Establishing New Zealand's LUCAS 2016 Land Use Map

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Establishing New Zealand's LUCAS 2016 Land Use Map

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Summary

Underpinning New Zealand's reporting of greenhouse gas emissions is the Land Use and Carbon Analysis System (LUCAS) Land Use Map (LUM). This is a national digital temporal map of land use and land use change compiled for nominal dates beginning at 1 January 1990. This report describes the delivery of a new LUM dated at 31 December 2016.

LUM 2016 is an update of the established 2012 Land Use Map (Newsome et al., 2013). It embodies land use change that occurred between nominal mapping dates of 31 December 2012 and 1 January 2017. These changes are identified using dated national satellite image mosaics based on SPOT 5 imagery acquired in the summers (October–March) of 2011/12 and 2012/13, and then based on Sentinel-2A imagery acquired in the summer (October–March) of 2016/17.

Six activities were agreed under this contract:

1 Generating a national satellite mosaic of the North and South Islands of New Zealand and the Chatham Islands, for the 2016/17 summer (Oct–Mar), based on Sentinel-2A imagery.

2 Detecting forest destocking during the 2015 and 2016 calendar years and producing:

   a A 2015 destock layer showing all areas where forest was removed between MfE's 2014/15 and 2015/16 Landsat 8 mosaics

   b A 2016 destock layer showing all areas where forest was removed between MfE's 2015/16 and 2016/17 Sentinel-2A mosaics

   c A 2015/16 infill destock layer showing all the areas where forest was removed between the imaging dates of the 2015/16 Landsat 8 mosaic and the 2015/16 Sentinel-2A mosaic

3 Improving the existing LUM 2012 by integrating verified enhancements from NZ Land Cover Database (LCDB) mapping of woody patches, LCDB mapping of exotic forest, WONI/LCDB wetland mapping, and LCDB mapping of urban areas.

4 Mapping land use change 2012–2016, for New Zealand (including Chatham Islands), maintaining (and where appropriate, correcting) land use classifications and associated attributes across the full time series 1990, 2008, 2012, and 2016.

5 Improving the mapping, classification (and sub-classification) of low- and high-producing grassland at 2008, 2012 and 2016, producing a layer for integration within the grassland areas of the LUM.

6 Incorporating confirmed 2015/16 destocking (from Activity 2) and integrating improved grassland mapping (from Activity 5) to deliver the final LUM 2016.

Of the 635,000 polygons in the LUM, over 6800 underwent land use change between 2012 and 2016.

More than 36,000 polygons were affected by boundary edits during mapping, either because of land use change or polygon refinements to more accurately delineate land features.

1 Introduction

Increasing anthropogenic greenhouse gas emissions during the industrial era has led to atmospheric concentrations of carbon dioxide, methane and nitrous oxide that are at their highest level in at least the last 800,000 years. This, together with other anthropogenic drivers, is extremely likely to be the dominant cause of observed global warming since the mid-20th century (IPCC, 2014).

New Zealand temperatures, as represented by the seven-station series (Mullan et al., 2010), have increased by almost 1°C over the last century, slightly less than the global land air temperature trend of about 1.1°C (MfE, 2016). Mid-range forecasts of New Zealand average temperature predict a continued increase of about 0.8°C by 2040, 1.4°C by 2090, and 1.6°C by 2110, relative to the period 1986–2005 (MfE, 2016).

The United Nations Framework Convention on Climate Change (UNFCCC) was instituted with the specific goal of stabilising greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. New Zealand is a signatory to the United Nations Framework Convention on Climate Change and its subsidiary agreement, the Kyoto Protocol. Both the UNFCCC (under Article 7) and the Kyoto Protocol (under Article 3.3) require signatory nations to submit an annual inventory of greenhouse gas emissions. Under the Kyoto Protocol, New Zealand committed to a quantified emissions reduction target for the first commitment period (CP1, 2008–2012), but for the second commitment period (2013–2020), established in Doha, Qatar, New Zealand reverted to an emissions reduction target under the UNFCCC (the parent body) rather than under the Kyoto Protocol itself. Nonetheless, New Zealand’s emissions accounting and reporting continue to apply Kyoto Protocol rules. New Zealand’s current, unconditional target is to reach 5 per cent below 1990 greenhouse gas emissions levels by 2020. Progress toward this target is reported annually in a net position report.

Underpinning New Zealand’s reporting of greenhouse gas emissions is the Land Use and Carbon Analysis System (LUCAS) Land Use Map (LUM). This is a national digital temporal map of land use and land use change compiled for nominal dates beginning at 1 January 1990.

2 Project objective

The objective of the work described by this report is the delivery of a new 2016 Land Use and Carbon Analysis System Land Use Map (LUM) for New Zealand. The LUM is a key element of New Zealand’s mechanism for calculating greenhouse gas emissions in the land-use, land-use change and forestry sector. In the last decade, Manaaki Whenua – Landcare Research (MWLR) has produced three LUCAS land use maps, representing New Zealand land use at 1 January 1990, and 2008 and 2012. This project required the production of a fourth time-step, 2016, to continue the regular time series from the 1990 benchmark.

The map covers all mainland New Zealand and offshore islands including the Chatham Islands, but not the more distant Kermadec, Auckland and Campbell Island groups. The map underpins New Zealand's international greenhouse gas reporting under the United Nations Framework Convention on Climate Change and the Kyoto Protocol.

New Zealand's net emissions position, and the international credibility with which that position is established, depends on accurately determining the location and extent of land-use and land-use change between 1990 and 2008, between 2008 and 2012 (the first commitment period (CP1)) and between 2012 and 2016 – particularly change in the area of forest land. Determining the area of change accurately can be difficult when the area of a given land-use activity undergoing change is commonly a small fraction of the total land area. Determining change with sufficient accuracy (determined to be 90%) requires an emphasis on validating individual areas of change, rather than the usual approach of validating two land-use datasets at adjacent dates and determining change by identifying their areas of difference. Validation is usually based on multiple sources of evidence – combining information from satellite images, aerial photography, forest databases, statistical sampling, local knowledge, and field inspection. This is coupled to a methodology to resolve issues that arise when interpreting land-use from observed land-cover. The mapping process and final LUM 2016 products meet the requirements of the Intergovernmental Panel on Climate Change Good Practice Guidance (IPCC GPG) (IPCC, 2003).

The mapping specification, established during 2008 mapping has continued with minor updates through 2012 and 2016, and includes:

- mapping land-use to an accuracy of 95% and land-use change to an accuracy of 90% as verified by post-mapping assessment,
- all mapping is in reference to the New Zealand Geodetic Datum 2000 with mainland New Zealand projected in New Zealand Transverse Mercator 2000 projection (NZTM 2000) and Chatham Islands projected in Chatham Islands Transverse Mercator 2000 projection (CITM 2000),
- mapping on a region-by-region basis, with in-house quality control during processing and before delivery.

3 Activities and Methods

LUM 2016 is an update of the established 2012 Land Use map (Newsome et., al. 2013). It embodies land use change that occurred between nominal mapping dates of 31 December 2012 and 1 January 2017. These changes, are identified using dated national satellite image mosaics based on SPOT 5 imagery acquired in the summers (October to March) of 2011/12 and 2012/13, and then another based on Sentinel-2A imagery acquired in the summer (October to March) of 2016/17.

In preparation for the actual 2012–16 change mapping the contract entailed improvement of LUM 2012 with deforestation, wetland, and woody mapping acquired from other sources. The full LUM 2016 process is described in this section.

Six activities (producing a range of deliverables) were agreed under this contract, as follows:

1 Generating a national satellite mosaic of the North and South Islands of New Zealand and the Chatham Islands, for the 2016/17 summer (Oct-Mar), based on Sentinel-2A imagery.

2 Detecting forest destocking during the 2015 and 2016 calendar years and producing:

    a A 2015 destock layer showing all areas where forest was removed between MfE's 2014/15 and 2015/16 Landsat 8 mosaics

    b A 2016 destock layer showing all areas where forest was removed between MfE's 2015/16 and 2016/17 Sentinel-2A mosaics

    c A 2015/16 infill destock layer showing all the areas where forest was removed between the imaging dates of the 2015/16 Landsat 8 mosaic and the 2015/16 Sentinel-2A mosaic

3 Improving the existing LUM 2012 by integrating verified enhancements from NZ Land Cover Database (LCDB) mapping of woody patches, LCDB mapping of exotic forest, WONI/LCDB wetland mapping, and LCDB mapping of urban areas.

4 Mapping land use change 2012-2016, for New Zealand (including Chatham Islands), maintaining (and where appropriate, correcting) land use classifications and associated attributes across the full time series 1990, 2008, 2012, and 2016.

5 Improving the mapping, classification (and sub-classification) of low and high producing grassland at 2008, 2012 and 2016, and producing a layer for integration within the grassland areas of the LUM.

6 Incorporating confirmed 2015/16 destocking (from Activity 2) and integrating improved grassland mapping (from Activity 5) to deliver the final LUM 2016.

The various mapping activities differed in their focus and impact on the various land use classes as illustrated in the land use change matrix in Appendix 2.

