory map (NVR Map) for all of New South Wales. Additional maps showing only the category 2–vulnerable regulated lands and category 2–sensitive regulated lands are also available.

Reviewing and updating the map (Section 9)

Section 9 describes the processes available for reviewing the map.

A map review process enables landholders to provide additional information if they believe that land has been incorrectly categorised. The map method is then reapplied to the landholding in the context of the new information and in some cases at a finer scale. The NVR Map is then amended if the analyst's review of new information results in a change of category.

The Environment Agency Head will also be able to initiate reviews of land categorisation in certain circumstances set out in the LLS Act. This will ensure that errors can be amended, new data and information can be incorporated, and lawful clearing in accordance with

appropriate approvals can be captured. When prescribed layers used in the NVR maps are updated, the NVR maps will also be updated to remain current.

The NVR Map is reviewed annually to make sure it reflects the most accurate and up-to-date data and imagery, and that all agreed re-categorisations have been correctly incorporated.

2022 updates to the native vegetation regulatory map method

The NVR Map method was published on 27 August 2017 with the amendments to the LLS Act and commencement of the *Biodiversity Conservation Act 2016*.

In the last 5 years, increased access to a range of imagery, changes in the legislation, updated datasets and improved remote sensing methods have resulted in multiple changes to the map method. These changes are captured in this 2022 version of the method statement.

Interactions with landholders and on-ground application of the NVR Map since implementation has refined mapping and analysis to better reflect different land management techniques across the State and how they are interpreted into legislative categories.

These changes, reflected in the currently published NVR Map, have resulted in increased spatial and temporal accuracy.

A summary of the changes as described in this document are outlined below.

Foundational layers updated to 2017

On publication of the NVR Map method in 2017, a number of the foundational layers (Figure 1) were mapped to reflect the categorisation of land in 2013 to ensure cleared land had been assessed under the former *Native Vegetation Act 2003* and *Threatened Species Conservation Act 1995* to determine its lawfulness prior to categorisation.

This compliance work has now largely been completed and the categorisation of the NVR Map aligns with the commencement of the native vegetation clearing framework under the *Biodiversity Conservation Act 2016* and LLS Act.

These changes are reflected in land use (Section 4), woody vegetation cover (Section 5) and non-woody vegetation cover (Section 6). In bringing the non-woody vegetation cover up to the 2017 commencement date, a number of SCDI products were developed to assist with categorisation decisions by analysts.

Updating the foundational layers to 2017 has been supported by a broader range of imagery types and platforms being available to further refine the accuracy of the mapping.

Changes in NSW Government structure

Since July 2019 the Environment Agency Head under the LLS Act has sat within the Environment, Energy and Science Group of the Department of Planning and Environment (DPE), formerly the Department of Planning, Industry and Environment. Prior to July 2019 the Environment Agency Head was referenced as the former agency, Office of Environment and Heritage (OEH).

Improved display

In April 2019, a new display class was added to the NVR Map to assist with interpretation of categories on the online portal at: www.lmbc.nsw.gov.au/Maps/index.html?viewer=NVRMap. The new display class (brown) shows where both category 2–sensitive regulated land (pink) and category 2vulnerable regulated land (orange) overlap (Figure 2).

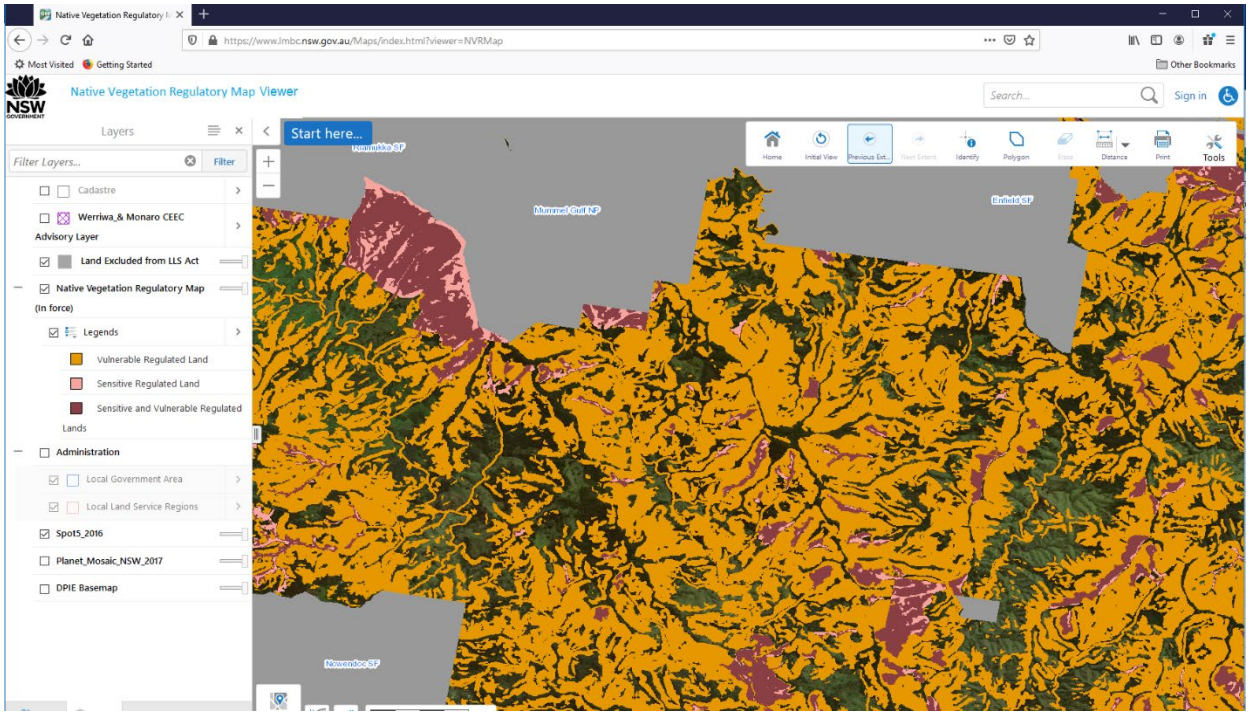


Figure 2 New display categories in the native vegetation regulatory map portal

Annual updates

Three annual updates have occurred since the NVR Map publication, including 2 types of changes.

1. New and/or updated data, for example, an improved steep lands layer (vulnerable land), new set asides under the LLS Act land management (native vegetation) code or updated private native forestry approvals as certificates expire.
2. Changes to the LLS Act and Regulation resulting in legislated category changes to rural land. For example, the making of the *State Environmental Planning Policy (Coastal Management) 2018* as category 2 land.

These changes are documented in the prescribed layers in Section 7.

1. Background to the native vegetation regulatory map

1.1 Introduction

1.1.1 Role of the native vegetation regulatory map

The native vegetation regulatory map ('the NVR Map') is made under Part 5A of the *Local Land Services Act 2013* (LLS Act) by the Environment Agency Head.

The map underpins the legislative framework for native vegetation clearing in 'rural areas' as established by the LLS Act.

Rural areas to which the map applies are set out in the LLS Act, and generally exclude metropolitan local government areas, as well as urban land use zones. These are set out in section (s.) 60A of the LLS Act and detailed in Section 3.

The map is used mostly by landholders, local government, Local Land Services and other government agencies. It helps users to understand when native vegetation clearing for agriculture is regulated. The map identifies where agricultural land management activities are regulated by either codes defined in the *Land Management (Native Vegetation) Code 2018* (Land Management Code) or by use of allowable activities defined in the LLS Act (Schedule 5a). It also provides information to support compliance actions in accordance with the legislative framework. Section 1.1.2 outlines the effect of the categories displayed in the NVR Map.

The NVR Map method does not assess the condition or environmental value of vegetation and does not replace site-based assessment required under approval processes. However, the LLS Act and Regulation does specify land with identified environmental values as category 2–regulated that may override a category 1–exempt land designation based on disturbance history.

1.1.2 Categories displayed in the map

The categories displayed on the NVR Map are described in Table 1 and displayed in Figure 3 and Figure 4.

Table 1 Categories displayed on the native vegetation regulatory map

Category/overlay	Regulatory effect	Reference
Category 1–exempt land	Land that has been cleared (including significantly disturbed or modified) as at 1 January 1990 or lawfully cleared between 1 January 1990 and 25 August 2017. This is land where clearing native vegetation in rural areas does not require approval under the LLS Act, and does not need to comply with provisions relating to 'allowable activities' or any Land Management Code made under the LLS Act.	Section 60H of the LLS Act

Category/overlay	Regulatory effect	Reference
	Other legislation and regulation may still apply on this land, e.g. development consent may be required under a Local Environmental Plan or a State Environmental Planning Policy.	
Category 2– regulated land	Land where native vegetation clearing in rural areas requires approval under the LLS Act unless the clearing complies with the provisions relating to allowable activities or any Land Management Code made under the LLS Act.	Section 60I(2)(l) of the LLS Act LLS Act – Schedule 5A Land Management Code
Category 2– vulnerable regulated land	Category 2 areas that include steep and highly erodible lands and riparian areas. Additional restrictions apply to Land Management Codes and allowable activities in these areas.	Section 60F(2)(c) of the LLS Act
Category 2– sensitive regulated land	Category 2 areas that contain sensitive lands such as critically endangered ecological communities (CEECs), rainforest, koala habitat, etc. Additional restrictions apply to allowable activities, and Land Management Code cannot be applied in these areas.	Section 108, 111, 113 of the LLS Regulation
Excluded land	The native vegetation clearing framework established by the LLS Act for rural areas does not apply.	Section 60A of the LLS Act

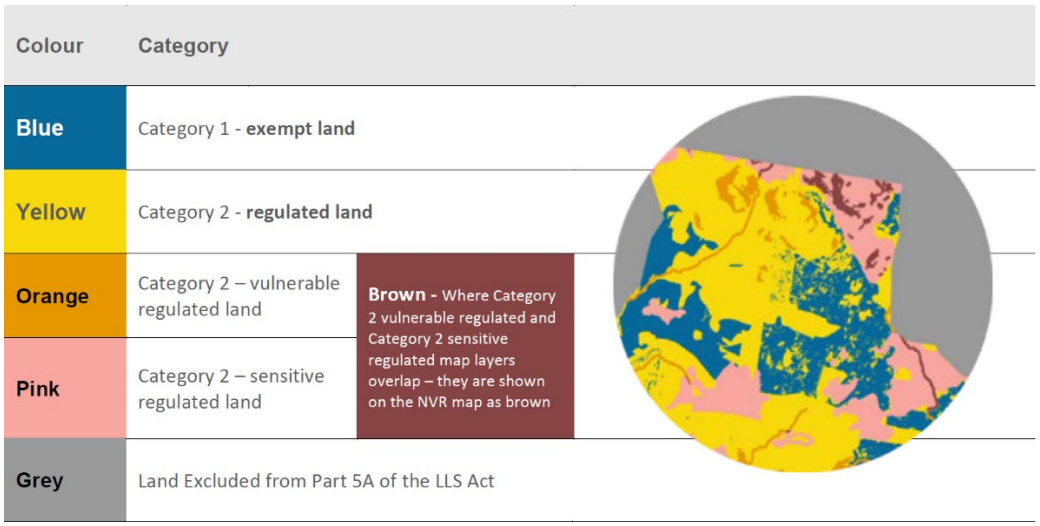


Figure 3 Visual display of categories on the native vegetation regulatory map

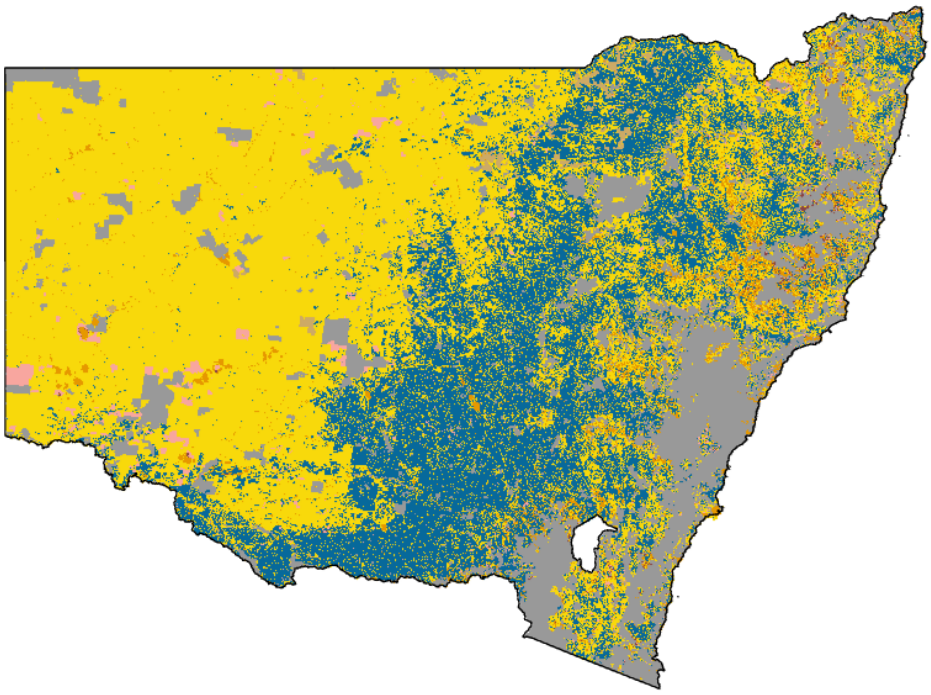


Figure 4 Native vegetation regulatory map categories for New South Wales (illustrative only; see Figure 3 for key to colours)

1.2 The legislative framework

1.2.1 Native vegetation regulatory map

The LLS Act provides for the preparation, publication and review of the NVR Map, under the administration of the Minister for Environment and Heritage. The LLS Act (s. 60E) provides that the NVR Map applies to the State (except excluded areas) and designates land where:

- native vegetation clearing is exempt from the clearing framework of the LLS Act (category 1–exempt land)
- native vegetation clearing is regulated and requires authorisation or approval under, or compliance with, the LLS Act (category 2–regulated land).

Some land is excluded from the operation of the map (LLS Act s. 60A) and is therefore neither category 1–exempt land nor category 2-regulated land (see Section 3). In practice, when excluded land is taken into account, the NVR Map generally only applies in rural areas.

The LLS Act (ss. 60G, 60H and 60I) sets out criteria to designate land as category 1 or category 2 (see Section 2 and Section 7) and makes provision for category 2–vulnerable regulated land sub-category and any other sub-category defined by the regulations. The LLS Regulation defines criteria for category 2–vulnerable regulated land and the provision for and definitions of category 2–sensitive regulated land sub-categories.

The LLS Act (s. 60G(4)) requires the Environment Agency Head to publish information about the scientific method used to prepare the NVR Map. This method statement has been prepared to meet this requirement, and is also published for transparency, accountability and communication purposes.

1.2.2 Publishing phases of the native vegetation regulatory map

Section 60G of the LLS Act requires the preparation and publication of a native vegetation regulatory map

Since commencement of the LLS Act in August 2017, transitional arrangements have been in place for identifying category 1–exempt and category 2–regulated land. The transitional arrangements continue to be in place while the NVR map is draft and will continue to apply until a final NVR map is published.

The LLS Act provides for a transitional period to allow for the preparation of a draft and final native vegetation regulatory map. The transitional native vegetation regulatory map displaying some land categories was published in August 2017.

Before the final native vegetation regulatory map is published, the Local Land Services Regulation 2014 requires that a draft native vegetation regulatory map be prepared and published.

This Map Method Statement informs all of the following 3 publication phases:

1. The **transitional NVR map** was published online at commencement of the LLS Act on 25 August 2017.

   Transitional arrangements are in place during the period of commencement of Part 5A of the LLS Act until land is mapped on a final NVR map. When this occurs the transitional period no longer applies to that land.

   Land designated on the transitional NVR includes only:

   - steep or highly erodible land, as protected riparian land or as special category land (taken to be category 2–vulnerable regulated land)
   - category 2–sensitive regulated land
   - land excluded from the LLS Act.

2. The **draft NVR map** will be published following Government approval. When published, landholders will be able to view all land categories described in the LLS Act.

   Note, transitional arrangements will remain in force following publication of the draft NVR map. During the transitional period, the category of land displayed on the draft NVR map is determined in accordance with the transitional NVR map **and** section 60F of the LLS Act for category 1–exempt land and category 2–regulated land.

   Land identified on the draft native vegetation regulatory map will include:

   - category 1–exempt land
   - category 2–regulated land
   - category 2–vulnerable regulated land
   - category 2–senstive regulated land
   - land excluded from the LLS Act.