3.1 Generating national satellite mosaics (Activity 1)

Objective

The objective of this activity was to create seamless island image mosaics corresponding to the New Zealand summer of 2016/17 using Sentinel-2A (S-2A) satellite imagery. The imagery was required to be corrected for the effects of atmosphere and topography and, by appropriate choice of component image strips, have minimal cloud.

Method

Individual S-2A images were converted to surface reflectance by atmospheric and BRDF correction methods (Dymond and Shepherd 2004; Newsome et al., 2013). With appropriate masking of cloud and cloud-shadow, this correction process enabled mosaicking into a consistent image product that has calibrated reflectance values and appears colour-balanced. We investigated automated methods for detection of cloud and cloud shadow but determined they would not meet the quality stands required for this contract. Therefore, a manual process of ranking and choosing image strips and digitising of cloud and cloud-shadow was performed. Sentinel2 “strips” (Fig. 1) were visually assessed to determine areas which would likely contribute to a cloud-free national 2016/17 summer mosaic and, greater effort was devoted to cloud masking these areas.

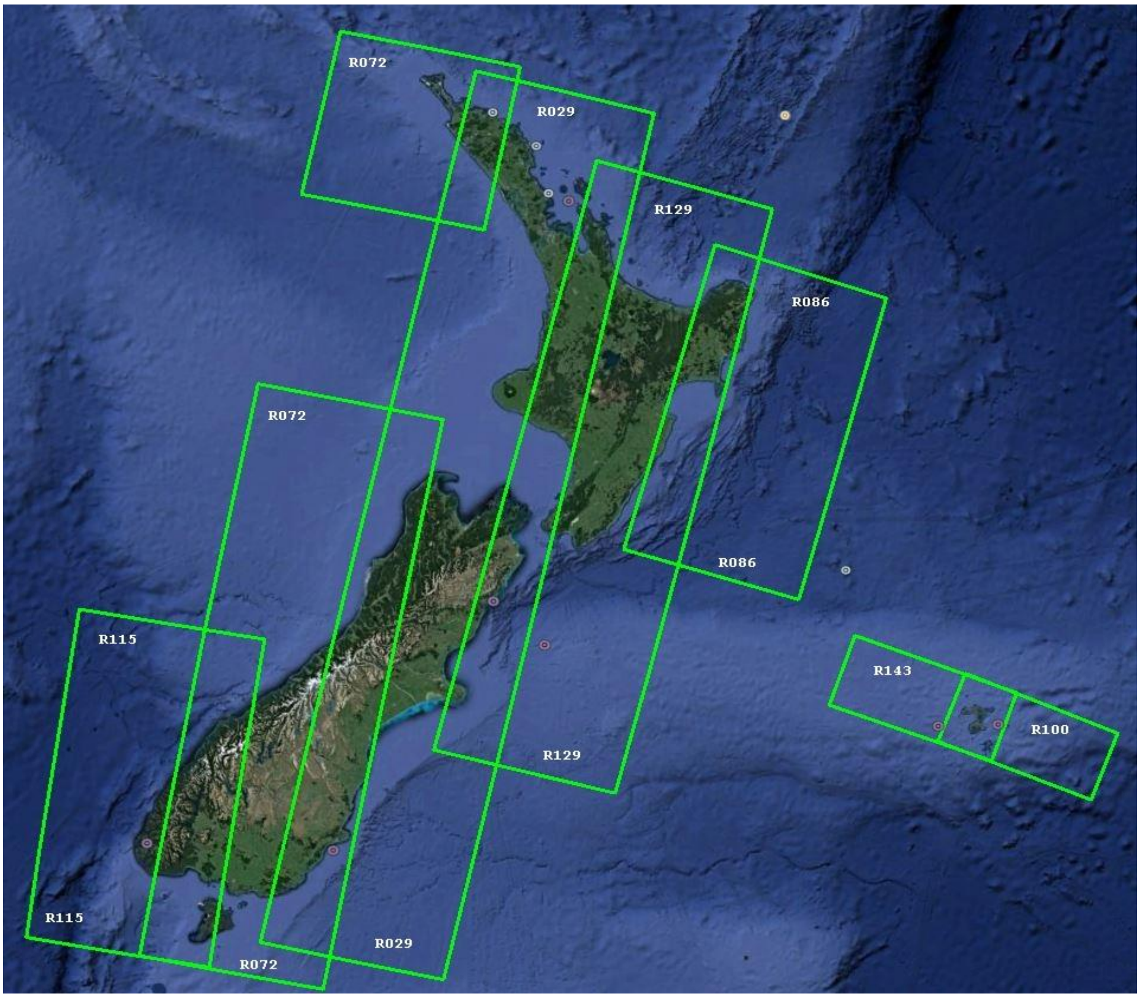

Figure 1: Sentinel 2 satellite coverage over New Zealand.

A total of 15 mainland and 2 Chatham Island strips were chosen and, within these strips, cloud (and cloud shadow) was manually digitised (Fig. 2). These strips were prioritised by cloud-free contribution and sun elevation angle and mosaicked into North and South Island composites in New Zealand Transverse Mercator 2000 (NZTM2000) projection, and Chatham Island composites in Chatham Islands Transverse Mercator 2000 (CITM2000) projection. For each area, a mosaic was provided as both cloud-minimised and standardised reflectance in ERDAS Imagine (*.img) format. A metadata raster was also provided showing which base image contributed to each pixel in the final mosaics. The cloud-minimised product is a mosaic of imagery corrected for atmospheric, view angle, and illumination effects, whereas the standardised reflectance mosaic is generated from imagery that includes additional processing for topographic correction (Dymond & Shepherd 2004).

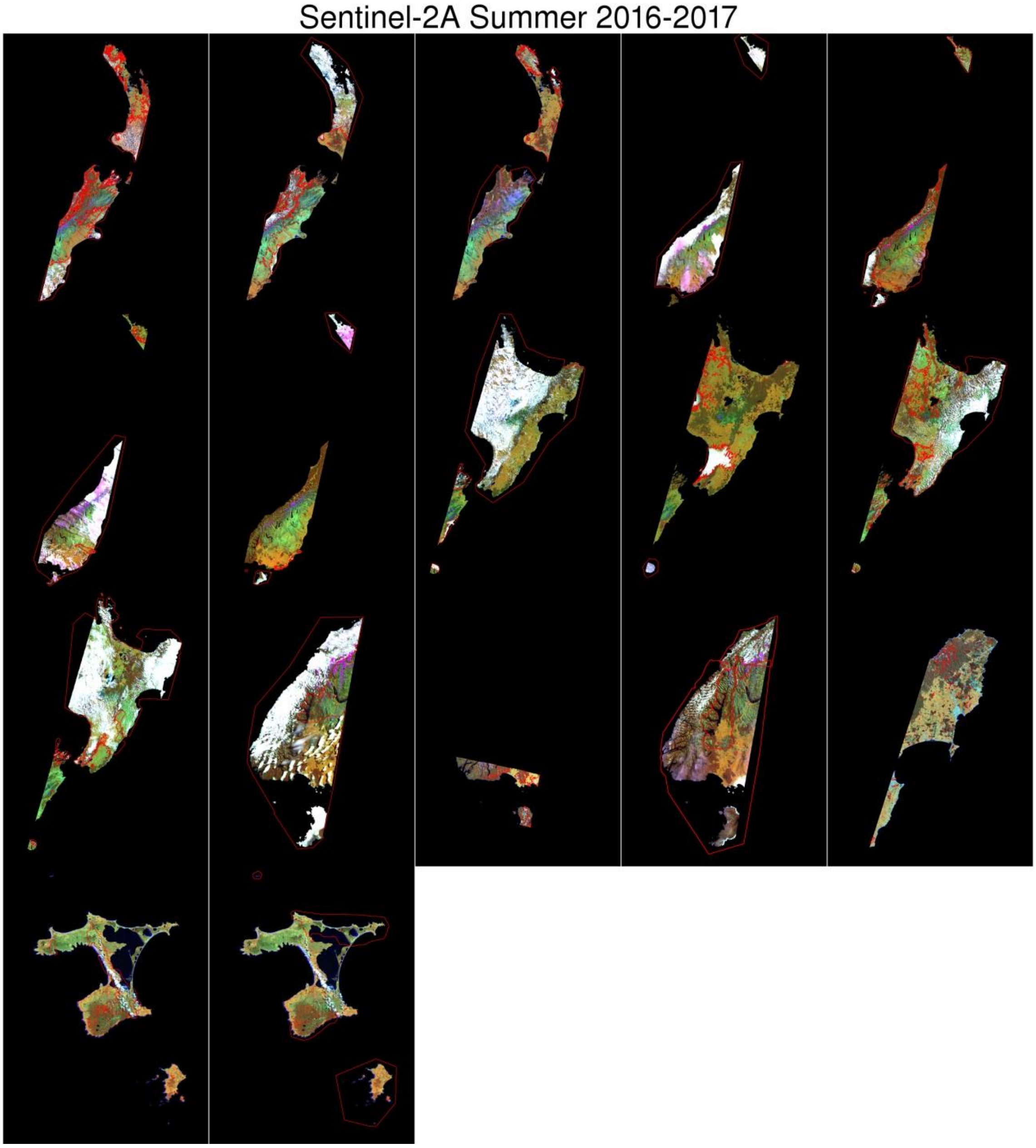

Figure 2: Sentinel 2A satellite imagery used for 2016/17 national mosaic. Cloud mask polygons produced by manual digitising are shown in red.

3.2 Detecting forest destocking during 2015 and 2016 (Activity 2)

Objective

The objective of this activity was to create annual destocking layers (identifying all areas of forest loss greater than 1 hectare) corresponding to the years 2015 and 2016. These layers were used to target land use change mapping in the 2016 LUM. The forest loss layer was expected to include both areas of harvesting and deforestation. The destock detection process was applied over the entire forested extent of the North and South Islands of New Zealand (including Stewart Island). The nominal period for destock mapping under this activity was 1 January 2015 to 31 December 2016. However, in practice, this was approximated by the dates of contributing imagery in the Landsat 8 14/15 and the Sentinel-2A 16/17 national mosaics (Fig. 2).

Method

Image processing techniques developed for the 2012 LUM mapping (Newsome et al. 2013) and refined for the detection of 2013 and 2014 destocking were used to identify all possible areas of forest destocking >= 1 hectare in size and 30 metres in width. These possible-destocking areas were then manually checked to remove “false positives” generated by such things as cloud or image mis-registration. Areas of non-anthropogenic change were retained in the destock layer but identified by an attribute flag. Each confirmed destock polygon was assigned to the year in which the destocking event occurred (2015 or 2016). Polygon outlines generated from the raster clump-based change process were smoothed to remove raster “staircase” artefacts.

The steps in the destock detection process, outlined in Figure 3, are summarised as follows:

a Detect 2015 destocking

We applied spectral differencing to detect possible 2015 destocking between the existing 14/15 and 15/16 Landsat 8 national mosaics. The detection process was applied to the area of the 2014 forest cover mask, which was created by removing all known destocking (supplied by MfE) from the LUM 2012 forest mask. The resulting possible destock areas were then vectorised, smoothed, attributed by destocking year, and QC-checked to confirm probable destocking. The 2015 probable-destocking spatial layer was then converted to ESRI file geodatabase format for delivery (Deliverable 2a).

b Detect 2016 destocking

We applied spectral differencing to detect possible 2016 destocking between an existing Sentinel-2A 15/16 and the new (Deliverable 1) Sentinel-2A 16/17 national mosaic. The detection process was applied to the area of the 2015 forest cover mask, which was created by removing all known destocking (supplied by MfE) from the LUM 2012 forest mask and 2015 detected destocking from a. (Deliverable 2a). The resulting possible destock areas were then vectorised, smoothed, attributed by destocking year, and QC-checked to confirm probable destocking. The 2016 probable-destocking spatial layer was then converted to ESRI file geodatabase format for delivery (Deliverable 2b).

c Detect destocking between the 15/16 Landsat 8 mosaic and the 15/16 Sentinel-2A mosaic

We performed a manual check for destocking occurring between the 15/16 Landsat 8 mosaic and the 15/16 Sentinel-2A mosaic where there was a temporal gap between image acquisitions. The resulting possible destock areas were then vectorised, smoothed and attributed by year of destocking. This spatial layer was then converted to ESRI file geodatabase format for delivery (Deliverable 2c).

These three deliverables became subject layers in a field validation programme by another contractor (InDuFor) who later returned verified targets for editing into the LUM 2016 under Activity 6.

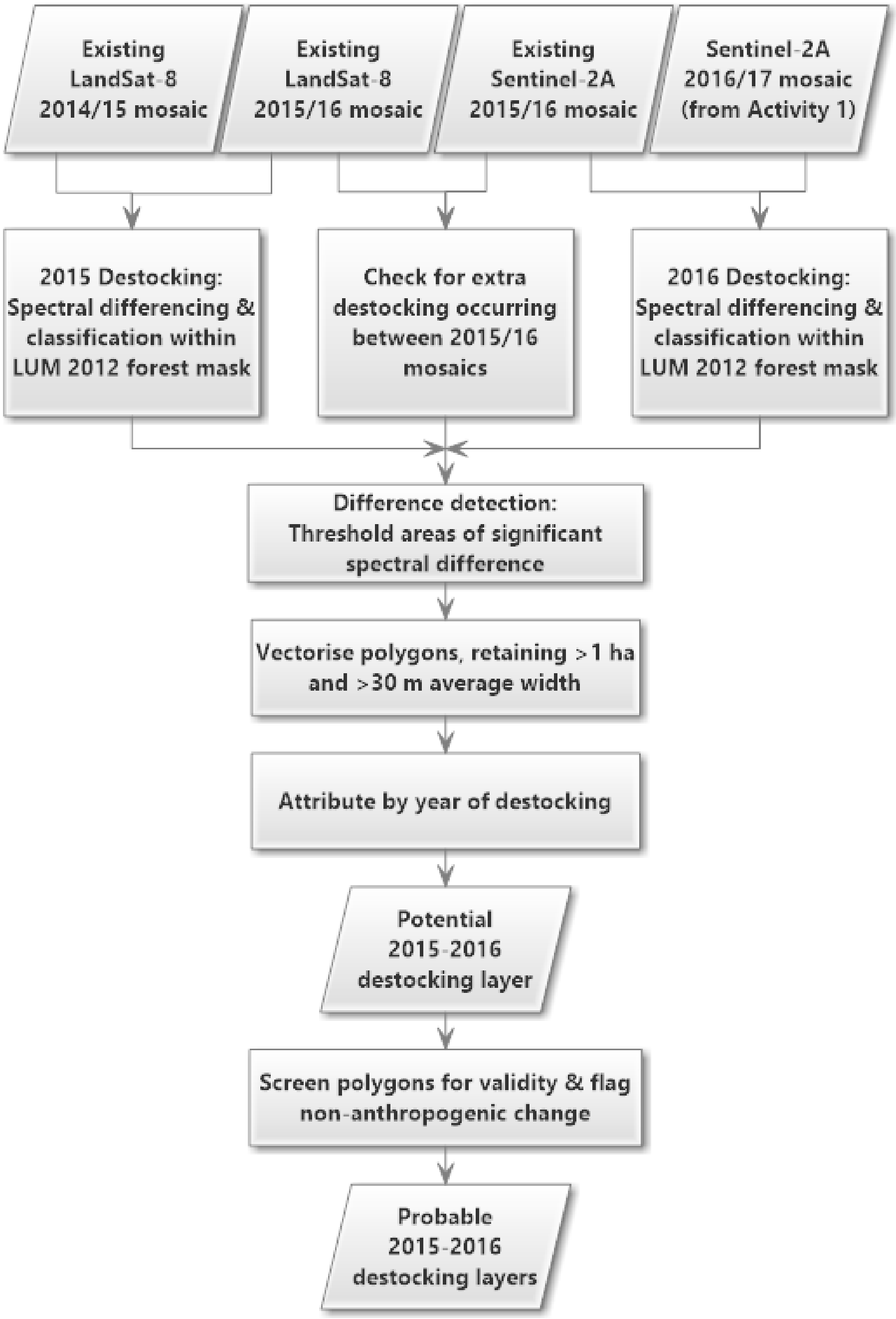

Figure 3: Methodology for 2015–2016 destock detection.

3.3 Improving LUM 2012 (Activity 3)

Objective

Before embarking on the 2016 Land Use mapping, the LUM 2012 was improved nationally with recent mapping of: Exotic forest; Grassland with Woody Biomass (GWB) and Settlements from the New Zealand Land Cover Database (LCDB); wetlands and wetland change from the Wetlands of National Importance (WONI) layer; and, if practical, MWLR cropland mapping of three regions. These processes are illustrated in Figure 4 and described below.

Specification and Standards

The LUM 2012 improvement activity covered North, South and Stewart Islands of New Zealand (including inshore islands) and the Chatham Islands. The operations were performed on two mainland layers (North and South islands), in New Zealand Transverse Mercator Projection (NZTM2000) and Chatham Islands in Chatham Islands Transverse Mercator (CITM2000).

Other specifications and standards included:

- Undertaking manual edits in Arc 10.2.1 using the 10.2.1 version of the LUM Attribute Tool.
- Maintaining the integrity of the layers such that they pass the topology checks embedded in the file geodatabase. In addition, attribute consistency was required to be maintained in accordance with the LUM 2012 Schema rules in Appendix 3. Topology and attribute schema were tested and had to pass the checks in an Attribute Checklist supplied by MfE for the geodatabases to successfully import back into the LUM production database.
- Maintaining the land use classifications in accordance with class and sub-class definitions in Appendix 1.
- Meeting or exceeding a land use classification standard of 95% agreement between the mapped class and a quality control assessment for a random set of sample points.
- Meeting or exceeding a land use change standard of 90% agreement between the mapped class and a quality control assessment for a random set of sample points.
- After mapping, the number of polygons less than 0.05 ha in size in each LUM layer should not have increased as a result of the mapping activity.