3. The **final NVR map** has not been published – this will occur following the publication period of the draft NVR map.

   When published the final NVR map will categorise land and the transitional period will end. Land identified on the final NVR map will include the same categories as those identified on the draft NVR map, including any changes made through the landholder map review process.

   Provisions in the LLS Act which provide for re-categorisation of mapped land, review of categorisation decisions and appeals against categorisation decisions will be available. Current maintenance and update processes to reflect map review changes and inclusion of new data as it becomes available will also remain ongoing.

Reviewing the map

Landholders can currently apply to review the categorisation of the transitional NVR map. The same review service will also be available during the publication period of the draft NVR map and will continue before and after publication of a final NVR map.

1.2.3 Clearing on category 2 land

The LLS Act provides that landholders can undertake allowable activities on category 2–regulated land without approval or notification. The LLS Act (Divisions 4 and 5 of Part 5A) also authorises clearing of native vegetation on category 2 land if it is carried out in accordance with the Land Management Code. Clearing certified under the Land Management Code may also require the landholder to establish set aside areas elsewhere on the landholding to promote vegetation integrity.

Category 2 land that requires certification may also require set asides. Additional restrictions on use of allowable activities and the Land Management Code apply to land mapped as category 2–vulnerable and/or category 2–sensitive regulated land (which includes set-aside areas under the Land Management Code).

Where clearing on category 2 land cannot be undertaken in accordance with an allowable activity or code, it may be considered and approved by the Native Vegetation Panel (Division 6 of Part 5A, LLS Act).

2. Overview of the native vegetation regulatory map method

2.1 Introduction

This NVR Map method statement ('the method') describes the underlying science and analytical processes used to build the NVR map. The method uses the best available science and data to assign land as category 1 or category 2 based on evidence of clearing or disturbance, and in accordance with legislated criteria.

2.2 Determining category 1-exempt land

Category 1–exempt land is determined either through:

- identification of detectable clearing or significant modification/disturbance since 1 January 1990 until the commencement of the Act as defined in the LLS Act s. 60H and LLS Reg clause (cl.) 114 – see Section 2.2.1, or
- through additional legislated criteria, for example, LLS Act s. 60H(3), land that is biocertified under Part 8 of the *Biodiversity Conservation Act 2016* (BC Act), and LLS Regulation cl. 116(2), land that was subject to a private native forestry plan under 5C of the *Forestry Act 2012* or property vegetation plan under the *Native Vegetation Act 2003*. These additional criteria and their application are described in Section 7 as prescribed layers.

Clearing on category 1–exempt land is not regulated and therefore does not require notification or certification under the code.

2.2.1 Detecting clearing or significant disturbance or modification

Clearing of woody vegetation is defined in s. 60C of the LLS Act as:

> (a) cutting down, felling, uprooting, thinning or otherwise removing native vegetation,
>
> (b) killing, destroying, poisoning, ringbarking or burning native vegetation.

Determination of significant disturbance or modification of non-woody vegetation is described in cl. 114 of the LLS Regulation:

> (1) Native vegetation that comprises grasslands or other non-woody vegetation is taken to have been significantly disturbed or modified (and therefore cleared) only if—
>
> > (a) there has been a detectable variation (from information obtained from aerial or satellite imagery) in the structure or composition, or both, of non-woody vegetation, and
> >
> > (b) that variation is consistent with management of pasture or crops for agricultural purposes, and
> >
> > (c) that variation has been sustained for at least 12 months on more than one occasion before the commencement of Part 5A of the Act, and
> >
> > (d) that variation has not been caused only by grazing on the land, and
> >
> > (e) that variation occurred (from information obtained from aerial or satellite imagery) between 1 January 1990 and the date of commencement of Part 5A of the Act.

In determining land that was cleared of native vegetation as at 1 January 1990, the Environment Agency Head may make decisions based on the best available aerial photographs or satellite imagery before or after the relevant date. Some discretion will be used when selecting the best imagery for forming this opinion. This is because in practice, it will be necessary to examine satellite imagery and aerial photographs across a range of dates. Relevant Landsat imagery is available from September 1989 to March 1990. Analysts will select the earliest and best available imagery to avoid situations where, for example, cloud cover makes the imagery unusable.

Table 2 summarises the key rules that are used to establish if land has been 'cleared', so that it can be identified and mapped as category 1 land (prior to applying prescribed layers which may override this determination).

These rules are explained in more detail in the relevant sections.

Table 2 Rules for establishing clearing/significant disturbance or modification that support identifying land as category 1

Method component	Section	Rule to determine land as category 1
Historical and current land use	4 & 5	Identified as applicable Australian Land Use and Management (ALUM) land use classes in Primary Categories 3, 4, 5 and 6 (see Figure 7 in Section 4.3). Identified as cleared or significantly disturbed or modified based on interpretation of aerial and satellite imagery and the seasonal cover disturbance products.
Detectable woody vegetation clearing	6	Identified as having been cleared through a change index under the Statewide Landcover and Trees Study (SLATS) mapping program.

2.3 Guiding principles

The following principles have been used to help in developing the method and applying it to prepare the NVR map:

- enable regulatory effect
- use best data and multiple lines of evidence
- enable response to uncertainty.

2.3.1 Enabling regulatory effect

The NVR Map must have sufficient spatial and visual accuracy to enable it to effectively operate as a regulatory tool, and to support the role it will play in compliance and enforcement actions.

Landholders and regulators must be able to determine, at a specific point in time, the current category of any relevant vegetation. This requires high spatial precision, to a level of detail that enables individual trees to be identified. It also depends on systems that provide and display the data in an appropriate format for users.

2.3.2 Using best available data and multiple lines of evidence

The method is based on best available data for aerial photo and satellite imagery analysis across different timeframes. This includes techniques that maximise the use of data to ensure the map is as reliable as possible so that the most informed decisions can be made.

The need for high spatial precision and accuracy is underpinned by using multiple lines of evidence rather than a single 'snapshot' interpretation of imagery. Imagery will range in temporal and spatial accuracy as well as resolution, therefore in many cases interpreters will make decisions based on multiple image types.

2.3.3 Responding to uncertainty

If there is uncertainty regarding the categorisation of land because of the quality of information available, that land will be included in category 2–regulated land.

This recognises the inherent challenges associated with combining remote sensing technology, land use data and multiple other datasets. It also recognises the availability of a map review mechanism that will enable land to be re-categorised if it has been incorrectly mapped. It is also consistent with the principles of ecologically sustainable development to assume that no clearing or modification has occurred where there is no evidence of it.

2.4 Process overview

The method is centred on using multiple lines of evidence and best available imagery to develop a map that has high levels of reliability and spatial precision. The process is designed to capture detectable, significant changes in the extent of vegetation or type of land use across New South Wales, reflecting the definition of cleared and modified vegetation in the legislation.

The method combines remotely sensed imagery (aerial and satellite platforms) with existing mapped data. Existing map products were updated and combined with new and available data to create the NVR Map.

Existing layers are:

- NSW Landuse maps – 1999 to 2013
- existing prescribed layers identifying land that meets specific criteria under the LLS Act and Regulation, such as relevant clearing approvals or conservation agreements
- woody vegetation clearing – 1990 to 25 August 2017
- woody canopy extent – 2011.

The assembling process gives some layers precedence over others, reflecting the legislative settings. The final map is a 5-metre raster product published online through a government website as required by the LLS Act (s. 60G(5)).

The map is designed to be a dynamic product that can be updated rapidly to reflect changes to the legislated components, such as new conservation agreements, changes in land zoning or reviews of map categories resulting from new information provided by landholders.

The complete process for building the map is described in Sections 3–9, with the key steps outlined in Section 2.5 below and key datasets described in Section 2.6 and Appendix A.

2.5 Key steps and sources of information

The process for developing and assembling the map involves combining multiple spatial data layers and products. This is not a linear process, as some layers will take precedence over others to develop the final map product for publication.

The method has been developed based on the following key components:

- Identifying rural areas where the map applies by compiling layers representing land that is excluded from regulation under the LLS Act, and therefore restricting the need for further analysis or mapping (Section 3).
- Identifying and mapping existing and historical agricultural land use based on updated mapping products – used to identify category 1–exempt land (Section 4).
- Supplementing the mapping of agricultural land use by creating and applying 'seasonal cover disturbance products' (see box). These products are a time-series analysis of satellite imagery which can be used to identify non-woody vegetation that has been significantly disturbed or modified for agricultural use between 1 January 1990 and 25 August 2017 – used to identify category 1–exempt land (Section 5).
- Identifying and mapping woody vegetation that has been lawfully cleared since 1 January 1990, based on satellite images and circa 1990 aerial photographs – used to identify category 1 land (Section 6).
- Applying any additional specific criteria listed in the LLS Act (ss. 60H and 60I) that allocate land to either category 1 or 2 incorporated as 'prescribed layers', including confirmation that any identified clearing has been conducted lawfully (Section 7).
- Integrating the input layers and processes to create the final map product (Section 8).

For a visual representation of the assembly process, see the images in Figure 5 and the flow chart in Figure 6 below.

Seasonal cover disturbance products

Seasonal cover disturbance image (SCDImage) and seasonal cover disturbance index (SCDIndex) are collectively referred to as 'SCDI products'.

The information gained from the SCDImage and SCDIndex helps identify areas that have been subject to agricultural land use outside the timeframes of existing imagery (see Section 5).

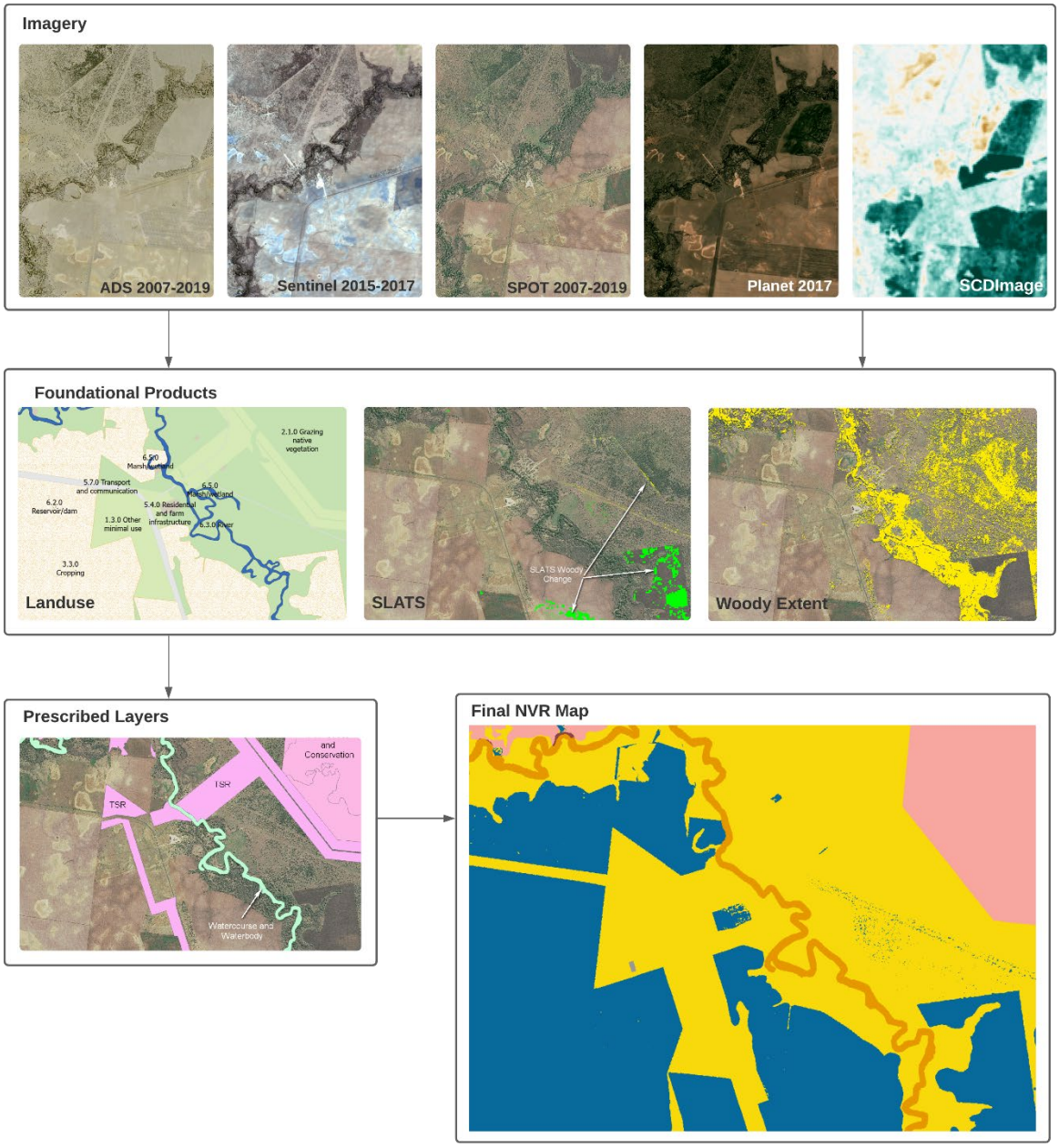


Figure 5 Sample key image layers used to develop the native vegetation regulatory map

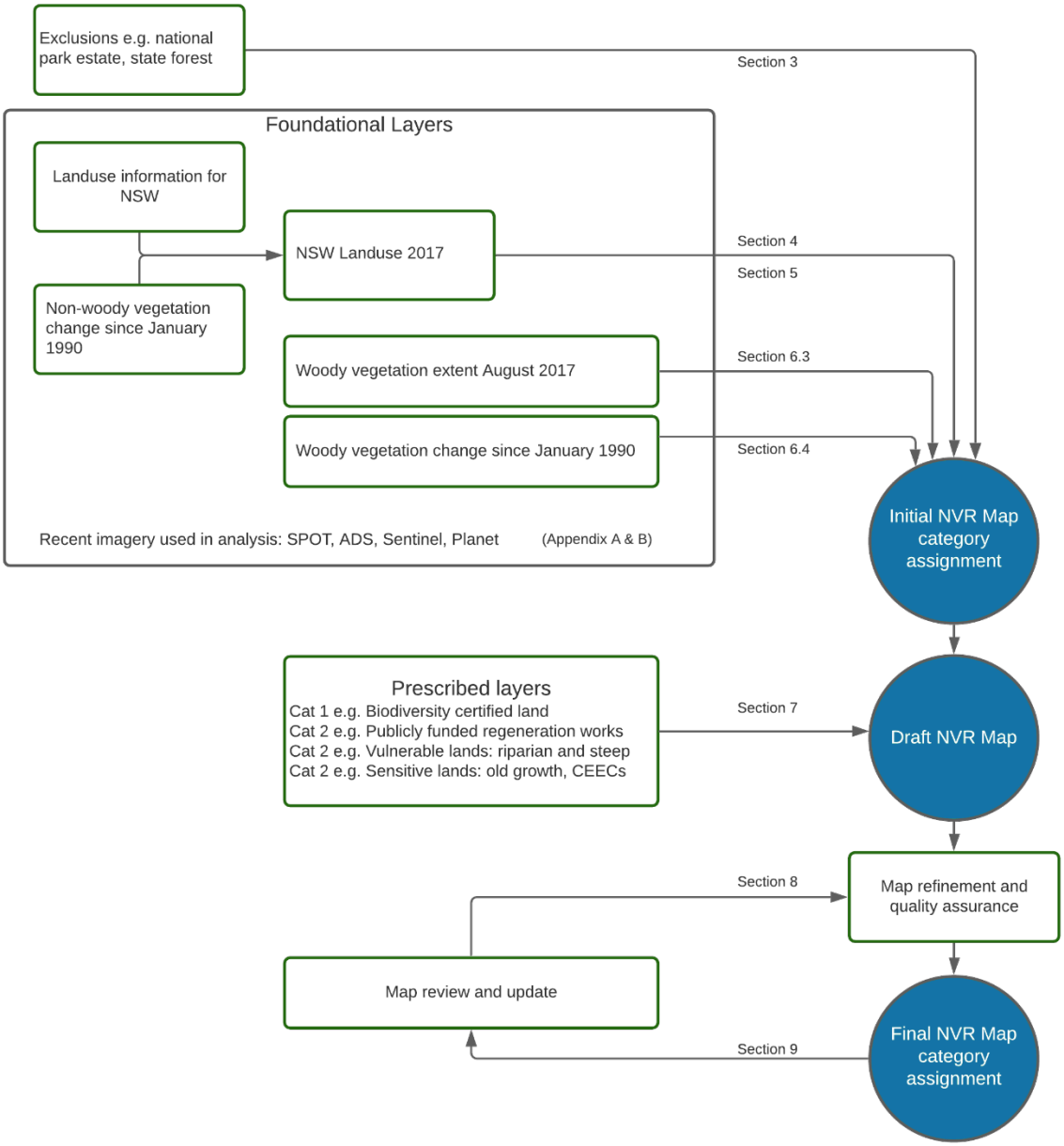


Figure 6 Overview of the process to create the native vegetation regulatory map

2.6 Data used in the method

2.6.1 Key data and imagery sources

Most of the information used to compile the map is based on satellite or aerial imagery. The most detailed imagery that was available in a consistent resolution for the whole State at the time of mapping was from the SPOT 5 satellite (see Appendix A). It provides imagery products with 5-metre resolution, which are rectified to a consistent standard. Maps can be produced at a scale of 1:10,000 using this data. In some areas where the information is derived from aerial imagery, the spatial resolution exceeds this minimum standard.