Method

The method used to improve LUM 2012 was a combination of automated merges and manual edits of target polygons into the LUM layers. Target polygons, most having originated as supervised edits in LCDB or some similar origin, were relatively trusted as sources of improvement. Some were sufficiently well delineated and attributed that they could be merged in a scripted process. Others were more spatially or thematically challenging and could only be integrated into LUM as a closely considered, manual, edit. Seven target layers were supplied by MfE as a result of comparison between LUM and LCDB v4. In addition, a tagged WONI polygon layer was used to supplement wetland improvement mapping. The general workflow is illustrated in Figure 4 and amplified in Figures 5–11.

As a first step, all polygons in each of these layers were visually assessed to:

- confirm polygons accurately represent a ground cover feature

- assess its 1990 status
- distinguish between exotic trees, indigenous trees and woody biomass for some target groups

In making this assessment, an operator simultaneously viewed each candidate polygon superimposed on imagery at several different dates in a pre-configured tool ("mapaccuracy"), to make quick multi-choice decisions. Defaults for the choice depended on LCDB's classification over four dates.

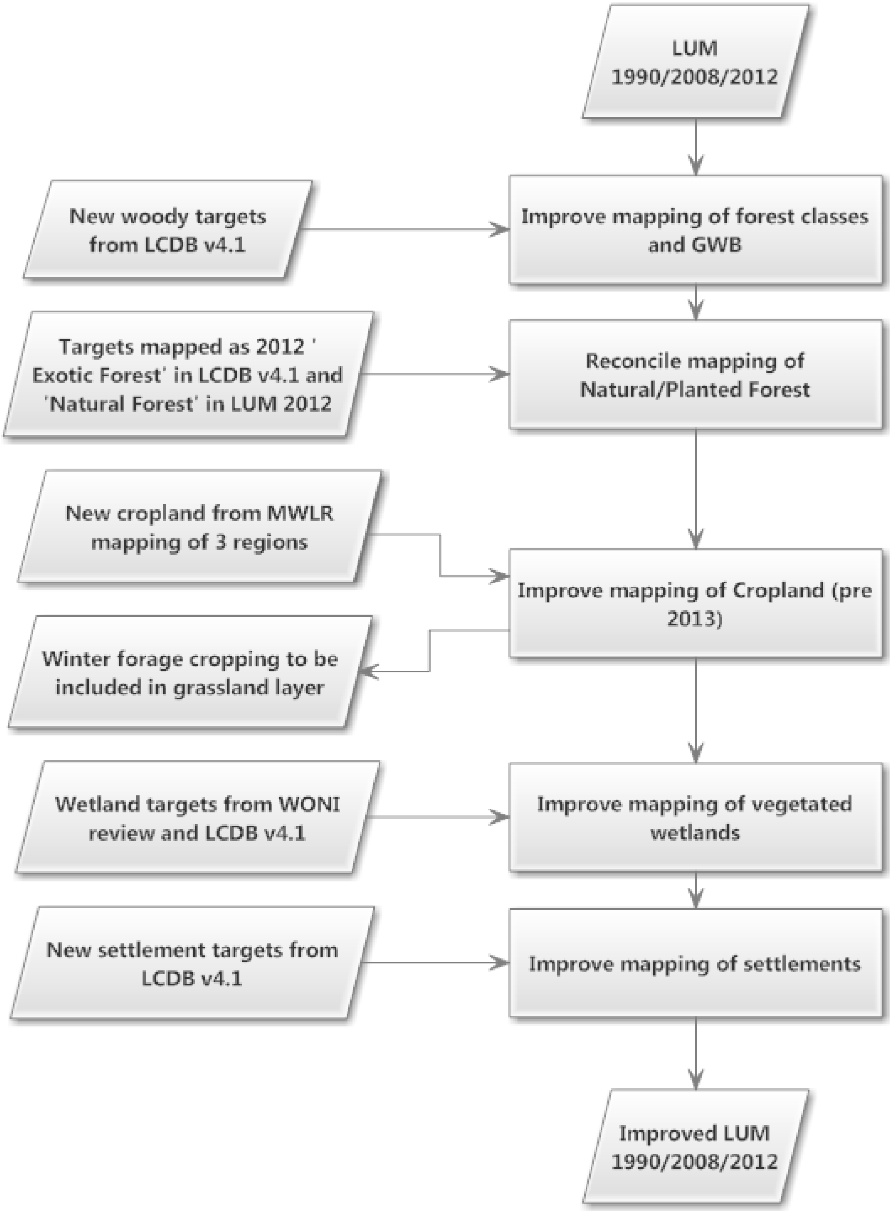

Figure 4: Improvements to LUM 1990_2008_2012 - general mapping workflow.

Woody_Add_Shrubs_1ha

One hectare or larger polygons of areas classified as scrub in the LCDB, but not woody on the LUM, were manually assessed as shown in Figure 5. Many of these target polygons originated from the LCDB v4 mapping where a significant number of hitherto undetected woody patches were mapped into LCDB's grassland environment based on a "woody" layer independently generated using both optical and radar satellite imagery followed by manual checking and classification. While classified as scrub in LCDB, a significant number were found to be exotic trees in the LUM context, hence the 'exotic' choices provided.

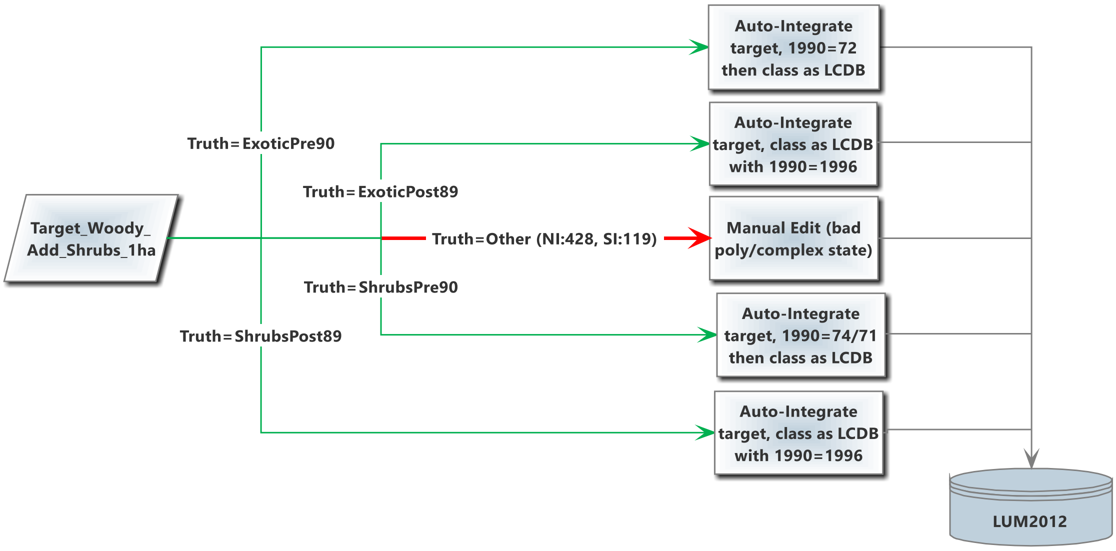

Figure 5: Woody_Add_Shrubs_1ha workflow, to add missing woody vegetation mapped as shrubland in LCDB (green line indicates an auto-integration process, red line indicates a manual integration process).

Woody_Add_Trees_1ha

One hectare or larger polygons of areas classified as trees in the LCDB, but not a woody class in the LUM, were manually assessed as shown in Figure 6. Again, many of these would have resulted from the "undetected woody patches" component of the LCDB v4 mapping programme. While the LCDB classification should distinguish exotic from indigenous classes, this information was used as a default and could still be overridden in the operator choice.

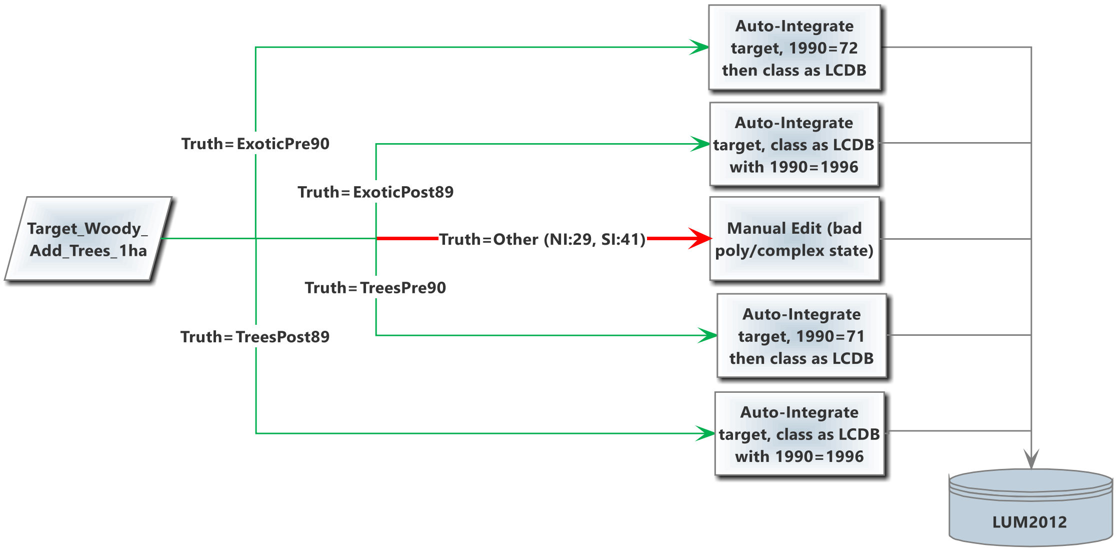

Figure 6: Woody_Add_Trees_1ha workflow, to add missing woody vegetation mapped as forest in LCDB (green line indicates an auto-integration process, red line indicates a manual integration process).

Exotic_Planted_Add_3ha

Three hectare or larger polygons of areas classified as exotic planted trees in the LCDB, but not a woody class in the LUM, were manually assessed as shown in Figure 7. As above, choices were provided to allow the operator to override the classification to be either natural or GWB classes in the LUM context.

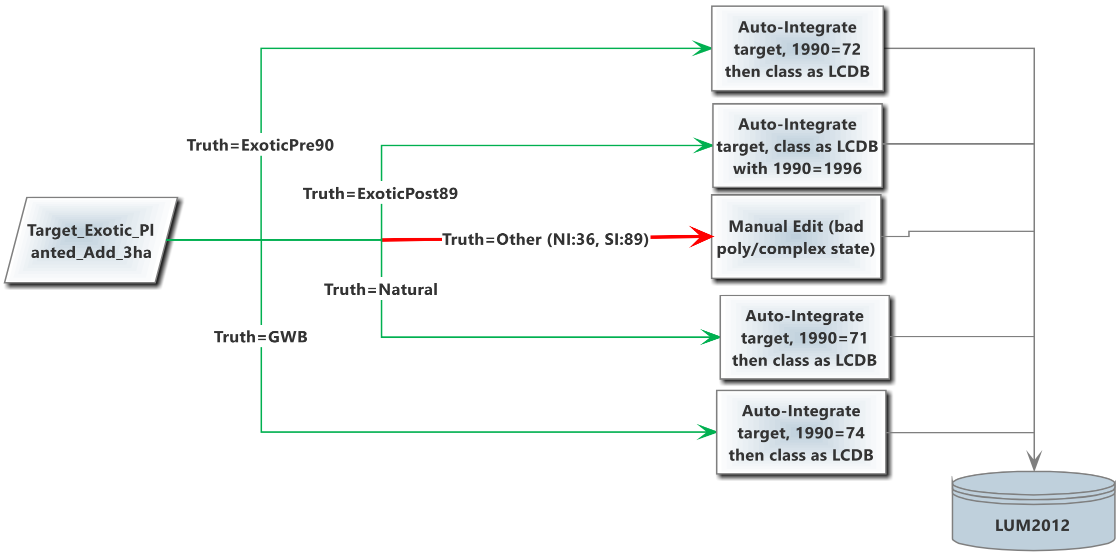

Figure 7: Exotic_Planted_Add_3ha workflow, to add missing woody vegetation mapped as planted forest in LCDB (green line indicates an auto-integration process, red line indicates a manual integration process).

Settlements_Add_1ha

One hectare or larger polygons of areas classified as settlements in the LCDB, but not in the LUM, were manually assessed and integrated, as shown in Figure 8. These would largely have come from the version 4 update to LCDB, as settlements had already been rationalised between the two in earlier versions.

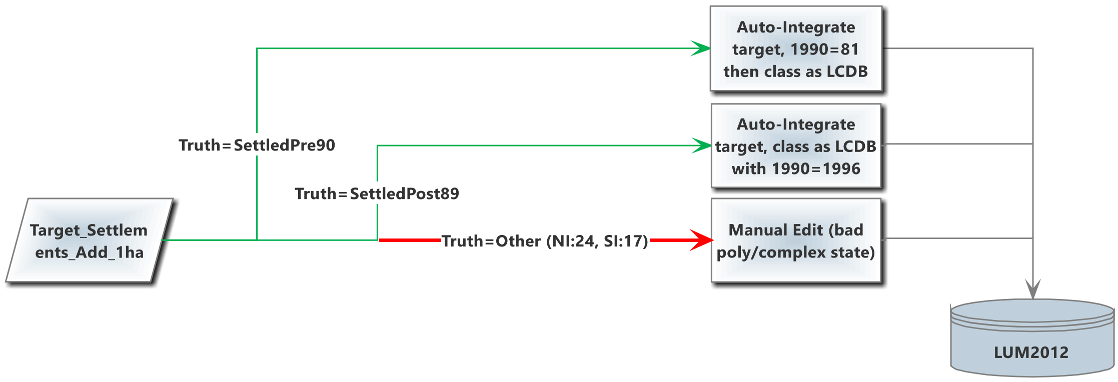

Figure 8: Settlements_Add_1ha workflow, to add missing settlements mapped in the LCDB (green line indicates an auto-integration process, red line indicates a manual integration process).

Wetlands_Veg_Add_5ha

LCDB mapping at v4.0 and v4.1 had improved the detection and delineation of wetlands in several regions, to the extent that its representation of wetlands was superior to LUM in these areas. Five hectare or larger polygons of areas classified as vegetated wetlands in the LCDB, but not in the LUM, were manually assessed as shown in Figure 9. Again, the operator could assess the polygon as trees or requiring manual editing. However, if it was a wetland, a choice was made between simply using the target polygon itself, or instead using the larger 'parent' LCDB polygon that it came from. In the latter case, some of the LCDB wetland area would have already been classified as wetland in the LUM, and therefore not part of the new target. However, taken as a whole, the parent LCDB polygon better represents the wetland. Note that an LCDB parent polygon could replace several targets and may also include areas around the original LUM wetland polygon that had fallen below the 5-hectare threshold.

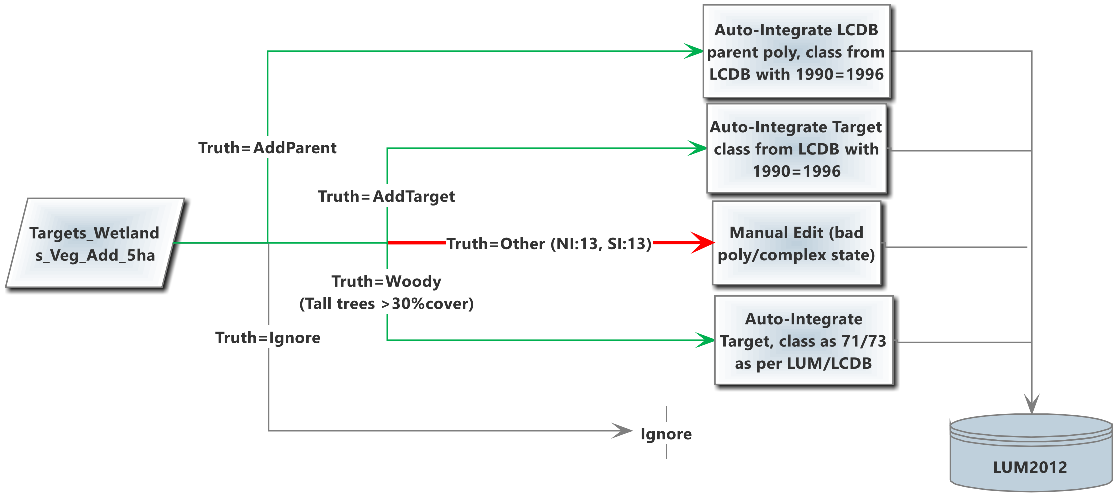

Figure 9: Wetlands_Veg_Add_5ha workflow, to integrate missing wetlands and improved mapping of wetlands from the LCDB (green line indicates an auto-integration process, red line indicates a manual integration process).

Wetlands_Veg_Remove_5ha and Wetlands_Open_Remove_10ha

These two sets of target polygons were instances where the LUM mapped a wetland but the LCDB hadn't. These were manually assessed as shown in Figure 10. Choices were provided to confirm that a wetland no longer existed and if so if it ever existed and its 1990 status. Note, generation of the vegetated removal target set did not take account of LCDB's 'WETContext' flag, so the operator was able to ignore some polygons on the basis that they were in fact wetland in LCDB also.

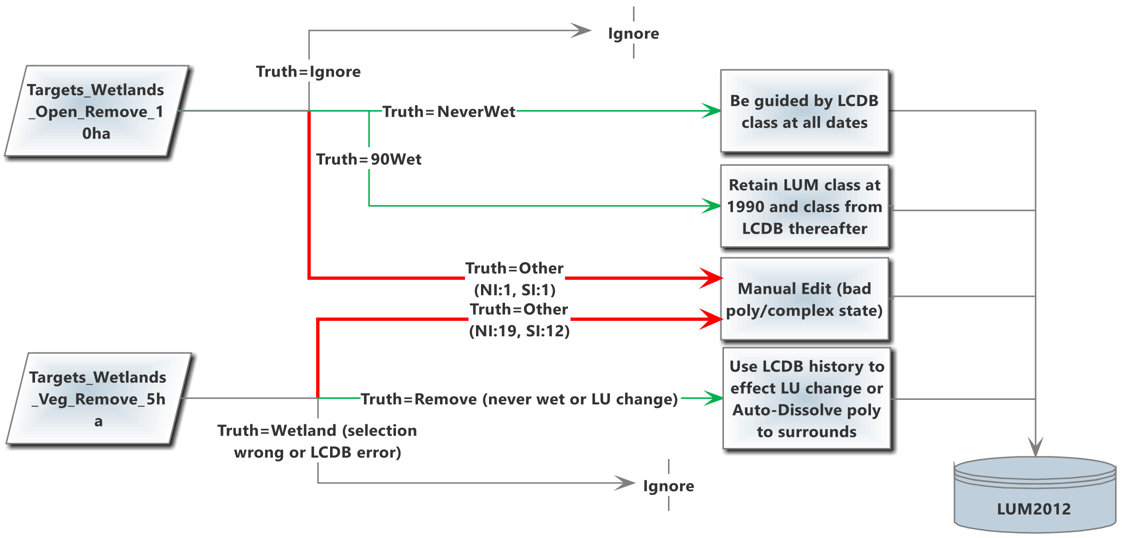

Figure 10: Wetland Remove workflow, to remove vegetated wetlands and open water where unsupported by LCDB and confirmed absent by our screening process (green line indicates an auto-removal process, red line indicates a manual removal process).