Appendix A summarises the foundational spatial datasets that are used to develop the major components of the map, including existing imagery, map products and descriptions of baseline processing of this data. Sections 3 to 9 of the method describe (as relevant) how these spatial datasets are used. They also refer to other datasets that contribute to the method.

Appendix B summarises the key datasets, sources and associated map products that use this data.

Appendix C provides a sample of analyst interpretation rules for how different types of land use are identified and classified (Section 4).

Appendix D provides further detail on the development of the SCDI products, which support the analysis of images to determine land use for non-woody vegetation (Section 5).

Appendix E provides further detail on the data and processes used to develop the products used when mapping woody vegetation extent and detectable clearing events (Section 6).

Appendix F lists the specific datasets that are used to develop the category 1 and category 2 prescribed layers, which are based on specific criteria in the LLS Act ad Regulation. (Section 7).

Appendix G provides further details related to the map formation process described in Section 8.

All appendices are in the separate publication: Native Vegetation Regulatory Map Method Statement: Appendices.

2.6.2 Updating data sources and databases

The data sources and databases relied upon in this method will be updated from time to time as new information becomes available. This is essential to ensure that the NVR map is accurate and reliable. The map needs to reflect the dynamic nature of vegetation change across the landscape in accordance with ongoing and changing land use.

The NVR map will be updated to reflect category changes as defined by the LLS Act, the code and LLS regulation; for example, through approval of land management (native vegetation) code certificates, or private native forestry agreements reaching term, or the determination and mapping of new critically endangered ecological communities.

The incorporation of updated information into the NVR map is essential to allow for vegetation change to be continually monitored for compliance purposes.

This information may be used as part of any map review process, whether that is a review initiated by a landholder, the annual map review, or a review initiated by the Environment Agency Head (LLS Act ss. 60K and 60L).

Section 9 provides detail on updating and revising the NVR map to maintain currency and include new information.

3. Exclusions

3.1 Introduction

The LLS Act states that the map will not apply to certain land, referred to as 'excluded land' (LLS Act s. 60A). This means that the regulatory framework for native vegetation clearing in rural areas will not apply on the excluded land.

This section describes how an 'exclusions layer' is created to identify this excluded land. No further analysis or mapping is undertaken on this land.

The map can be updated to show any future changes to the status of land that results in land either no longer being excluded land, or becoming excluded land (e.g. as a result of rezoning decisions). Updates will be integrated through the map update and review process (Section 9).

3.2 Land excluded by the LLS Act

3.2.1 Excluded local government areas

The map does not apply to the following local government areas (LGAs): Bayside, Blacktown, Burwood, Camden, Campbelltown, Canterbury–Bankstown, Canada Bay, Cumberland, Fairfield, Georges River, Hawkesbury, Hornsby, Hunters Hill, Inner West, Ku-ring-gai, Lane Cove, Liverpool, Mosman, Newcastle, Northern Beaches, North Sydney, Parramatta, Penrith, Randwick, Rockdale, Ryde, Strathfield, Sutherland Shire, Sydney, The Hills Shire, Waverley, Willoughby, Woollahra.

3.2.2 Excluded local environmental plan zones

The map does not apply to the following land use zones under an environmental planning instrument made under the *Environmental Planning and Assessment Act 1979*:

- Zone RU5 Village
- Zone R1 General Residential
- Zone R2 Low Density Residential
- Zone R3 Medium Density Residential
- Zone R4 High Density Residential
- Zone R5 Large Lot Residential
- Zone B1 Neighbourhood Centre
- Zone B2 Local Centre
- Zone B3 Commercial Core
- Zone B4 Mixed Use
- Zone B5 Business Development
- Zone B6 Enterprise Corridor
- Zone B7 Business Park
- Zone B8 Metropolitan Centre
- Zone IN1 General Industrial
- Zone IN2 Light Industrial
- Zone IN3 Heavy Industrial

- Zone IN4 Working Waterfront
- Zone SP1 Special Activities
- Zone SP2 Infrastructure
- Zone SP3 Tourist
- Zone E1 National Parks and Nature Reserves
- Zone E2 Environmental Conservation
- Zone E3 Environmental Management
- Zone E4 Environmental Living
- Zone RE1 Public Recreation
- Zone RE2 Private Recreation
- Zone W3 Working Waterways

In effect this means that the map applies only to the following zones (if they are not in an excluded LGA):

- Zone RU1 Primary Production
- Zone RU2 Rural Landscape
- Zone RU5 Primary Production Small Lots
- Zone RU6 Transition.

3.2.3 Other exclusions

The map does not apply to the following land (LLS Act s. 60A(b–c))*:*

- National park estate and conservation areas, namely –
  - a wilderness area declared under the *Wilderness Act 1987*
  - land reserved under the *National Parks and Wildlife Act 1974* or acquired by the Minister for Environment and Heritage under Part 11 of that Act
  - land dedicated or set apart as a flora reserve under the Forestry Act (or any Act repealed by that Act)
  - land to which an interim heritage order or listing on the State Heritage Register under the *Heritage Act 1977* applies (this will generally be identified as per curtilage in the listing, rather than the entire lot)
  - a declared area of outstanding biodiversity value under the *Biodiversity Conservation Act 2016*
  - an area declared to be critical habitat under Division 3 of Part 7A of the *Fisheries Management Act 1994*
  - a declared World Heritage Property within the meaning of the *Environment Protection and Biodiversity Conservation Act 1999* of the Commonwealth
  - land dedicated or reserved under the *Crown Lands Act 1989* for similar public purpose for which land is reserved, declared or listed under the other Acts referred to in this paragraph
  - land to which an interim protection order under Part 11 (Regulatory compliance mechanisms) of the *Biodiversity Conservation Act 2016* applies
  - Lord Howe Island.
- State forestry land, namely:
  - land that is a state forest or timber reserve under the Forestry Act

- land acquired under Division 4 of Part 3 of the Forestry Act for the purposes of a state forest (not being any such land that is acquired for the purposes of a timber plantation).

3.3 Other excluded land or vegetation types

The map method is not applied to marine vegetation as per s. 60B(4) of the LLS Act.

3.4 Developing the exclusion layer

The NSW Government maintains databases for all spatial datasets used for compiling the exclusion layer. The spatial datasets that are used are described below.

3.4.1 NSW Digital Cadastral Database

The following data layers from the NSW Digital Cadastral Database are used to compile the exclusion layer:

- NSW local environment plans – standard instrument
- NSW local government areas
- National parks estate layer (gazetted, acquired not gazetted and lands under the Minister for Environment)
- Forestry NSW estate layer (boundaries, timber and flora reserves)
- NSW cadastre
- NSW boundary.

The NSW Digital Cadastral Database is maintained by NSW Department of Customer Service.

3.4.2 Department of Planning and Environment databases

The following Department of Planning and Environment (DPE) data layers are also used:

- database for ‘areas of outstanding biodiversity value’ made under the *Biodiversity Conservation Act 2016*
- database for wilderness areas declared under the Wilderness Act.

4. Identifying and mapping existing and historical land use

4.1 Introduction

This section describes the process for identifying and mapping existing and historical agricultural land use since 1 January 1990 to create a NSW Landuse 2017 map. This Landuse 2017 map then contributes to identifying land for inclusion in category 1–exempt land in the NVR Map.

Mapping existing and historical land use focuses on identifying patterns or evidence of agricultural land uses according to high-resolution aerial or satellite imagery and classifying land under a national land use classification system.

4.2 Overview

Creating NSW Landuse 2017 involved the following key steps:

1. reviewing existing NSW Landuse maps, namely, NSW Landuse 2007 (date of mapping varies across the State between 1999 and 2012) and NSW Landuse 2013
2. capturing land use activity since 1990 using recent high-resolution SPOT 5, Leica Airborne Digital Sensor (ADS) digital aerial imagery, available historical aerial imagery flown circa 1990, as well as more frequent but lower resolution Planet mosaics and Sentinel–2 satellite imagery
3. identifying patterns of land use history and land use change using the seasonal cover disturbance products and time-series cover difference (Section 5)
4. confirming the spatial and positional accuracy of this existing land use information (including rectifying any misalignment resulting from cadastral boundaries where possible, as described in Section 8.5).

Land is then categorised into the Australian Land Use and Management classification system (ALUM). Each of these ALUM classes is identified as category 1 or category 2 (Section 4.3, Figure 7).

Rule sets for identifying land that falls within each class (and therefore whether it is initially assigned as category 1 or 2) are described in Section 4.4.3 and are supplemented by the guidelines that analysts use in interpreting images (Appendix C).

The NSW Landuse 2017 map, in combination with other layers of data, contributes to determining land that should be category 1, as per the final integration process described in Section 8.

The NVR Map published on August 2017 used the NSW Landuse 2013 to generate draft category 1 and 2. These draft categories have since been updated using Landuse 2017 to reflect the land use at the commencement of the native vegetation clearing framework.

4.3 Available NSW Landuse

The NSW Landuse maps are spatial datasets that capture land use activities in accordance with the ALUM classification system. This classification system was devised by the Australian Collaborative Land Use and Management Program (ACLUMP) to capture standardised land use information in Australia.

ACLUMP defines land use as (ABARES 2011, p.3):

> The purpose to which the land cover is committed. Some land uses, such as agriculture, have a characteristic land cover pattern. These usually appear in land cover classifications. Other land uses, such as nature conservation, are not readily discriminated by a characteristic land cover pattern. For example, where the land cover is woodland, the land use may be timber production, grazing or nature conservation.

The ALUM land use classification system (ABARES 2011, pp.13–40) used in the NSW Landuse datasets are based on the level of modification to the 'natural' landscape. The ALUM system comprises 6 primary classes, each of which includes secondary and tertiary classes (Figure 7), with increasing degrees of specificity. Figure 7 shows the ALUM classes which are assigned to category 1 in blue, classes assigned to category 2 in yellow, and land that is ultimately excluded from the application of the map in grey.

The 6 primary ALUM classes are:

1. Conservation and natural environments
2. Production from relatively natural environments
3. Production from dryland agriculture and plantations
4. Production from irrigated agriculture and plantations
5. Intensive uses
6. Water.

The ALUM hierarchical structure enables land to be classified based on the ability to define the type of land use present. Land use can be grouped or separated according to related land uses. NSW Landuse products are mapped to ALUM tertiary classes where possible, although the minimum required level is ALUM secondary classes. Land is classified to the tertiary level where the ancillary data or information allows or there is sufficient visual evidence in the imagery to make a determination.

The objective under the LLS Act is to identify land that has been modified or disturbed for agricultural land use, therefore the focus of the land use mapper is in delineating the following primary land use ALUM classes that are predominantly category 1 (Figure 7):

3. Production from dryland agriculture and plantations
4. Production from irrigated agriculture and plantations
5. Intensive uses
6. Water features (built or formed to store, capture or deliver water for agricultural purposes).

ALUM primary classes 1, 2 and 6 are substantially natural environments and are primarily category 2.

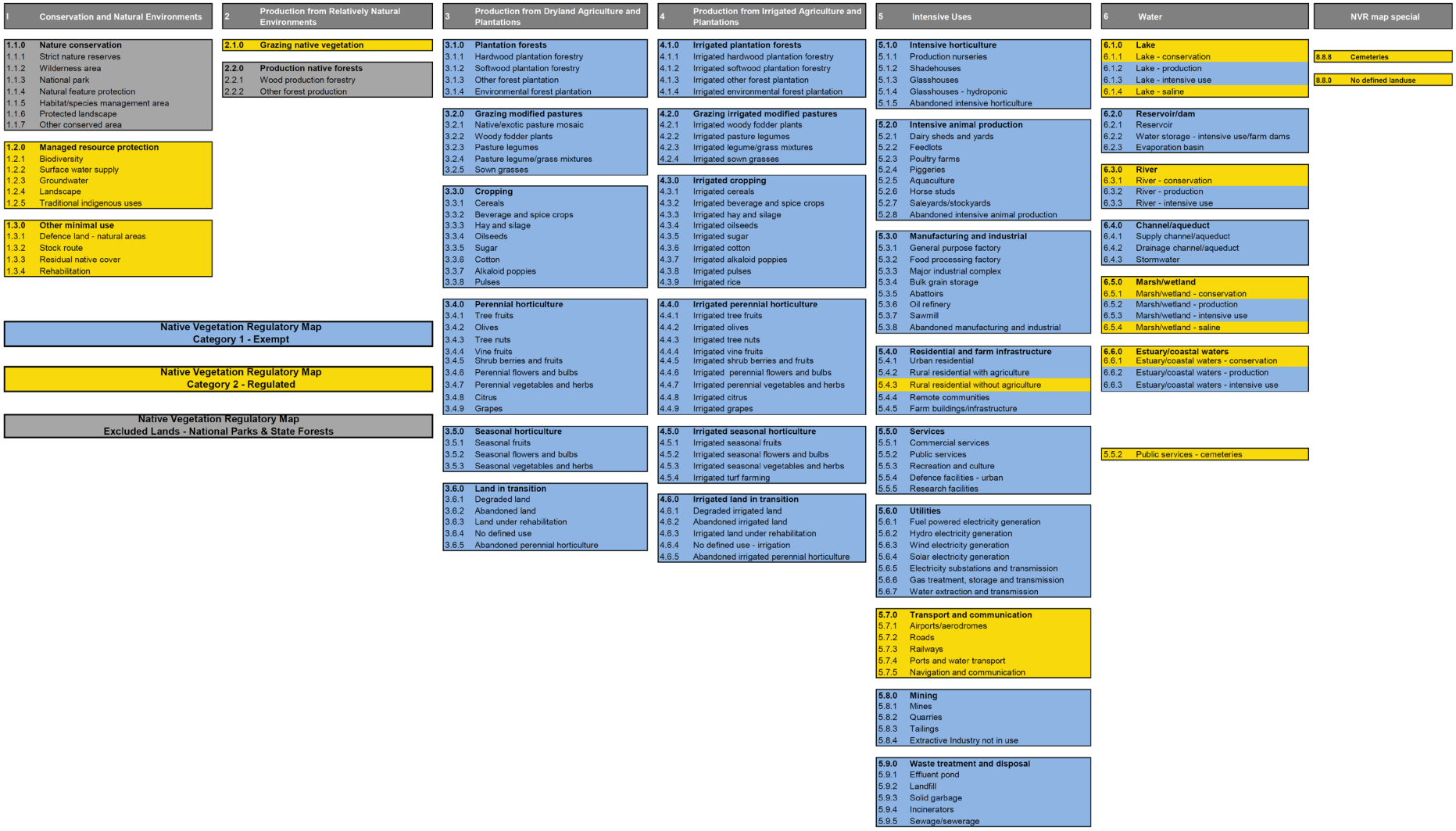


Figure 7 ALUM classification version 8 assigned to the native vegetation regulatory map category 1-exempt and category 2-regulated land, and excluded lands

The NSW Landuse 2007 map was captured through ACLUMP between 1999 and 2007 (with a median capture year of 2003) and was based on aerial photographs viewed in 3 dimensions using a stereoscope. As more advanced imagery became available it was incorporated into the mapping program, including 2005 SPOT mosaics and ADS imagery from 2007 onwards.

The NSW Landuse 2013 map was captured as part of the development for the August 2017 publication of the NVR Map. This product was built from the Landuse 2007 map with the advantage of position-accurate, high-resolution satellite and aerial imagery and the benefit of advances in the geographical information systems software used to capture spatial information.

The NSW Landuse 2013 map was mapped at 1:10,000 scale, with a minimum polygon size of 2 hectares and land use class was captured from imagery dated 1990 up to July 2013.

The first version (v1) of the SCDImage was used in Landuse 2013 to identify paddocks or management units that met the criteria of being cleared at 1990, or lawfully cleared since. The SCDImage was used primarily to identify non-woody grassland areas that indicated high disturbance and hence were considered cleared or significantly disturbed.

In some instances, sub-paddock or management units were mapped where a distinct difference in disturbance was present within the management unit, as a result of terrain or geographical constraint.