WONI Review Targets

WONI (Waters of National Importance) had been the subject of a review to estimate wetland loss since 2001-03 and to screen the quality of its wetland delineations. This review was contracted to MWLR by MfE resulting in a tagged set of WONI where the sebTruth attribute indicated types of wetland loss. That tagged dataset was used as input in this contract, and, as shown in Figure 11, polygons were further assessed to determine if they were never wet (therefore should be removed) or, if there was wetland loss, by which timestep it had happened. All the WONI targets that were chosen for inclusion onto the LUM were first smoothed to remove the pixilation due to its raster origins.

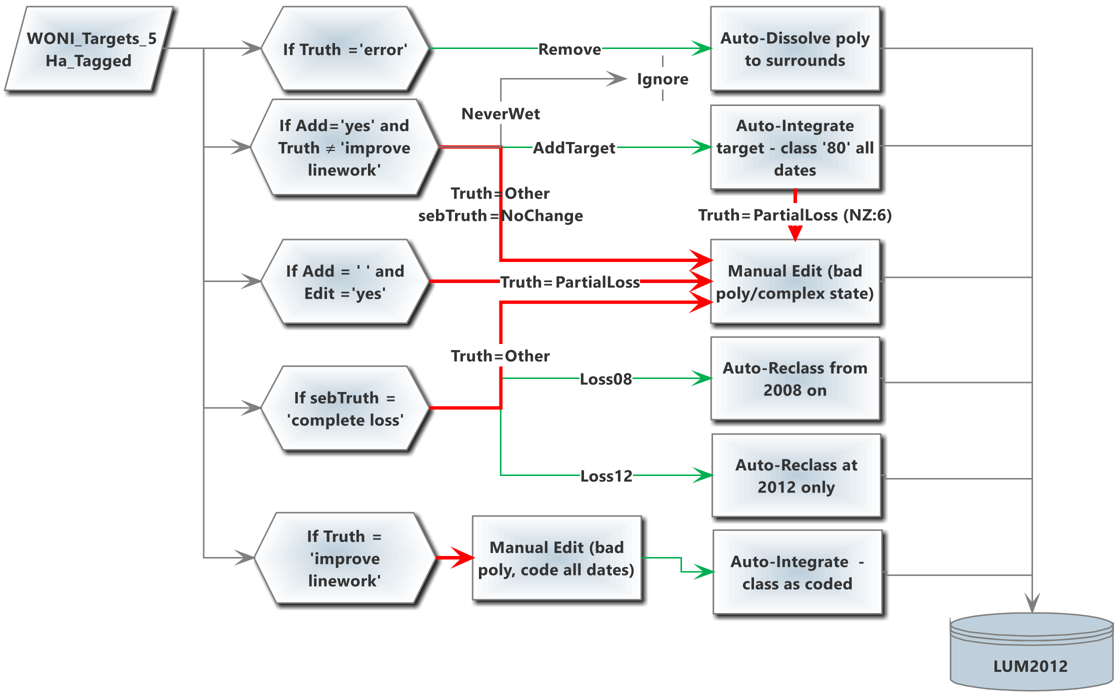

Figure 11: WONI Review Targets workflow, to integrate, alter, or remove polygons on the basis of an earlier review undertaken of WONI.

Integration of target polygons into the LUM

The datasets listed in table 1 were generated by selection, screening (manual review), and editing of polygons in the databases described above. These polygons were used as input to a script to integrate them into the LUM. Because polygons generated as manually improved linework (from WONI or from the LCDB) could potentially overlap, a check was made to exclude any that did overlap. The numbers rejected in this way are shown in Table 1.

Table 1: Final layers to modify in LUM

Layer name	North Island (polygon count)		South Island (polygon count)	
	Accepted	Overlapped (reject)	Accepted	Overlapped (reject)
Woody_Add_Shrubs_1ha	2980		1200	
Woody_Add_Trees_1ha	1981	3	1169	1
Exotic_Planted_Add_3ha	1034		731	
Settlements_Add_1ha	377		308	
Wetlands_Veg_Add_5ha	154	17	174	30
Wetlands_Veg_Remove_5ha	121	5	129	12
Wetlands_Open_Remove_10ha	17		72	
WONI_5HaSmoothed	26		91	8
WONI_ImprovedLinework	82		303	

Improve mapping of Perennial and Annual Cropland classes

Under separate contracts MWLR has created paddock-scale maps of cropping in three Regions (Southland, Canterbury and Hawke's Bay) using remote sensing techniques. It was intended to generalise these and then use them also as target polygons as above. However, the scale of those maps is a lot finer, and generalising them in a satisfactory way to match the LUM mapping standards proved difficult. Also, the paddock-scale maps only covered single, or very limited, time steps so that other timesteps would need manual confirmation. Instead, it was decided to use inconsistencies between those maps and the LUM to identify potential areas to map as part of the 2016 revision mapping.

3.4 Mapping land use change 2012–2016 (Activity 4)

Objective

To meet New Zealand's obligation under the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol, a map of 2016 land use (embodying 2012–2016 land use change) was prepared. The map covers the whole of New Zealand. The mapping process and the final map products meet the Intergovernmental Panel on Climate Change Good Practice Guidance and used a mapping approach consistent with the approach used to produce the LUCAS 1990, 2008, and 2012 land use maps.

Specification and Standards

Extent

The 2012–2016 land use change mapping covers the North and South Islands of New Zealand (including inshore islands), Stewart Island, and Chatham Islands.

It was assumed that there has been no change in land use on New Zealand's more distant off-shore islands (Antipodes, Bounty, Auckland, Snares, Campbell, and Kermadec Islands). These areas were not mapped at 2016 and existing data held at the Ministry for the Environment were used to account for these areas.

Maps were produced in New Zealand Transverse Mercator Projection (NZTM2000) for all areas except the Chatham Islands which will were mapped in Chatham Islands Transverse Mercator Projection (CITM2000).

Minimum mapping unit

The minimum mapping unit for the 2016 land use map (and all previous maps) is 1 hectare and polygons are required to have an average width greater than or equal to 30m.

The 2016 land use map was edited into the existing 1990-2008-2012 land use map (LUM). For this reason, new polygons of less than 1 ha in size were allowed where a (≥1 ha) land use change event crosses boundaries in the underlying maps. The rule in these circumstances is that, when underlying map boundaries are removed, no 2016 mapped polygons will be less than 1 hectare in size.

To preserve the integrity of the composite 1990-2008-2012-2016 LUM, no new polygons of size less than 0.05 ha were allowed in the finished LUM.

Other specifications and standards

Like the LUM improvement activity discussed in the preceding section, other specifications included:

- Undertaking manual edits in Arc 10.5.1 using the 10.5.1 version of the LUM Attribute Tool.
- Maintaining the integrity of the layers such that they pass the topology checks embedded in the file geodatabase. In addition, attribute consistency was required to be maintained in accordance with the LUM 2016 Schema rules in Appendix 4. Topology and attribute schema were tested and had to pass checks in the Data Acceptance Checklist supplied by MfE (Appendix 5) for the geodatabases to successfully import back into the LUM production database.
- Land use classifications based on class and sub-class definitions in Appendix 1.
- Meeting or exceeding a land use classification standard of 95% agreement between the mapped class and a quality control assessment for a random set of sample points.
- Meeting or exceeding a land use change standard of 90% agreement between the mapped class and a quality control assessment for a random set of sample points.

Method

The method used to create the 2016 land use map was broadly consistent with the approach used by Manaaki Whenua to produce the 1990, 2008 and 2012 land use maps.

The 2016 land use map was edited into the existing 1990–2008–2012 LUM in a workflow illustrated in Figure 12.

Land use changes were mapped according to the land use classifications and sub-classifications provided in Appendix 1, with attributes updated as specified in the LUM 2016 dataset schema (Appendix 4).

The 2012–2016 land-use change mapping followed a sequence of steps beginning with spectral differencing and change detection followed by a succession of predominantly manual visual analyses and digitising processes, as illustrated in Figure 12 and described below:

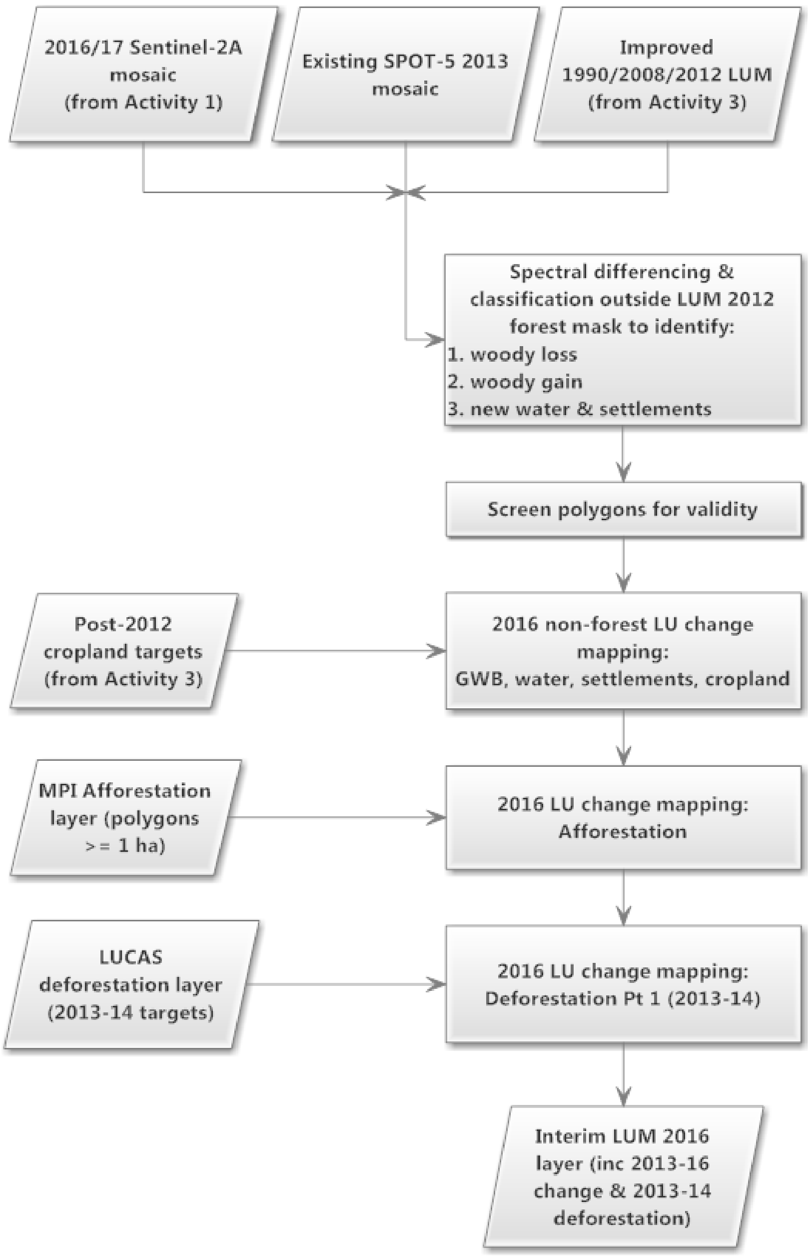

Figure 12: 2016 land-use change mapping workflow.

Spectral differencing and classification outside the improved LUM 2012 forest mask

The red, near-infrared and short-wave infrared spectral bands of the SPOT5 2012 and the 2016/17 S-2A standardised-reflectance mosaics were combined to generate a 6-band image stack. This multi-date image stack was segmented into homogeneous spectral units of at least 1 hectare in size. The resulting map then contains areas of consistent change and no change in the years 2013-2016. These features provide a candidate suite of polygons from which areas of interest can be extracted. An algorithm based on the Ecosat process (as documented in Dymond and Shepherd (2004), Dymond et al. (2001), and Shepherd and Dymond (2003)) was applied to extract features where spectral characteristics were inconsistent with the non-forest land use mapped at 2012 or the spectral difference between dates suggested change. This method was adapted slightly for detection of the Open water and Settlement classes. In those cases, average Sentinel 1 radar backscatter values (VV, VH, VV/VH) were helpful and added as an additional attribute to each optically derived candidate feature. This provided better discrimination and subsequent classification accuracy.

Difference detection

The features that were selected from above were combined into a 2012–-2016 change raster. The combined raster was vectorised and separate change layers produced for Grassland, Grassland with Woody Biomass (GWB), Open water and Settlements.

Areas less than 1 ha, and areas with an average width of less than 30m were removed from this layer because they are below the threshold for mapping. Areas obscured by cloud in the 2016/17 satellite imagery defaulted to ‘no change’.

Confirm change

Areas of potential change were reviewed in a rapid-screening process using the Manaaki Whenua-developed ‘TuiView’ environment and the associated ‘MapAccuracy’ program, to inspect and condense the set of potential change sites into a smaller number of probable change sites which were tagged for more careful consideration.

These probable change targets were each visually re-assessed in a customised ArcGIS 10.5 editing environment (Figure 13) to determine whether the change could be confirmed from visual reference to satellite imagery from 1990, 1996, 2001, 2008, 2012, and 2016, with guidance from the LUCAS Satellite Image Interpretation Guide (MfE 2012). Where necessary, reference was also made to evidential layers (including MfE/MWLR in-house reference layers of ‘environmentally limiting factors’ and tree line) and available aerial photography to determine the correct land use classification at each mapping date (1990, 2008, 2012, and 2016).

2012–2016 non-forest land-use change mapping

Areas of confirmed 2012-2016 land use change (outside forested areas) were edited into LUM regional file geodatabases using conventional ArcGIS editing tools mediated by the

MfE-supplied LUM Attribute Tool. The LUM Attribute Tool applies a level of quality control during editing (preventing non-permitted land use changes from becoming embedded) and maintaining some attributes (such as FEATURE_ID and AREA_HA). Target polygons (and their immediate environs) are checked to ensure their boundaries are captured with appropriate fidelity and the land use classifications at 1990, 2008, and 2012 are correct, before the 2012–2016 land use change is edited in.

The mapping environment was a customisation of ArcMap Desktop. ArcGIS 10.2.1 was used prior to (this) Activity 4 because the LUM Attribute Tool had not been developed beyond that version but, from Activity 4 onward, the switch was made to ArcGIS 10.5.1. Under both ArcGIS versions, the desktop environment looked like that illustrated in Figure 13 below. The environment comprised synchronised map frames whereby early-date reference frames render the same extent, in a smaller view, as the main editing frame and reference frames pan and zoom in response to movements in the editing frame. In each frame a selection of imagery at different dates can be viewed beneath evidential, target, and LUM vector layers.

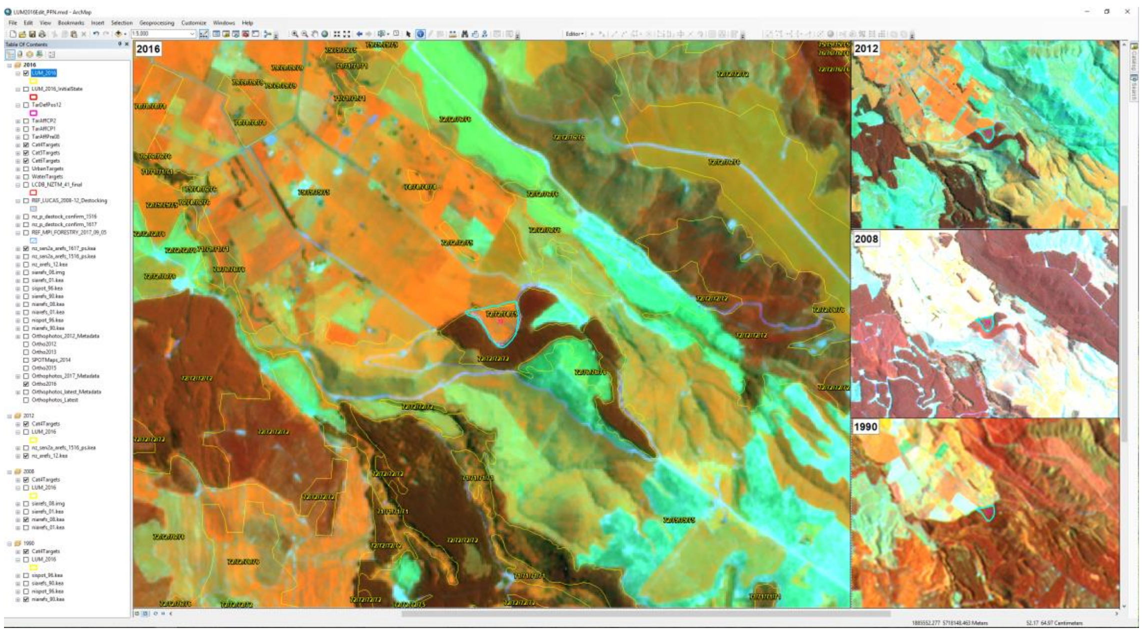

Figure 13: ArcMap editing environment showing the large main editing frame synchronised with smaller (early-date) reference frames. A change target is highlighted in the centre of each screen, outlining an area deforested to a scrubby (GWB) state in 2008 and further altered to a grassland state at 2016.