The NSW Landuse 2013 map used a multiple lines of evidence approach combining available aerial and satellite imagery, SCDImage (v1), ancillary data and available coverage of circa 1990 historical aerial imagery.

4.4 Updating NSW Landuse

The NSW Landuse 2017 map was captured to the commencement date of the LLS Act (i.e. 25 August 2017) and followed the same mapping method and parameters as Landuse 2013 while benefiting from additional imagery, mapping tools and SCDI products.

The Landuse 2017 product incorporated additional available satellite and aerial imagery (Figure 8), including:

- Planet 2017 mosaic with images as close as possible to 25 August 2017
- Sentinel-2 imagery available from 2015
- additional coverage of historical aerial imagery (circa 1990)
- an updated version of SCDImage 1988–2017 (v2) with improved ground calibration and refinements, a SCDIndex across the same dates and a seasonal cover disturbance differencing index (‘SCDDifference Index’) that identified potential areas of land use change between 2013 and 2017. Further information on these products is available in Appendix D.

Additional tools available to mappers included access to a wide range of imagery dates from 2013 to 2017 in Google Earth (including street view) and Planet Web Mapping Services monthly mosaics.

NSW Landuse 2017 is subject to ongoing improvements as data becomes available. This may be from applying the NVR Map method during landholder initiated map reviews or from on-site visits from Local Land Services and DPE staff.

The most current version of NSW Landuse 2017 map is publicly available on the NSW Sharing and Enabling Environmental Data portal (SEED).

On including NSW Landuse 2017 into the NVR Map, an additional layer depicting building footprints is incorporated as category 1. This captures development that has occurred within

the Landuse polygons at a sub-2-hectare scale. When this layer is incorporated, additional woody extent is not applied as vegetation within this footprint can be legally cleared under allowable activities of the land management (native vegetation) code.

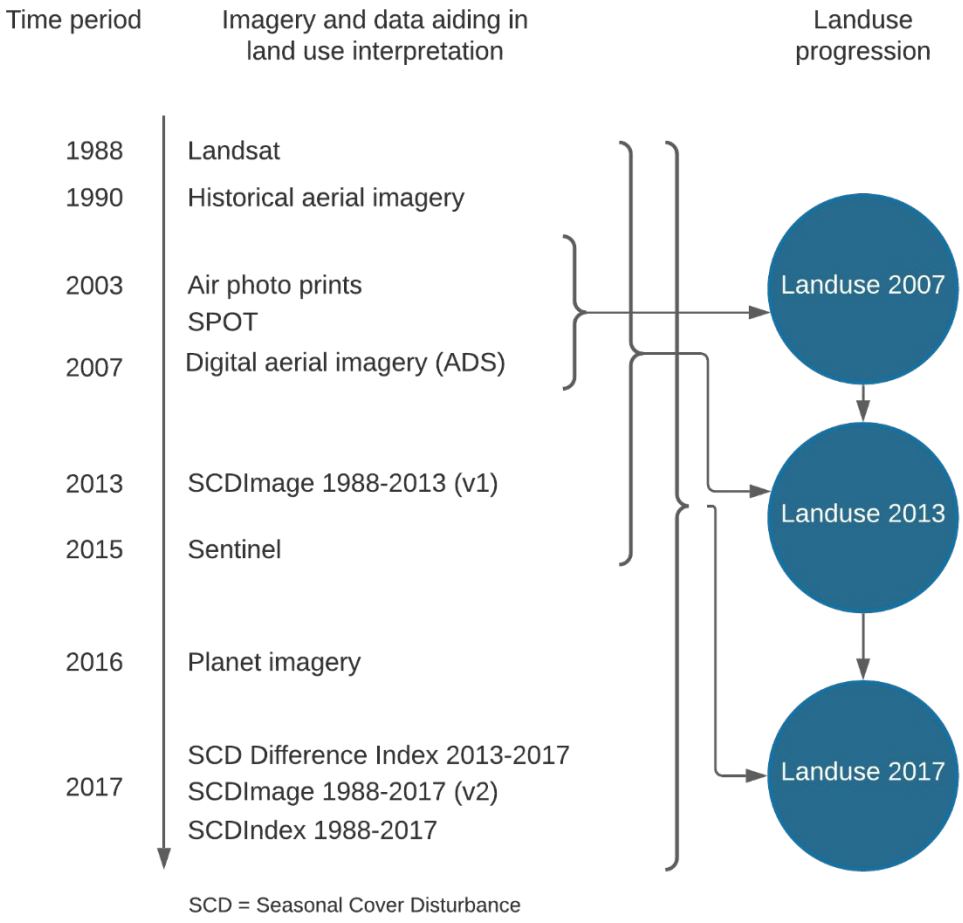


Figure 8 Imagery and data available to aid in land use interpretation and ALUM classification in successive NSW Landuse map versions

4.4.1 Using ADS, SPOT 5, Planet mosaics, Sentinel-2 and historical aerial imagery

The high-resolution digital aerial imagery (ADS), SPOT 5 and historical aerial imagery, as well as lower resolution but more regular Planet mosaics and Sentinel–2 imagery, are used to identify patterns or evidence of agricultural production. Patterns in the imagery are interpreted visually, the boundary delineated and the area assigned an ALUM class. The patterns that are considered include:

- soil disturbance
- exposure and compaction
- cultivation activity patterns associated with agricultural implements
- uniform planting patterns associated with horticulture (tree crops) and plantation forestry
- tonal and textural differences present in the imagery, for both groundcover and canopy cover (overstorey).

Both current and historic land use patterns can be identified in the imagery because land use patterns associated with agricultural production are often evident for several years after the activity has taken place. Trained analysts can detect soil compaction and disturbance from heavy machinery, or the presence of crop stubble retained after the crop has been harvested. This analysis ensures agricultural land use will be captured despite the variation in availability of satellite and aerial images since 1 January 1990.

4.4.2 Using the seasonal cover disturbance image

The SCDI products described in Section 5 are used to ensure more thorough accounting for episodic agricultural activity.

The information gained from the SCDImage and SCDIndex (collectively referred to as 'SCDI' products) helps in the identification of areas that have been subject to agricultural land use outside the timeframes of existing imagery. Where there is evidence of earlier ground modification/disturbance events, SCDImage and SCDIndex may detect land use activities that are different from those identified in recent high-resolution satellite and aerial imagery.

Figure 9 displays the temporal coverage of existing land use information, and how this is supplemented by the SCDI products (which is applied across the entire timeframe of 1 January 1990 to 25 August 2017 for the 2017 NVR Map).

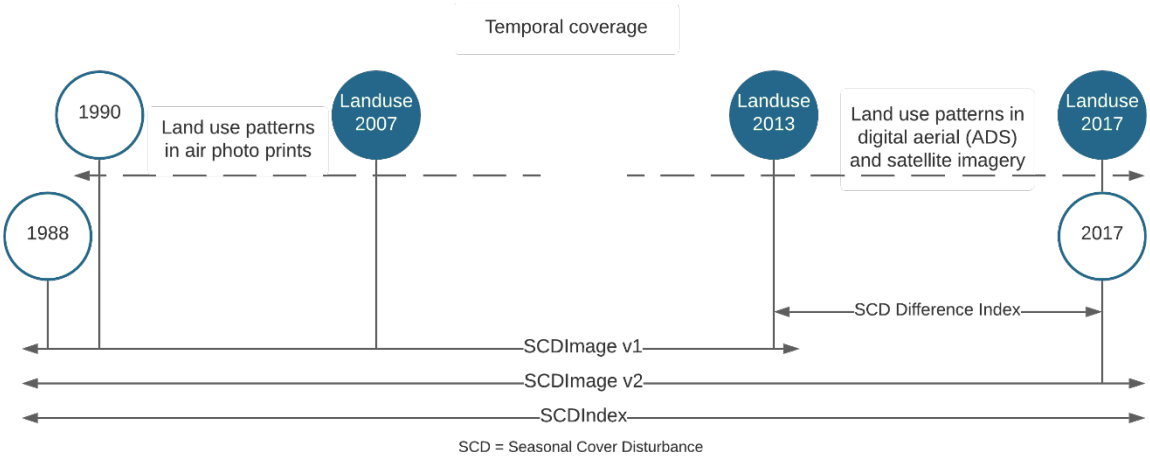


Figure 9 Temporal coverage of existing land use imagery and seasonal cover disturbance (SCD) image products

The SCDI products assist in identifying areas subject to agricultural activities that may not show physical evidence in aerial photography or satellite imagery. Examples include pastures that have been repeatedly over-sown, fertilised and/or have had ameliorant applied. These activities become evident in the SCDI products due to the high variation in groundcover of these areas over multiple seasons and across multiple years (Section 5). In most instances the SCDI products are used with other imagery sources as part of a multiple lines of evidence approach looking for indications of disturbance to determine whether an area is modified. The SCDI products provide a vital role in delineating between ALUM classes of high disturbance — 'modified pastures' (ALUM class 3.2.0) — and areas that show low disturbance or patchy disturbance, which may indicate variation caused by grazing only – 'native pastures' (ALUM class 2.1.0).

NSW Landuse 2013 used SCDImage (v1). This version was based on Landsat time series 1987 to July 2013. Three shorter SCDI sequences of approximately 8-year intervals were

produced to aid interpretation, particularly where the complete sequence was inconclusive based on mixed disturbance values within a paddock or management unit.

Some of the limitations of the SCDImage (v1) are related to areas subject to regular or consistent inundation and various soil types. This was mitigated by mappers using the water prevalence image (see Appendix A) to identify areas that were influenced by inundation rather than modified through agricultural clearing.

Further refinements to the SCDImage based on ground validation data and processing improvements resulted in version 2 (v2) which was used in NSW Landuse 2017. SCDImage (v2) incorporated Landsat time-series information from 1987 to August 2017. More recently an SCD Index (Section 5) has been developed. Both products have improved performance in detecting clearing or modification in these landscapes through improved on-ground calibration.

The SCD Difference Index is a change index that uses the same Landsat fractional cover information as the SCDImage products for 1987–2013 and 1987–2017. This Index identified where potential changes in land use had occurred between 2013 and 2017, as part of the Landuse 2017 method. Land use changes were confirmed with high-resolution satellite imagery and mapped.

The SCD Difference Index has been used to systematically review NSW Landuse 2017 and identify areas where the attributed map category does not align. These areas are then put under further scrutiny in reapplying the NVR Map method using:

- satellite and aerial imagery (circa 1990–2017) – to determine whether the area aligns with linear/geometric paddock shapes or geographic constraints present within the paddock
- multiple lines of evidence using available imagery and in context to the surrounding areas of limited disturbance (such as road and rail corridors, geographic features such as rocky areas, steep slopes, treeline areas and riparian areas), compared to areas of high disturbance with consistent SCDImage values, where they may provide context or indication to the type of agricultural disturbance present
- the water prevalence image – to ensure the variation in cover is not the result of inundation.

Appendix C provides examples of how the SCDImage is used to define paddock features as modified pastures or native pastures, based on the level of disturbance.

4.4.3 NSW Landuse map fieldwork

Fieldwork is a vital component of any land use mapping program. Fieldwork conducted to inform all three eras of NSW Landuse (2007, 2013 and 2017) has informed the final categorisation of the NVR Map.

Extensive fieldwork was undertaken for NSW Landuse 2007, with most of the central and eastern areas of the State along with developed areas in western NSW being field validated.

Fieldwork for NSW Landuse 2013 and 2017 was undertaken between 2016 and 2018 to validate the mapping, build confidence and familiarise staff with the landscape. The mapping staff were able to relate the patterns, textures and tones they were observing in aerial and satellite imagery to on-ground features. In-depth fieldwork was undertaken where the SCDImage was used to distinguish areas of low and high disturbance in pasture-dominated landscapes.

Fieldwork was also undertaken where the land use class was unclear, using available aerial and satellite imagery and the SCDImage. Mapping staff would visit the site and identify if these areas showed in-field indicators which would indicate whether the area may have been subject to past agricultural disturbance. Field points were used as a line of evidence

against the era being mapped, that is, a site might appear as ‘undisturbed native’ in 2016, however, 2012 imagery would show cropping, therefore the site would remain as category 1. If areas showed limited or no visual cues of past disturbance, either in the field or in imagery, the precautionary mapping principle was applied assigning them to category 2-regulated land ALUM classes.

Fieldwork associated with Landuse 2013 and 2017 covered around 114, 1:100,000 topographic map sheets or approximately 33% of the State. It was focused in the Central West, Southern Tablelands, Murray and Riverina, Northern Tablelands and coastal areas of New South Wales.

The fieldwork method involved driving accessible loops across the areas represented on map sheets, which ensured that a good representation of a particular landscape was covered. Visual observations were recorded as points in a GIS dataset. Fieldwork focused on landscapes where it was more difficult to assign a land use class based on agricultural practice.

The fieldwork was a snapshot of agricultural activity (2016–19) in the overall temporal coverage of the agricultural activity considered in the map. It was used to link visual cues present in aerial imagery for particular landforms or landscapes to the likelihood of extensive or minimal agricultural disturbance in the past.

4.4.4 Peer review of NSW Landuse maps

NSW Landuse 2013 and 2017 were subject to peer review to ensure that the land use interpretation was consistent, followed the Landuse method and considered all the available information.

Mapping is reviewed at a scale of 1:25,000 on-screen using Arc GIS. Any changes made through the peer review process are made at 1:10,000, or better, to maintain the consistency of the line work in the mapping. Reviewing at 1:25,000 allows the person undertaking the peer review to gain a more regional perspective of agricultural activities and patterns in the aerial and satellite imagery, along with the SCDI products.

Peer review is undertaken when a map sheet has been completed, and the mapping has been through a series of GIS data management checks. The checks include edge matching between areas mapped by different staff members, topology and addressing any other data management issues.

As part of the peer review process, the person who mapped the land use and the reviewer discuss any changes. If the mapper and the reviewer disagree on the changes, a senior mapper mediates and makes the final decision.

In creating NSW Landuse 2013, approximately 30% of map sheets were nominated for review by DPE operational staff who had not been involved in the mapping but held valuable experience and understanding of on-ground land management and biodiversity conservation activities across the State. Staff used local knowledge to identify any areas for review in the Landuse map to ensure consistency and accuracy in the application of the mapping method.

Once the peer review process was completed, the map sheet was subjected to another series of data management checks, including topology.

The mapping is then merged into a statewide land use dataset. As part of this process further data management checks are undertaken and the data management staff and a senior mapping staff member address any issues.

The mapping product was then ready for accuracy assessment and to form the NVR Map product (Section 6).

4.4.5 Accuracy assessment

Accuracy assessment was undertaken on NSW Landuse 2013 to assess consistency between land use mappers in the accuracy of individual land use classes, and the overall accuracy of the NVR categories. Fourteen map sheets were selected for accuracy assessment. They were chosen on the basis that they provided a cross-section of both land use mappers and regional areas. The same mappers and method were applied in bringing Landuse 2013 up to Landuse 2017.

The accuracy is assessed at a number of points across the map sheets, which are chosen using a random stratified approach. This ensures points are selected randomly but also that an appropriate number of points are placed in each land use class. The accuracy assessor then gives each point an ALUM category, using the same information provided to the land use mapper, that is, a range of SPOT imagery dates, SCDImage and ADS40 imagery. If the assessor identifies points where the land use could not be interpreted confidently from the desktop, advice is sought from senior mappers or regional experts.

To assess the agreement between the land use mapper and the independent assessor, an error matrix is calculated. This identifies the level of agreement between the map category and the identified reference points and provides an accuracy figure.

The overall land use accuracy for each map sheet assessed was greater than 90%. Accuracy was also assessed after combining the land use classes to represent the NVR map categories. The user and producer's accuracy based on the NVR Map categories was greater than 80% and the upper confidence interval was greater than 90% in all but 2 map sheets. These map sheets were thoroughly investigated by the assessor in consultation with the land use mapper and a senior expert to establish the cause of the low values. The low values resulted from a combination of reference points being distributed across ALUM classes, not NVR categories, and the variation in mapped area of the 2 NVR categories. These factors resulted in insufficient sample points in some classes.

The accuracy assessment method and results are presented in more detail in Appendix C-2.

5. Identifying and mapping non-woody vegetation change

5.1 Introduction

This section describes the process of analysing evidence of past or ongoing significant disturbance or modification of non-woody vegetation in accordance with the LLS Act and LLS Regulation. This evidence is used to supplement and refine the NSW Landuse maps described in Section 4.

It describes how Landsat imagery was analysed to develop seasonal cover disturbance products, which help the identification of changes in non-woody vegetation. The products include a seasonal cover disturbance image (SCDImage) and a seasonal cover disturbance index (SCDIndex), which are collectively referred to as SCDI. The SCDI products show where non-woody vegetation has been significantly disturbed or modified for agricultural purposes.

Non-woody vegetation is everything outside of the definition of 'woody' (i.e. with defined woody stems and over 2-metres tall), and includes grasses, shrubs, small trees and seedlings.

The LLS Act and Regulation also outline criteria for designation of land on the map based on the conservation value of grasslands and other groundcover as determined in accordance with the legislation. The map will be updated as determinations of conservation value of grasslands and other groundcover are made.

5.2 Overview

The SCDI products were used to identify and map non-woody vegetation change beyond established land use data classifications. These products identify:

- disturbance from cropping
- modified pastures (sown, over-sown, fertilised and ameliorant applied)
- pastures or other non-woody vegetation displaying variability compared to the surrounding area, signalling the likelihood of agricultural disturbance.

The SCDI products do this by identifying the pattern of change in vegetation cover over multiple seasons and across multiple years. For example, land that has been cultivated will show much greater variability in the amount of green and non-green vegetation cover on the land, compared to a low level of variability in vegetation cover that native grasslands or other native vegetation typically display.

The results of this analysis are image and index products that are used in conjunction with ADS, SPOT and Planet imagery to guide land use interpretation by identifying non-woody vegetation for inclusion in category 1-exempt land. The process for combining the various layers to create the final map product is described in Section 8.

5.3 Identifying disturbance of non-woody vegetation

5.3.1 Introduction

The process for identifying and mapping non-woody vegetation that has been subject to significant disturbance or modification since 1 January 1990 is based on analysis of fractional cover images.

Where non-woody vegetation has been significantly disturbed or modified, it is taken to have been lawfully cleared and is category 1-exempt land.

The fractional cover images are derived from Landsat images by applying an extensively validated model that calculates the proportion of green cover and non-green vegetation cover and bare cover for every pixel in each Landsat image. This model is applied to a time series of approximately 700 Landsat images for every location in New South Wales. The time series of fractional cover images are then combined to form seasonal composite images, which are further analysed for non-woody vegetation disturbance. The Landsat, fractional cover images and seasonal composite images are further described in Appendix A.

The SCDI products used in the NVR Map combine information from fractional cover seasonal composite images spanning seasons from summer 1988 to winter 2017 to identify areas that have experienced change in, or disturbance of, non-woody vegetation.

The algorithm for the SCD images is based on the following observed trends:

- cultivated areas show significantly more variation in the level of cover and the relative proportions of green and non-green vegetation cover due to the cropping cycle
- pasture areas, in particular native pastures, are relatively stable over time, with a higher proportion of non-green vegetation cover at most times and less fluctuation in the level of green cover, when compared to cultivated areas
- modified pastures generally have a greater proportion of green cover when compared to native pastures.

5.3.2 Role of the seasonal cover disturbance image

Existing NSW Landuse maps, based on interpretation of satellite and aerial images, are described in Section 4. As high-resolution satellite or aerial imagery may only be available for a few image dates, there are some areas with a history of agricultural activity (such as cropping or pasture modification) that will not be captured through this more static land use mapping process. Areas may have been cultivated less frequently, or were cultivated outside the time frames of the imagery used to establish the land use maps. Figure 9 in Section 4.4.2 compares the temporal coverage of seasonal cover images and air photographs used in land use mapping.

The SCDI is designed to overcome these potential gaps in the Landuse mapping. The images are used to detect cultivation and improved or modified pastures using the time series of Landsat images since 1988. These products are used to refine the Landuse maps.

5.3.3 The seasonal cover disturbance image and index

Development of the seasonal cover disturbance image and index

The algorithm is based on the concept that cultivated or modified pastures can be distinguished from other land cover types by identifying how the composition of green and non-green vegetation cover changes over time. A range of cultivated, modified pasture and

native pasture sites were selected and the patterns in the green/non-green vegetation cover space over time were analysed. Cultivated and modified non-woody vegetation sites were found to have different patterns to the native grassland sites. The cultivated and modified sites had a greater variation in green and non-green vegetation cover. They typically had a higher peak greenness and much lower minimum non-green vegetation cover when compared to native grassland sites.

To optimise the discrimination of these different cover types in the green/non-green vegetation cover space, these cover values were transformed into proportional measures of cover and several time-series statistics were calculated.

Three of the statistical images were combined to create the colour composite image known as the seasonal cover disturbance image (SCDImage). SCDImage products were developed for 4 time periods. One is based on the entire 1988–2013 time series and there is a set of three images, each covering approximately 8 years of the same time period.

The SCDIndex was developed later in the mapping program after developing a set of training data based on high-resolution satellite imagery, visual interpretation of time-series Landsat imagery covering 1987–2017, and roadside survey observations. The index was developed using this training data and more time-series images than used in the SCDImage. It classifies disturbance into a 0–1 range that can be displayed as a number of disturbance classes. This approach makes the interpretation of disturbance less subjective, but the SCDIndex was still used in a multiple lines of evidence approach with other data sources.

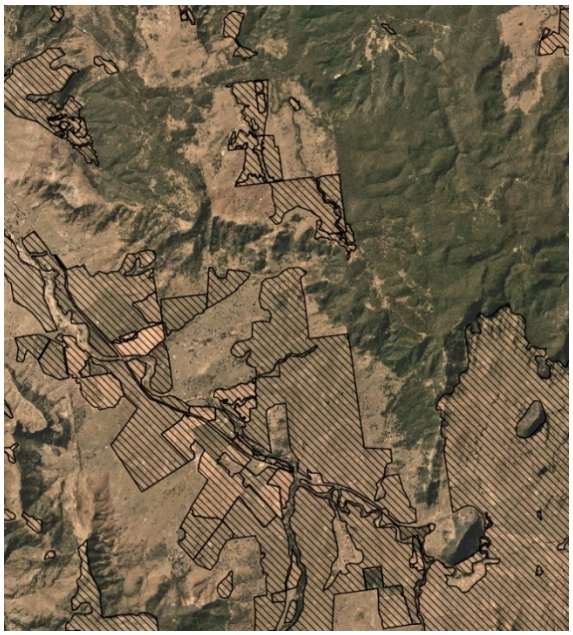
Examples of the SCDI product

An example of the SCDI product is shown in Figure 10. Figure 10(a) shows a single-date Planet colour composite image for 2017. The hatched polygons overlaid on this image represent the areas mapped as cropped or modified pastureland use classes.

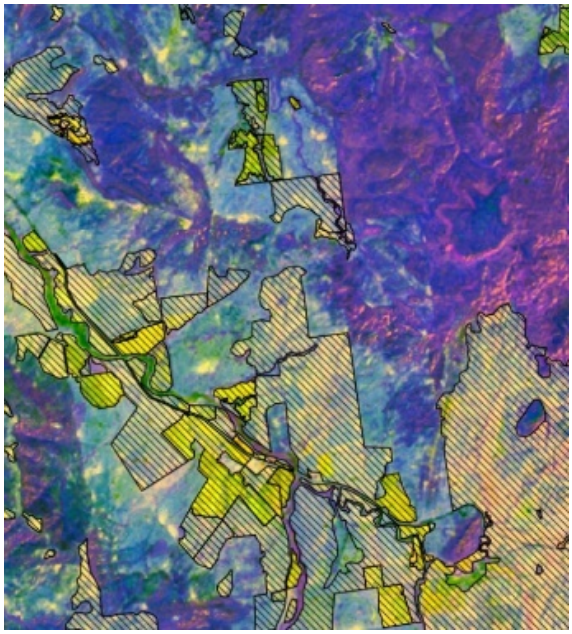
Figure 10(b) shows an example of the SCDImage. It is based on 120 seasonal fractional cover images covering the 30-year period from summer 1987–88 to winter 2017. The green and non-green vegetation cover fractions for each single-date image have been processed using the algorithm described above to create the time-series product. It shows:

- stable areas of pasture or woody vegetation as mid to dark blue
- a higher level of disturbance in cover associated with cropping or improved pasture as yellows and light green
- areas of woody vegetation as dark blue and purple.

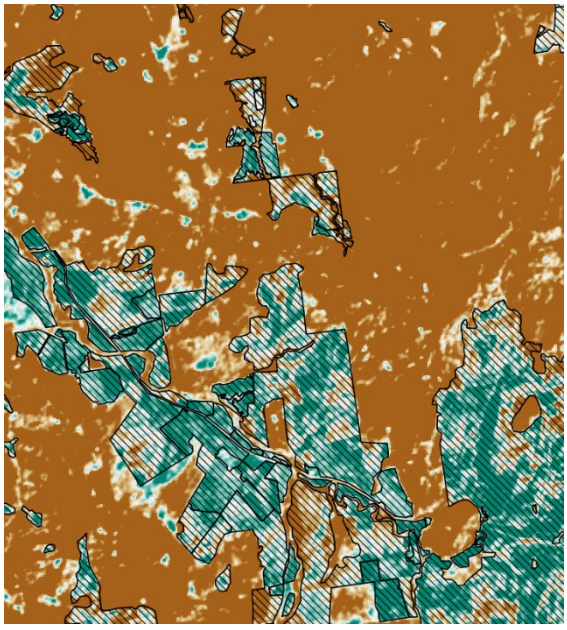
There are some anomalies where modified pastures look like native grasslands in the SCDImage and vice versa. To avoid misinterpretation, the seasonal cover disturbance image and index are used in conjunction with other imagery sources when interpreting the land use class. The interpretation process and rules are explained in Section 4 and Appendix D.



(a)



(b)



(c)

Figure 10 (a) Planet colour composite image for 2017; (b) SCDImage (v2) based on 1987–2017 Landsat images; (c) SCDIndex image

Modified non-woody vegetation classes from NSW Landuse 2017 are shown as black-hatched polygons.

The 3 images in Figure 10 have been overlaid with NSW Landuse 2017. The black-hatched polygons delineate land use boundaries of modified non-woody vegetation classes. The SCDImage in Figure 10(b) highlights additional areas of cultivation and modified pastures not distinguished in the SPOT 5, ADS or Planet imagery alone. It allows greater discrimination between cultivated or modified pastures and perennial vegetation that is more likely to be native. A SCDIndex was developed using the same fractional cover time series as used for the SCDImage. The SCDIndex image, shown in Figure 10(c), is represented by a colour ramp ranging from brown for low disturbance to aqua for high disturbance. The white areas represent the middle of the disturbance range. This approach helps to maintain consistent interpretation of the seasonal cover disturbance products when mapping land use.

The SCDImage, SCDIndex, ADS, SPOT 5 and Planet images are interpreted to identify areas of cropping and modified pastures. These areas are integrated into the land use mapping, by assigning them the appropriate primary ALUM class (Section 4), which would then result in this land being mapped as category 1–exempt land.

6. Identifying and mapping woody vegetation and change

6.1 Introduction

This section describes the process used to identify and map woody vegetation and where it has been cleared since 1 January 1990.

Woody vegetation is trees and shrubs taller than 2 metres and visible at the resolution of the imagery used in the analysis.

Woody vegetation is mapped as category 2 on the NVR Map, unless it was lawfully cleared (see LLS Act s. 60J(3) and LLS Regulation cl. 115) since 1 January 1990, or it is otherwise included as a prescribed layer that overrides the category 2 designation.

6.2 Overview

The process for identifying and mapping woody vegetation involved establishing 2 map layers that contributed to the final map product:

- baseline woody vegetation for August 2017 (described in Section 6.3)
- detectable clearing events since 1 January 1990 (described in Section 6.4).

The basis for mapping woody vegetation extent was the SPOT5 satellite images, augmented with information from high-resolution ADS aerial imagery and the detectable clearing events.

The bases for identifying detectable clearing events were annual monitoring of woody vegetation change and analysing trends in ‘vegetation greenness’ over a longer period.

In combination, these layers allowed woody vegetation to be identified and included in category 2–regulated lands, and woody vegetation clearing since 1 January 1990 to be identified and included in category 1–exempt land. Section 7 explains how prescribed layers and unlawful clearing are included in the NRV Map and categorised.

6.3 Establishing the baseline woody vegetation extent layer

6.3.1 Introduction

This part of the method established a baseline of woody vegetation for August 2017.

Foundational spatial dataset

The August 2017 woody vegetation extent map is an update of a 2011 map of woody vegetation extent. Figure 11 shows the 2011 woody vegetation extent map. It displays the location, extent and density of foliage cover for stands of woody vegetation across New South Wales. The resolution is fine enough (5-metre pixel size) to identify small features such as trees in paddocks and scattered woodlands, through to the largest expanses of forest in New South Wales. The detailed process for creating and validating the 2011 woody vegetation extent map is described in Appendix E.

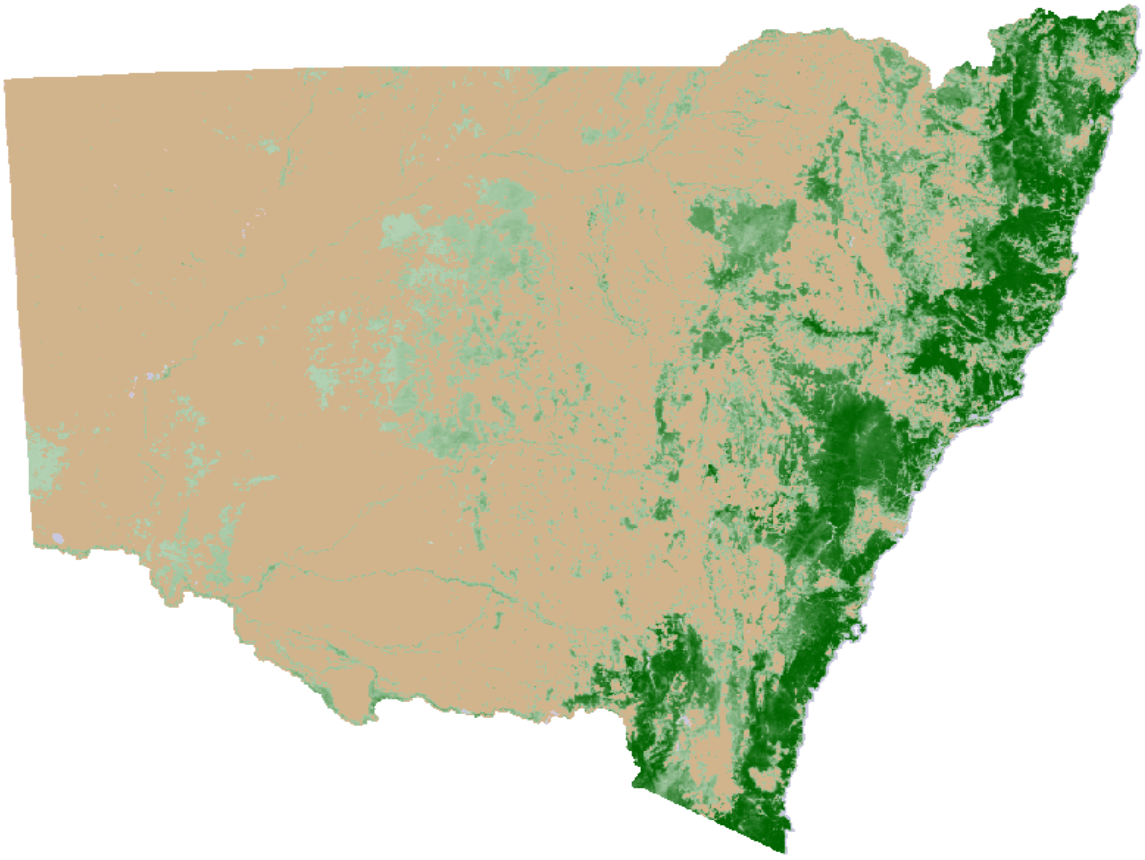


Figure 11 2011 woody vegetation extent map

Green areas are woody vegetation – the darker the green, the denser the vegetation cover

The August 2017 woody vegetation extent map was created from the 2011 woody vegetation extent map and maps of woody vegetation loss from the Statewide Landcover and Trees Study (SLATS) program. The SLATS data were used to modify the 2011 woody vegetation extent map in 2 cases.

Firstly, the 2011 woody vegetation extent map was created by analysing SPOT images captured from 2008 to 2011 (details given in Appendix E-1). It is possible that areas cleared during this period (i.e. non-woody areas) were incorrectly mapped as woody. To address this, SLATS clearing layers for 2009–10 and 2010–11 were used to correctly map these areas as non-woody.

Secondly, the SLATS annual clearing layers for the period January 2011 to January 2017, and a clearing layer from January 2017 to August 2017 were used to update the woody extent map to August 2017. The updates were carried out using an automated (scripted) process.

Table 7 in Appendix E-3 shows the data source, SPOT5 or Sentinel–2, of the SLATS maps used to remove woody vegetation from the 2011 map (from 2009–10, to August 2017).

6.3.2 Identifying additional areas of woody vegetation

The August 2017 woody vegetation extent map does not contain all of the trees in the landscape. The omissions occurred for 2 main reasons: either the tree canopy was much smaller than the 5-metre pixels of the SPOT 5 images, or the canopy appeared to have a similar colour to the ground.

We addressed these problems by checking for undetected trees using ADS digital aerial images with 50-centimetre pixels (Figure 12). Trees that were omitted from the woody vegetation extent map were detected using image processing methods (Appendix E-2). The woody vegetation extent map was then supplemented with the trees detected in the ADS images.

The ADS tree maps were incorporated into a ‘refinements’ image that analysts examined when checking the maps and making refinements. Analysts identified pixels to be reassigned to category 2 where they corresponded to trees detected in the ADS image that were not in the woody vegetation extent map and had not been cleared previously. Section 8 and Appendix G provide further details of the map checking and refinements process and the guidelines used by the analysts when interpreting the images and reclassifying pixels in the maps.

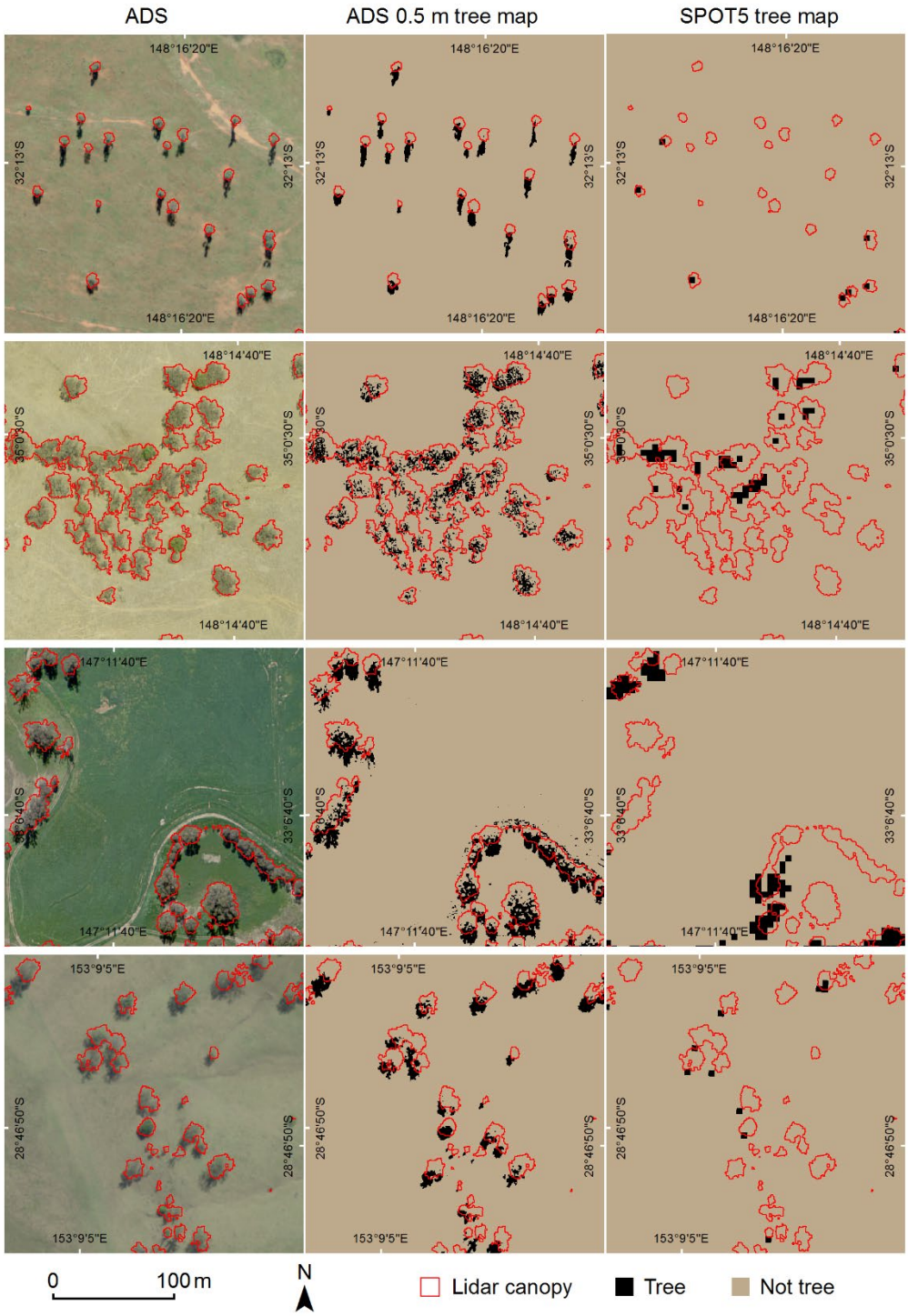


Figure 12 Trees not shown in the woody vegetation extent map (right) are detected (middle) by applying an image processing method to ADS digital aerial images (left)

The red outlines show the extent of the tree canopy detected by LiDAR sensors on board aircraft.

6.4 Identifying ‘detectable clearing events’ since 1 January 1990

6.4.1 Introduction

This section describes how ‘detectable clearing events’ for woody vegetation, which have taken place since 1 January 1990, were identified.

Figure 13 provides an overview of this process.

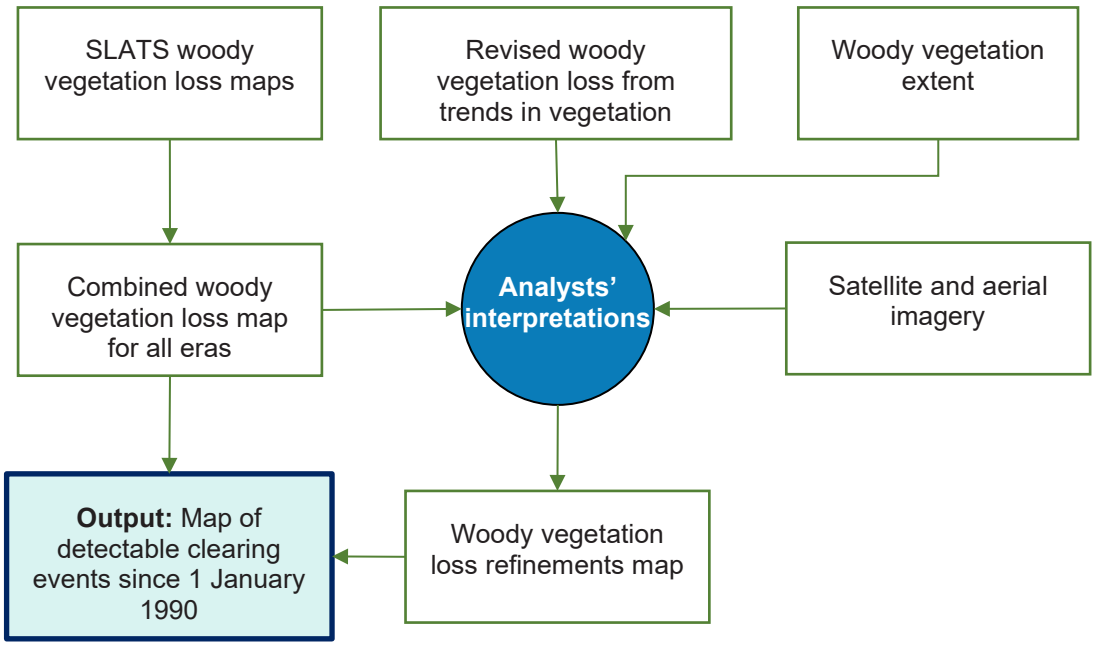


Figure 13 Process for mapping detectable clearing events for woody vegetation since 1 January 1990

Each box represents image data and the circle represents a process requiring analyst intervention. Most clearing events were previously detected and mapped by the SLATS program. Analysts checked for any missed or falsely detected woody vegetation loss events and revised them. The existing and revised datasets were combined to give a map of detectable clearing events since 1 January 1990.

6.4.2 Foundational data: SLATS mapping program

This section describes the existing datasets used to identify clearing of woody vegetation (the box in the top left corner of Figure 13). The primary data source is the SLATS mapping program.

Woody vegetation loss mapping involves the analysis of two images of the same location, captured at different times approximately one year apart, to produce evidence for woody vegetation loss. The relatively short time periods for these analyses means that woody vegetation loss can be detected before any potential regrowth reduces the ability to detect the change. Analysts used Landsat 5 TM, Landsat 7 ETM+, SPOT 5 HRG, and Sentinel–2 satellite images to produce SLATS maps. Two satellite images are used in each era – a ‘before’ and an ‘after’ image – on which a calibrated computer model is run to create an

image of the likelihood of woody vegetation loss for each pixel. This is the ‘change index’, described in more detail in Appendix E. The change index shows areas of possible woody vegetation loss. Trained analysts interpret the change index image using other images (captured from both satellites and aircraft) to verify that loss has occurred.

The change information for each era is stored in a raster file. ‘Raster’ is a method for storing spatial information digitally, also known as an image. It is composed of rows and columns of cells of the same dimension. The cells are also called pixels (picture elements), and each cell is associated with a number.

Each pixel in the raster has a code, assigned by an analyst, which shows if woody vegetation loss occurred at that location. If woody loss was identified, the code assigned to the pixel also described the reason for the loss. Five categories were used:

- agriculture
- infrastructure
- forestry
- fire
- natural processes (e.g. landslips).

Maps were produced every two years from 1988 to 2006, annually between 2006 and January 2017, and one for the period from January to August 2017. From 2008 onwards, analysis periods were based on SPOT and Sentinel–2 imagery with 10-metre and 5-metre resolution. Prior to this, Landsat imagery with 30-metre resolution was used (see Table 7 in Appendix E-3). As a result, maps used from 2008 onwards have a higher level of accuracy. The maps of woody vegetation loss were developed for 20 ‘change eras’, each spanning one or two years (see Appendix E). The detailed process used to detect woody vegetation loss in the SLATS program is outlined in Appendix E.

6.4.3 Revising the SLATS maps

This section describes the datasets and process to identify areas of inaccurate SLATS mapping derived from Landsat data, up to circa July 2009 (the top middle box in Figure 13). The output is a map that shows areas of incorrectly mapped clearing and previously unmapped clearing, which was used to revise the SLATS maps.

SLATS mapping accuracies

The accuracies of the SPOT and Landsat change index are different, with the SPOT index being more accurate (see the discussion on index accuracy in Appendix E; note that the SPOT index was also used with the Sentinel–2 images as the sensors are similar). This is due to the higher resolution of the imagery (5–10 metre pixels). Thus, the objective of this analysis was to revise the SLATS maps created using Landsat data.

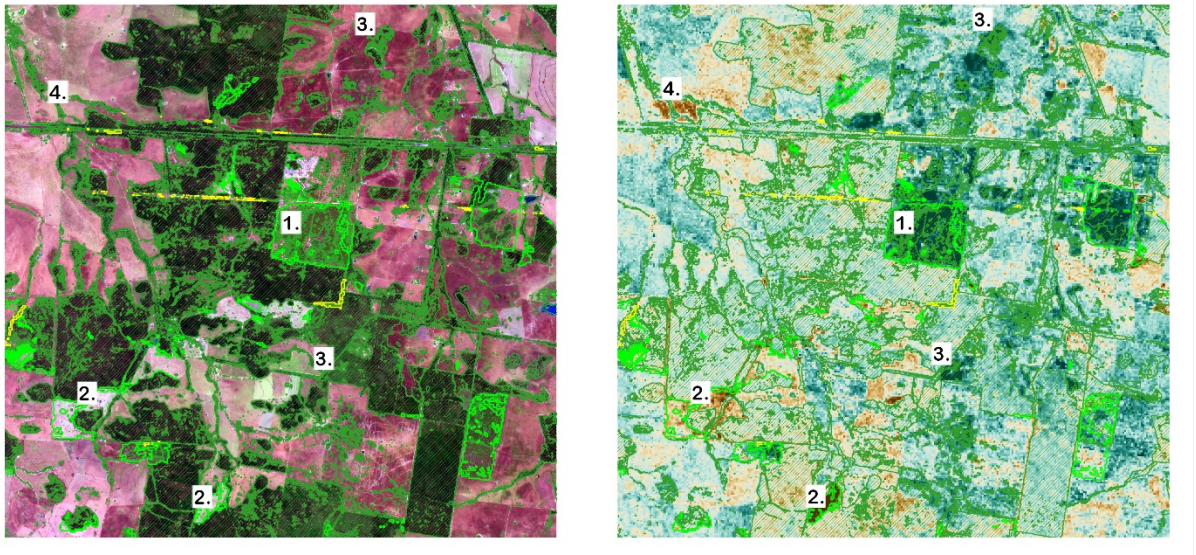
The indexes identify many more pixels as potential change than are ultimately found to represent change. Analysts mediate this issue when interpreting the change index images. However, there are limitations to using only 2 images to analyse change, which warranted further refinements to the Landsat SLATS maps. The limitations are:

- cloud cover
- images captured during wet periods as the index relies on dry-season images
- woody vegetation regrowing quickly after clearing.

Previously unmapped clearing

Analysts used the historic imagery to create a map of vegetation trends (the 'trend map'). The trend map helps to identify clearing events that were missing from the SLATS maps for the period circa 1990 to 2009. The trend map was created using the method described in Appendix E-4, with Landsat images from 1987 to 2013. Note that this period (i.e. to 2013) extends beyond the Landsat SLATS clearing images being revised (i.e. up to 2009). This was done to avoid over- or under-estimating the long-term trend where a short-term disturbance (e.g. greening or significant drying of the herbaceous understorey layer) occurred around 2009.

Large increases and decreases in the trend map in Figure 14 may correspond to woody vegetation clearing, as shown by the areas labelled 1 (increasing trend) and 2 (decreasing trend), which were mapped as clearing for agriculture in the SLATS layers. Large increasing trends may show clearing that occurred near the start of the analysis period, while large decreasing trends may show clearing that occurred near the end of the analysis period.



(a) (b)

Figure 14 Example of the relationship between woody vegetation, the trend map and clearing detected using the SLATS change layers for all change eras

The background image on the left (a) is a SPOT satellite image. The background image on the right (b) is the trend map, which shows large decreasing trends in vegetation as dark shades of brown and large increasing trends as dark shades of blue. Overlaid on both images are the woody extent layer (dark green outlines), clearing for agriculture (light green outlines) and clearing for infrastructure (yellow outlines). The features identified by the numeric labels 1–4 are described in the text.

Creating the woody vegetation loss refinements map

An automated process was used to create a single map of woody vegetation loss from the SLATS maps for all eras up to 2013. Analysts used this map to help determine the relationship between woody vegetation clearing and the trend map. Where both SPOT and Landsat data were used in the same SLATS era to map woody vegetation loss, only the change maps derived from the SPOT imagery were used because of SPOT's higher accuracy. The one exception was the 2008–09 change era when the earlier dates of the SPOT images for 2008–09 occurred after the later dates of the Landsat images for 2007–08,

leaving a small time period that wasn't analysed. To address this gap, 2008–09 information from both the Landsat and SPOT analysis was used.

For cases where a pixel showed woody vegetation removed more than once across all eras, the change category that could cause the pixel to be mapped as category 1 was coded in the output map. For example, an early woody loss event was caused by fire, but the woody vegetation was later removed for agriculture, so it was coded as having been removed for agriculture.

When checking previous SLATS mapping and identifying additional areas of woody vegetation loss using the trend map, analysts used the following guidelines:

- Determine the magnitude of the trend that may indicate woody change by analysing the trend values within the areas known to be cleared. The SLATS data were used for this.
- For those areas determined to be potential change, analyse the 'before' and 'after' images to confirm the change. The images used were from these sources: ADS aerial imagery, SPOT 5 and Landsat satellite imagery.
- Check that previously mapped areas had been classified correctly as one of 5 change categories: agriculture, infrastructure, forestry, fire or natural processes. They were reclassified if necessary.

For example, the analyst saw that the areas labelled 3 in Figure 14 were mapped as woody in the woody extent map and had an increasing trend that was as large as the trend in area 1, which was mapped as woody clearing. As a result, it was possible that the areas labelled 3 were also previously cleared. The analyst checked the ADS and/or satellite images to determine if woody clearing had occurred since 1 January 1990.

As another example, the analyst considered the area labelled 4 in Figure 14. It had a large decreasing trend similar to that of the areas labelled 2 that were mapped as cleared. This area is not woody, so the analyst checked the early aerial and satellite images to determine if woody vegetation was present after 1 January 1990 to see if clearing had occurred.

The output from this process was the 'woody vegetation loss refinements map'. If additional cleared areas were identified, and they were from clearing activity (as defined in LLS Act s. 60C), the pixels in the refinements map were coded as agriculture, infrastructure or forestry. When the analyst saw that an area had been incorrectly mapped as cleared, the pixels in the refinements map were coded with a value to show the area had not been cleared.

6.4.4 Creating a map of detectable clearing events since 1 January 1990

An automated process was used to merge the combined, all-eras, SLATS woody vegetation loss map with the woody vegetation loss refinements map (Figure 13). The following rules were used:

- Only pixels mapped as loss due to agriculture, infrastructure or forestry were included in the final map. Fire and other natural processes are not woody vegetation clearing events for the purposes of the map.
- Pixels showing areas that have not been cleared, as shown in the refinements layer, were not included in the final map.

Section 9 provides further detail about reviewing and updating the map.

7. Applying specific criteria in the LLS Act and Regulation.

7.1 Introduction

This section explains how areas of rural land that are specifically described by sections of the LLS Act or Regulation as either category 1 or 2 (including sub-categories vulnerable and sensitive) are included in the native vegetation regulatory map (NVR Map). It also explains how unlawful clearing is included in the map and its categorisation.

The legislation has several provisions that define areas of rural land as a specific category, regardless of any categorisation resulting from the processes set out in Sections 4–6. Examples include:

- conservation agreements (category 2–sensitive regulated land)
- regrowth under a property vegetation plan (category 1–exempt)
- prosecutions under the Native Vegetation Act (category 2–regulated land).

These areas are drawn from existing spatial layers, defined as ‘prescribed layers’ and are used to update the initial NVR Map category assignment (Figure 6). This ensures that the final categorisation of an area of rural land reflects the legislated criteria. An area may be initially mapped as category 2 by the processes listed in Sections 4–6, however, if it is overlain by any of the prescribed layers listed in Appendix F, its final category will reflect the prescribed layer as defined by the legislation.

7.2 Defining prescribed layers

The LLS Act and Regulation specify that rural land that meets specific criteria are to be designated as a certain category. These areas are spatially defined using prescribed layers.

The prescribed layers have been created by consolidating data that has been extracted from existing databases or developed for the purposes of the NVR Map. The prescribed layers come from a variety of organisations, sources and time periods, with many of the layers created to different standards or spatial tolerances to the foundational layers used to define the initial NVR Map category assignment (Figure 6).

7.3 New and amended datasets

This section describes new and amended datasets for the purposes of the LLS Act and Regulation.

7.3.1 Identifying and mapping ‘lawful clearing’ (category 1)

The LLS Act provides that land may be designated as category 1–exempt where the Environment Agency Head reasonably believes that the land was cleared of native vegetation as at 1 January 1990, or was lawfully cleared of native vegetation at any point after that, up until the commencement of Part 5A of the LLS Act.

Sections 4–6 of the method describe how ‘clearing’ is identified (including the significant disturbance or modification of non-woody vegetation). This section explains how the Environment Agency Head would form a reasonable belief as to whether the clearing was lawful or unlawful.

7.3.2 Lawful clearing prior to commencement of Part 5A of the LLS Act

Clearing that has taken place prior to the commencement of Part 5A of the LLS Act, and after 1 January 1990 (as determined by the Environment Agency Head in accordance with best available satellite imagery and aerial photographs), is considered to be lawful for the purposes of the map, unless the clearing has been the subject of compliance or enforcement actions (see LLS Act s. 60J(3) and LLS Regulation cl. 115).

Compliance or enforcement action means, generally, the conviction of a person, or an order of a court in civil proceedings to remedy or restrain a contravention of a clearing offence provision of applicable legislation, including but not limited to, s. 12 of the Native Vegetation Act; s. 17 of the *Native Vegetation Conservation Act 1997*; ss. 118A(2), 118C(1) and 118D(1) of the National Parks and Wildlife Act; and s. 125 of the Environmental Planning and Assessment Act in particular circumstances.

In these circumstances, the clearing is unlawful and land will be categorised as category 2, unless the land meets certain criteria (including, for example, land that has been biodiversity certified under Part 8 of the BC Act or any Act repealed by that Act).

Land where vegetation change is identified to have been caused by natural bushfire, flood, drought or other natural causes is also not considered lawful clearing for the purposes of the map and is retained in category 2.

7.3.3 Re-categorisation of land following commencement of Part 5A of the LLS Act

The LLS Act and Regulation set out the basis for assigning a category to cleared land that contained native vegetation. If the Environment Agency Head reasonably believes the land was not cleared at 1 January 1990 or was unlawfully cleared between 1 January 1990 and commencement of the LLS Act, it will generally be category 2.

Category 2 land which is cleared after Part 5A of the LLS Act commences may be re-categorised from category 2 to category 1 in certain circumstances, including where:

- clearing is carried out in accordance with a panel approval granted under Division 6 the LLS Act
- the land has been lawfully cleared after commencement in accordance with an in-force property vegetation plan approved under the Native Vegetation Act in certain circumstances
- land is authorised to be re-categorised by a land management (native vegetation) code.

The LLS Act states that land that has been cleared in accordance with allowable activities, or land that has been cleared in accordance with authorisation under other legislation, cannot be re-categorised to category 1 land unless the re-categorisation is authorised by Part 5A of the LLS Act, a land management (native vegetation) code or the LLS Regulation (see LLS Act s. 60K(6)).

7.3.4 Compliance processing and validation

The NSW Government's existing satellite mapping compliance program (SLATS) is used to identify where vegetation has changed from year to year. This dataset identifies unexplained clearing.

Unexplained clearing that occurred up until the commencement of the LLS Act will be uncategorised until investigations are completed and outcomes finalised.

Compliance staff will be reviewing any unexplained clearing to establish if it has been undertaken unlawfully, in which case the clearing will be investigated, as a result of which compliance action may be taken and the mapped area categorised.

7.3.5 Identifying and mapping native vegetation that has been regrown or preserved with the assistance of public funds (category 2)

A dataset has been established that identifies native vegetation that the Environment Agency Head believes was grown or preserved with the assistance of public funds (other than funds for forestry purposes).

This includes areas of environmental works associated with:

- biodiversity conservation
- soil erosion remediation
- riparian restoration.

These works have been funded/co-funded through (former) catchment management authorities, Local Land Services, Commonwealth and state funding sources such as National Heritage Trust, Caring for Country, Landcare and NSW Environmental Trust and other grants.

This land is mapped as category 2 as per s. 60I(2)(a) of the LLS Act.

Further detail of the datasets used is provided in Appendix F.

7.3.6 Identifying and mapping vulnerable lands (category 2-regulated vulnerable land)

Category 2–vulnerable regulated land (LLS Act s. 60I(2)(b) includes 3 components):

1. steep or highly erodible land
2. protected riparian land
3. special category land.

Steep or highly erodible land

Steep or highly erodible land is land with a slope >18 degrees and/or where soil characteristics, slope and erosivity of rainfall present a high erosion risk

Steep or highly erodible land is included in the map when land is identified as ≥18 degrees from a surface model enhancement digital elevation model (SME DEM) data. Further detail on the generation of this high resolution 5-metre steep data is available in Appendix F-2.

Protected riparian land

The existing vulnerable lands layer identifies protected riparian land by displaying a buffered centre-line of the river. The legislative definition states that the protected riparian land includes the stream bed plus 20 metres from the upper bank of a named stream.

Watercourses included are generally named and identified as natural in state or function. The foundation data used to create the protected riparian land layer is known as Hydroline and HydroAreas data layers to which the Department of Customer Services are the custodians.

Buffering for watercourses in protected riparian land is 22.5 metre from the stream centre-line, this allows for a 5 metre stream bed width. Buffering for waterbodies is 20 metres. See Figure 16.

Supporting information regarding this process is available in Appendix F. Improvements to this layer include the attribution of prescribed streams under (repealed) s. 26D of the NSW *Water Act 1912* to assist with stream protection along side supplementary information.

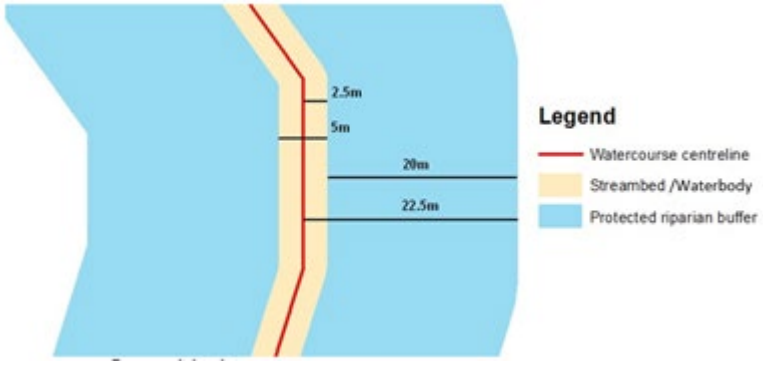


Figure 15 Riparian buffer distances

The development of the 5-metre SME DEM has provided an opportunity to generate stream lines to a greater accuracy. Currently, the 5-metre SME DEM is used to improve stream accuracy during the landholder initiated map reviews. This is done in combination with assessing each riparian feature using high-quality digital imagery and cross-checking with supporting information, such as time-series analysis. A project is planned to extend this more accurate mapping of stream lines across catchments for inclusion in future updates of the NVR Map.

Special category land

Special category land exists over some areas of New South Wales considered to be environmentally sensitive or at environmental risk and includes land vulnerable to soil erosion, salinity, sedimentation and/or landslip.

8. Forming the final map product

8.1 Introduction

This section describes how the input layers from the method are combined to develop the final map product, an example of which are shown in Figure 3.

Previous sections have described how the various data sources were created, interpreted and consolidated into the input layers. Once the input layers were finalised, they were brought together to create the final NVR Map.

8.2 General rules

The following general rules are used to develop the final map layer:

- layers may overlap, and are applied in the order determined by the LLS Act
- excluded areas have the highest precedence, followed by the category 1 and category 2 prescribed layers (including sensitive and vulnerable) and then the land use
- the land use class determines the rule used to combine the information in the land use, woody extent and detectable clearing layers.

8.3 Map formation

The map is formed by combining the input layers in a specific order and following the general rules set out above. Appendix B contains a summary of the datasets and associated map layers and products.

The final map was formed in 2 stages (Figure 17). In the first stage a script creates the draft NVR Map from the foundation and prescribed layers. In the second stage, analysts refined the map by checking for and correcting errors in the 2017 woody vegetation extent map and other errors in the map category assignments, which may arise due to problems in the input layers (see the details in Appendix G). The refinements process is also used as a quality assurance step, checking to ensure that all category 1 and category 2 prescribed layers (including sensitive and vulnerable) are accurately represented according to the best available information.

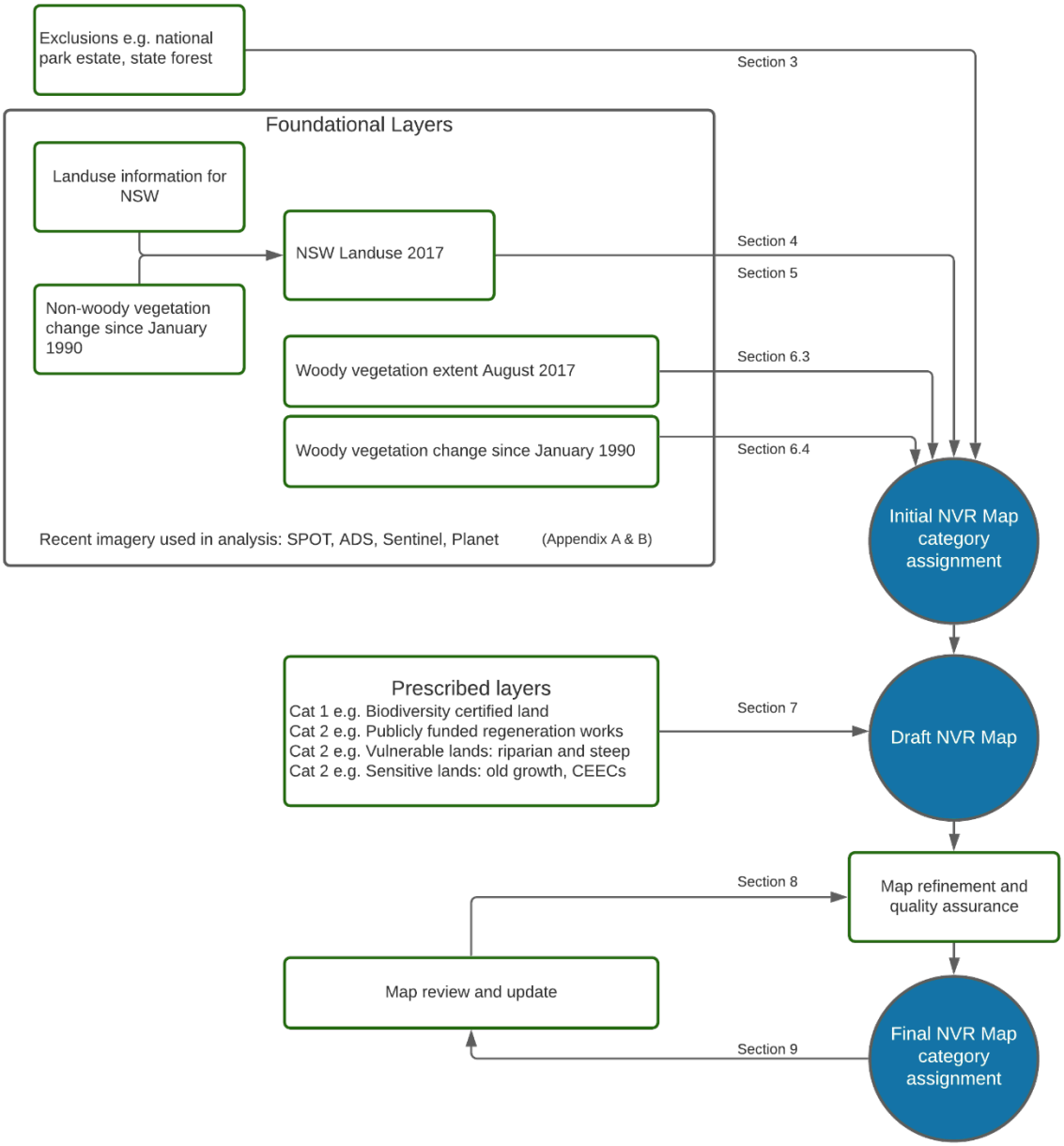


Figure 16 Overview of the process to create the native vegetation regulatory map

Stage 1 collates the input map layers into the following groups:

- NSW Landuse 2017
- 2011 woody vegetation extent
- detectable clearing events
- category 1 and 2 prescribed layers (including sensitive and vulnerable)
- excluded areas.

The processing is as follows:

- the updated Landuse 2017, 2011 woody vegetation extent and detectable clearing events (Sections 4–6) are combined to assign a map category, using one of 5 rules
- the category 1 and 2 prescribed areas (including sensitive and vulnerable) are then applied, in order of precedence (Section 8.4).

- excluded areas are applied last (Section 3).

One of 5 rules is applied to each land use polygon to determine the initial map category assignments. The land use class determines the rule to apply (Appendix G-1). The rules are:

1. category 1, always
2. category 1, except for woody vegetation not detected as being cleared, which is mapped as category 2
3. category 1, except for woody vegetation regardless of whether woody clearing is detected, which are mapped as category 2
4. category 2, always
5. category 2, except for those areas where woody vegetation clearing is detected, which are mapped as category 1.

Table 3 shows explicitly how the map categories are assigned for each rule given the presence (or absence) of woody vegetation and detectable clearing events in the input data layers.

Table 3 The map formation rules for the initial map category assignments

The map categories within a rule can vary depending on the presence (or absence) of woody vegetation and/or detectable clearing events. These rules are scripted and applied automatically.

Map formation rule	Woody in the woody vegetation extent map	Clearing detected	Map category
1	Not considered	Not considered	1
2	No	Not considered	1
2	Yes	No	2
2	Yes	Yes	1
3	No	Not considered	1
3	Yes	Not considered	2
4	Not considered	Not considered	2
5	Not considered	Yes	1
5	Not considered	No	2

Stage 2 creates a ‘refinements’ image that is edited by analysts who identify where the initial map categories need to change (Appendix G). A script then applies the edits from the refinements image to the final map.

The layers used to create the refinements image were:

- the initial map category assignments
- woody vegetation extent
- ADS tree maps
- detectable clearing events
- category 1 and category 2 (including sensitive and vulnerable) prescribed areas.

Table 4 summarises the cases where the initial map category assignments could change. The pixels in the refinements image are coded with numbers representing information about the conditions that caused the initial map categorisation. Analysts systematically checked the refinements image and reassigned the map category if required using the rules in Table 4. Checking was performed by interpretation with the satellite and ADS images.

Table 4 The conditions under which a re-assignment of the map category could occur

Map formation rule	Woody in the woody vegetation extent map	Woody in the ADS tree cover map	Clearing detected	Potential re-assignment to category
2 or 3	No	Yes	No	2
2, 3 or 5	No	Yes	Yes	2
2 or 5	Yes	Yes or No	Yes	2
2 or 3	Yes	Yes or No	No	1
3	Yes	Yes or No	Yes	1

The information from the ADS layers was used only where needed. Areas where it isn't used are those that would not, or were unlikely to, result in a change to the map category regardless of the woody vegetation status. These are:

- excluded areas
- category 1 and category 2 prescribed areas (including sensitive and vulnerable)
- land use polygons that correspond to the mapping rules 1 or 4, which are always mapped as category 1 and category 2 respectively.

8.4 Precedence of categorisation

Excluded areas have the highest precedence, followed by the category 1 and category 2 prescribed layers, and then the category assignment based on the map formation rules (Table 3). In some cases, multiple prescriptions apply to a single area of land, in which case an 'order of build' is used to assign the map category (see Appendix F).

8.5 Responding to cadastral misalignment

In some locations there may be underlying misalignment of the NSW Digital Cadastral Database with spatial imagery data. As a result of this misalignment, when map boundaries taken from the NSW Digital Cadastral Database are integrated with data that is based on imagery (such as the satellite images used to develop the map), the spatial locations of the cadastral boundaries will not always be aligned with the 'on the ground' reality (for example, the physical location of a road or the boundary of a national park).

Directly adopting the datasets derived from the NSW Digital Cadastral Database could result in inaccuracies in the final map product. For example, private land that should be zoned as RU1 – Primary Production could be reflected as a road (Zone SP2 – Infrastructure) and would therefore be excluded from the map. The possibility of updating the digital cadastral boundaries was investigated. This investigation found the boundaries were not always visible in the imagery, and it is also known that boundary fences are not always physically located on exact cadastral boundaries. The only accurate way to locate the boundary is to have a survey carried out by a registered surveyor. Without a statewide resurvey, the only alternative was to use the digital cadastre to define exclusion areas.

To mitigate this risk, only the excluded areas and some prescribed layers were based on the digital cadastral boundaries. The land use mapping process outlined in Section 4 identifies the boundaries based on the image base (rather than cadastral map lines). This is through visual inspection and manual corrections by analysts.

Not all cadastral misalignments will be corrected through the land use mapping. Cadastral misalignment may be visible in the final map due to contributing layers being based on the cadastre.

An example in Figure 18 shows the implications of cadastral misalignment on the maps. The purple line shows the digital cadastral representation of a state forest boundary, which will be mapped as an excluded area in the map. In this case the misalignment of the digital cadastre will cause some areas (south of the state forest) that would normally be mapped as category 1 or category 2 to be mapped as excluded. Some areas (along the northern edge of the state forest) that should be excluded will be mapped as category 1 or category 2. These areas can be seen at the top and bottom of the forested area in Figure 18. Misalignment of the yellow boundaries will not affect the accuracy of the mapping in those areas as it will be based on interpretation of the imagery, rather than the lot boundaries from the NSW Digital Cadastre Database.

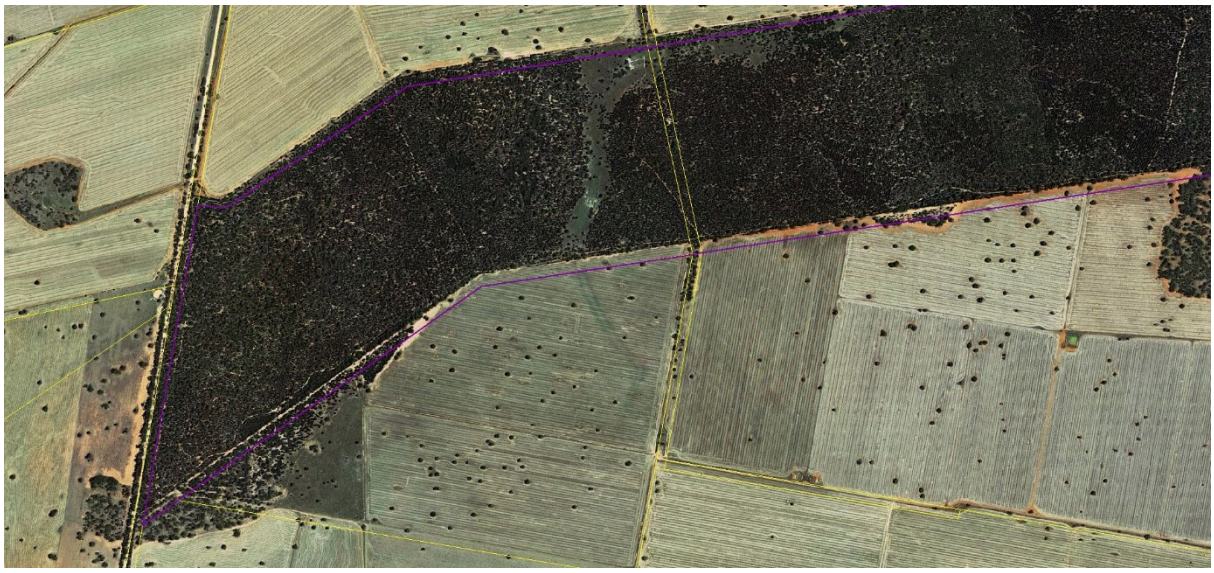


Figure 17 Aerial imagery overlaid with digital cadastral boundaries showing the impacts of misalignment on the NVR maps

8.6 Data and processing management

Thousands of files from many sources are used to create the NVR Map. A carefully designed data management, storage and processing environment has been established to combine these layers and to create the map. The provenance of every layer was recorded for future reference and different versions of the map tracked.

8.6.1 The computing environment

There are 2 main computing environments:

- the working environment for analysis, which uses desktop personal computers
- the data processing and storage environment, which is DPE's 'Science-Data-Compute' (SDC) facility, comprising a high-performance computer and mass data storage.

The land use map, category 1 and 2 prescribed layers (including sensitive and vulnerable) and excluded layers are prepared in the working environment using ArcGIS software and ingested into the data processing and storage environment on the SDC. All other inputs (Section 8.3) had previously been ingested to SDC.

The data processing to create the initial and final maps occur on the SDC using custom-built scripts. The scripts are written in the Python programming language and use open-source geospatial software packages for data manipulation and reading and writing files. The map checking and refinements take place in the working environment using Erdas Imagine software.

8.6.2 File management

The State of New South Wales is divided geographically into tiles, defined by the NSW 1:100,000 topographic map sheet boundaries. All input data are clipped to these boundaries. The maps are created on the MGA Cartesian coordinate system, with input data being reprojected as necessary.

The prescribed layers and excluded layers are merged into a single Esri geodatabase file, containing multiple layers. The land use data is created as a single Esri geodatabase file. The prescribed layers, excluded layers and land use data are vector data. All other inputs are rasters in the Erdas Imagine or Geotiff file formats. All data are converted to rasters with 5-metre pixels during the creation of the map for efficiency and ease of data manipulation.

All files are given a filename that adheres to a rigorous naming convention. The convention stores a number of attributes that identify the data source, location, reference date, a processing stage code, coordinate reference system and other optional components. The type of information stored for each attribute may vary by data source, but is well defined for each data source. For example, the reference date for a satellite image is its image-capture date whereas for the NVR Map it is the year the map relates to.

Consider this filename for the NVR Map: *naluma_m8335_2017_aahm5_c20201209_u8_v63.img*. The following information is stored:

- *naluma* is the data source and is defined generically as land use related (e.g. native vegetation regulatory map) product
- *8335* the location using a 1:100,000 topographic map sheet number, prefixed with an ‘m’
- *2017* is the reference year that the map is relevant to – it captures the state of the landscape in 2017
- *aah* is an example of the processing stage code, in this case *aah* is defined as the checked and refined NVR Map
- *m5* is the coordinate reference system code, in this case the MGA in UTM Zone 55
- *c20201209* is the version date, 9 December 2020, which corresponds to the date on which the land use and/or prescribed layers input files were created (Section 8.6.3)
- *u8* is the map update number, incremented when large changes to land use or prescribed layers are made
- *v63* is a revision number, which corresponds to revisions due to landholder reviews
- *img* is the file format extension, in this case an Erdas Imagine raster.

8.6.3 Map versioning and reprocessing

The design of the file naming convention allows for multiple versions of a map to be stored for a single topographic map sheet. This means that continued improvements and refinements to the maps can be made and earlier versions of the maps maintained for comparisons. The published version of the map is created by selecting the most recently created map for each topographic map sheet. This is the one with the most recent version date and map update number and a processing stage code that identifies it as having been checked and refined.

It is necessary to create many versions of the files as updated land use, prescribed layers or excluded areas information become available. Different versions of the maps will also be made in the future as new information becomes available, requests from landholders are made and changes in the landscape are captured.

Versioning is stored in 5 parts of the file name: the processing stage code; the reference date; the version date; the map update number; and the map revision number (Section 8.6.2). The processing stage code defines the different stages of the map creation process. For example, maps are assigned a different stage code to identify those with initial class assignments and those that have been checked and refined (as described in Section 8.3). The reference date is a year and shows that the map represents the state of the landscape for that year. The version date is the date the input land use and/or prescribed layers was created for the topographic map sheet. The map update number captures the number of times large changes were made to the land use and/or prescribed layers and the map updated. The map revision number shows when the map changed because of landholder reviews.

A trail of the entire processing chain and file provenance back to the point of ingestion onto the data processing and storage environment, SDC, is kept for all map versions. The script used to create the map for each map sheet, the date and time it was processed, and the input data used to create it are stored with the map in the metadata section of the file. Each of the inputs also stored the script and input data used to create it, and so on for each file. This means that the entire processing chain is captured. The data sources for the prescribed layers and excluded layers were maintained in a separate metadata file, which is also stored at SDC and given the same filename as the ingested file, but with a different file extension.

All scripts used to process the data at SDC are managed under version control. Also logged are the date and time of every change made to the scripts, when the scripts were installed on the system and when a map file was saved to the data storage archive. Therefore, if there is a problem with a file it can be tracked to the version of the script that created it. All other maps created by the same version of the script can be easily identified and reprocessed if necessary.

8.6.4 Data storage and backups

All files at SDC are stored on stable tape media for archiving and future access. Two additional copies are made: an on-site copy and an off-site copy. A copy of the updated land use is also maintained in DPE’s corporate spatial database.

9. Reviewing and updating the map

9.1 Introduction

This section explains how updated data sources and remote sensing technology will be reflected in the final map in the following circumstances:

- on an ongoing basis, primarily in response to re-categorisations that result from the landholder initiated map reviews
- as required via sub-annual updates
- through the annual update process mandated by the LLS Act.

Where a relevant criteria for re-categorisation, including new or improved information, prompts the Environment Agency Head to consider re-categorising land, the landholder consultation requirements of the LLS Act and Regulation will apply.

9.2 Process for landholder reviews and ad hoc updates

Landholders may apply for re-categorisation of their land in certain circumstances and may also apply for a review of a decision relating to the categorisation or re-categorisation of land on the map (LLS Act s. 60L).

Landholders may also appeal to the Land and Environment Court against a decision relating to the categorisation or re-categorisation of land on the draft and final NVR map (LLS Act s. 60M). This mechanism for appeal does not apply to the transitional NVR map.

Information provided by landholders will be used in conjuction with satellite and aerial imagery through the normal application of the NVR Map method when reviewing the categorisation.

9.2.1 Map review process

Requests for landholder initiated map reviews of the transitional, draft or final NVR map are submitted to the map review team and entered into a content management system. This system records information regarding the specifics of each map review request, including the date it was lodged, areas of the map that have been requested to be reviewed, the associated landholding by the applicant and any other supporting information. This information allows the team to monitor the review workflow and time taken for the various aspects of each review.

The map review team will work with the landholder to identify the ‘landholding’ and ‘area under review’.

A **landholding** is defined in the LLS Act (s. 60D) to include:

- several parcels of land (whether held under the same title, different titles or different kinds of titles) that constitute or are worked as a single property and that –
  a. are contiguous with one another or are separated from one another only by a road, river, creek or other watercourse, or
  b. are certified in writing by Local Land Services to be in the same sub-bioregion and within sufficient proximity to one another so as to constitute a single landholding for the purposes of this Part.

The **area under review** is the footprint that the landholder would like to have reviewed. The area under review is required to identify the area of the map that requires scrutiny and potential map update if category changes are identified. For example, an area of a critically

endangered plant within a small part of the landholding might be reviewed. This constitutes the area under review; it is the subset of the landholding that has been asked to be reviewed.

Once the review information has been collected, each layer that has been requested to be reviewed is forwarded to the relevant data custodian with the supporting information. The custodian then assesses the merit of the review request and makes any changes to the source data. If the custodian decides to make a change to the source layer, it is required to be updated in the source dataset before proceeding to the next step, which is the creation of a 'map patch'.

Once the source layer has been updated, an extract of the data for the landholding or area under review can be extracted. This modified source data is then passed through a script which recompiles the map using the same rules as the map formation (Section 8.4). The script is written in Python and run on the SDC facility. For any given review, 4 key pieces of information are required to run the script: the landholding boundary, the area under review, the date of lodgement of the review, and the modified source data.

These 4 pieces of information are consumed by the script to generate a map patch which is visually assessed prior to acceptance. This map patch is typically the shape of the landholding, with the area under review modified to some degree depending on the custodian's decision. This map patch is then approved by the authorised officer in the map review team hierarchy.

Once a patch has been assessed and approved, all of the relevant documentation, correspondence and data files are added to a record in the DPE record management system for future reference. Each map review has its unique identifier.

9.2.2 Application of map patches

Once a final map patch has been created and approved, it can be included in the monthly map version build. The map is recompiled once a month on the first Monday of each month for each 100,000 map sheet that has a successful map review patch located on it. For map sheets that have not had a map review, this process is not required.

The map is recompiled exactly as the initial map formation (Section 8.4) in terms of order of layers and map formation rules. This formation takes the map patches and applies them to the final map, creating an incremental change to the map. This new monthly map is given a separate version number to distinguish it from the pre-patch applied version.

9.2.3 Ad hoc reviews

Ad hoc reviews and updates will also be made in response to successful appeals against decisions relating to categorisation or re-categorisation to the Land and Environment Court that result in the re-categorisation of land. Sections 60L and 60M of the LLS Act set out a right for landholders for map review and to appeal to the Land and Environment Court against a decision relating to the categorisation or re-categorisation of land on the map.

Ad hoc updates may be required to ensure the map reflects other information obtained or criteria requiring re-categorisation.

9.3 Process for annual reviews and updates

The map will be updated on an annual basis by incorporating the updated datasets to identify land that has changed category.

Operational guidelines will outline the internal map review process that is provided for under the LLS Act (Part 5A). Areas that are re-categorised based on the internal review outcome will be incorporated into the map.

Broadly, the method will be applied annually as described for Sections 4–6 using the most recent high-resolution imagery available at that time. The updated overriding map layers (Section 7) will then also be reapplied.

Key components of the update can include:

- new or updated prescribed layers, that is, improved mapping of critically endangered plants or removal of expired property vegetation plans
- land categorisation changes as a result of legislation changes, that is, scientific determinations of critically endangered ecological communities
- clearing and set asides in accordance with the land management (native vegetation) code
- incorporating determinations of the conservation value of grasslands and other groundcover in accordance with the assessment method.

9.4 Using more accurate local data

As set out in Section 2.6.1 and Appendix A, the method identifies the key data that is used to develop the map.

However, there may be more accurate local data that should be incorporated into one or more layers of the map.

This more accurate data can be used in internal review processes, when re-categorisation of the land is initiated and proposed (by the Environmental Agency Head as per the LLS Act), or during the annual update process (Section 9.3).

In order for this data to be incorporated into the map, it should:

- contribute additional information to the existing key data and be suitable for incorporation into the method described herein
- come from published sources
- have acceptable thematic and spatial accuracy, in a defined spatial coordinate system.

The Environment Agency Head retains the discretion to determine whether or not the local data provided is of sufficient quality or accuracy to be adopted.

References

ABARES 2011, *Guidelines for land use mapping in Australia: Principles, procedures and definitions*, 4th edition, Australian Bureau of Agricultural and Resource Economics and Sciences, pp.13–40, available at: www.agriculture.gov.au/abares/aclump/land-use/mapping-technical-specifications

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