Areas of deforestation identified neither in the Ministry-supplied deforestation mapping, (described below) nor in MWLR's potential destock layers, were checked against the Ministry for Primary Industries (MPI) forestry scheme dataset to see if post-2007 re-planting is recorded (i.e. planting that may not be clearly visible in the latest imagery). If no re-planting is recorded and the suspected destocking is not already present in an MfE or MWLR target layer, the area is spatially delineated and the deforestation flag (IS_DEFORESTED = 1) raised. These areas of suspected deforestation, needed to be verified by field observation before a land use change in LUM is recorded (during the second tranche of destock mapping in Activity 6 of the project).

Post-2012 croplands, open water and settlements

During Activity 3, a target set of hitherto undetected cropland was created. New croplands occurring before 2013 were incorporated into the LUM during Activity 3, with those representing new cropland since 2012 incorporated in this (the 2012–2016 change) phase.

A dedicated search for post-2012 change also generated targets representing new (both hitherto undetected and post-2012) open water and settlements. These were edited into the LUM at this stage.

Afforestation mapping

The principal reference for afforestation, at all dates, was a layer provided by the Ministry for Primary Industries (MPI) which administers most of New Zealand's afforestation incentive schemes (notably the Emissions Trading Scheme, Afforestation Grants Scheme, Permanent Forest Sinks Initiative, and East Coast Forestry Scheme). Information from this layer, supplemented with other sources of information, enabled MfE to compile afforestation target layers for Pre-2008, 2009–2012 (Commitment Period 1 (CP1)) and 2013–2016 (Commitment Period 2 (CP2)).

Afforestation was incorporated into the LUM one target layer at a time. In every case, the area of afforestation was 'cut' into existing polygons by digitising its periphery (or tracing the target polygon if it was good enough) and the land use change assigned from the planting date recorded in the target layer, confirmed by reference to the MPI layer and visual inspection of imagery.

Deforestation mapping – Part 1, 2013–2014

Indicative deforestation in the years 2013-2014 had been prepared by MWLR under an earlier contract. These areas were verified in the field and, together with other confirmed destock areas, including previously detected deforestation remaining without a forest tree cover longer than 4 years, were compiled into a first tranche target set for incorporation into the LUM at this stage. The second/final tranche set of destock targets were incorporated just before the final delivery of the 2016 LUM as part of Activity 6 (discussed later in this report).

These targets were incorporated into the LUM by manual editing with close reference to the target, underlying photography and satellite imagery and ancillary layers (notably the MfE deforestation tracking layer). In every case, as well as recording the land use change, attributes identifying the deforestation event and the year of deforestation were maintained and, for polygons greater than 10 ha afforested since 1989, an estimate was recorded of its planting year.

Once all the foregoing edits were complete, regional LUM maps were checked for quality by MWLR before return to MfE for final quality control checking and acceptance.

In all, this 2016 land-use change phase delivered mapping as 16 regions covering the North and South Islands of New Zealand and one further deliverable covering the

Chatham Islands. Mapping and quality control were based on the LUM 2016 schema (Appendix 4).

3.5 Improving the classification of grasslands (Activity 5)

Background

Both the LUCAS LUM and the LCDB have similar definitions of high and low producing grassland. However, there are significant differences in the mapped extent of these classes in the two maps. Grassland mapping in the LUCAS LUM was originally inherited from the vegetation cover mapping in the New Zealand Land Resource Inventory (NZLRI), whereas LCDB grassland classes were mapped from visual interpretation of satellite imagery. While both have been updated and improved during mapping of subsequent versions, neither data set does a particularly good job of mapping the current distinction between low and high-producing grassland.

Grassland mapping has received very little attention in earlier LUCAS map improvement activities, with the only updates occurring because of land use change to grassland, primarily as a result of deforestation. The change from low-producing to high-producing grassland has largely been missed, although statistics on land use intensification indicate that this change is likely to be widespread.

Objective

The objective of this deliverable was to improve the discrimination of low- and high-producing grassland areas by creating a grassland map covering those areas which are in a grazing land use at 2012 and, for areas that have changed into grassland since 1990, determine whether this change happened before 2008; between 2008 and 2012; or after 2012.

Scope, Method and Result

This was a New Zealand-wide activity employing techniques developed in MWLR’s MBIE-funded Innovative Data Analysis (IDA) project. Included in this activity were:

- undertaking a brief review to determine appropriate classes and threshold values for differentiating ‘high and low producing’ grassland
- quantifying the likely size of error in grassland classification in the 2012 LUM by comparing the low and high-producing grassland mapping with a similar grassland classification derived from the Land Use New Zealand (LUNZ) map created as part of the IDA project.
- generating a ‘contemporary grassland’ map, with a nominal mapping date of 31 December 2016, which maps low- and high-producing grassland based on a range of input data sets potentially including:
  - Corelogic rural valuation data set
  - Farms online (if approved for use)

  - LCDB 4.1
  - MfE national irrigation map
  - NZLRI land use capability
  - Agribase (if licensing permits)
- validating the grassland layer with point information from soil data collection or historical point datasets.
- testing the value of Agribase by removing Agribase from the input data set and evaluating impact.
- testing a fuzzy-logic approach for grassland classification, giving more weight to concurring GIS layers.
- adding a simple sub-classification to each major grassland class (e.g. dairy and stock finishing in high-producing grassland. Include "winter forage crop" mapping derived from the regional cropland mapping undertaken as part of Deliverable 3a in the layer at this point.
- exploring which maps require updates for areas that have changed to high-producing grassland since 1990 i.e. when did the change occur: before 2008 (update 2008, 2012 and 2016 maps); between 2008 and 2012 (update 2012 and 2016 maps); or after 2012 (update only the 2016 map).

The method used, the workflow and the result are described in the companion to this report – Grassland improvement mapping using Innovative Data Analysis (IDA) techniques (Manderson, et. al. 2018).

3.6 Incorporating confirmed 2015–16 destocking and improved grassland classifications (Activity 6)

The final phase of creating the 2016 LUM involved incorporating recently-confirmed deforestation in a predominantly manual process and upgrading classification of grasslands in a predominantly automated process, as illustrated in Figure 14 and described below:

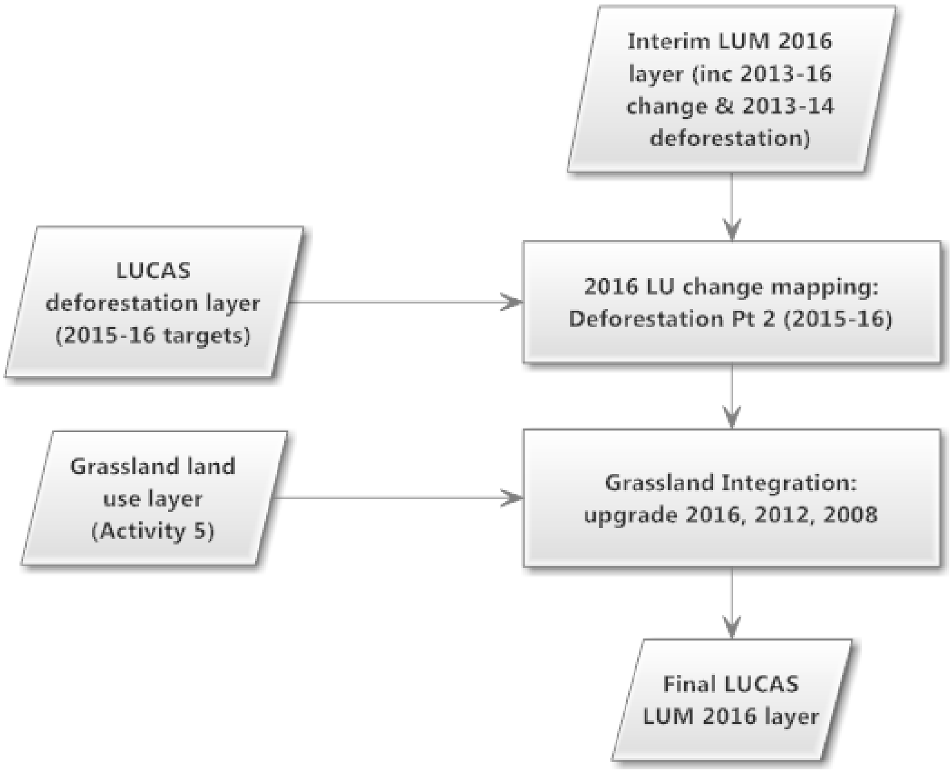

Figure 14: Incorporating confirmed 2015–16 deforestation and improved grassland classifications to produce the final LUCAS LUM 2016 layer.

Deforestation mapping – Part 2, 2015–2016

Indicative deforestation in the years 2015–2016 were prepared in Activity 2 of this contract. These were verified in the field by another contractor and, together with other confirmed deforestation (including previously detected deforestation remaining without a forest tree cover longer than 4 years), were compiled into a second set of targets for incorporation into the LUM.

These targets were incorporated into the LUM in the same fashion as Activity 4 – by manual editing with close reference to the target, underlying photography and satellite imagery and ancillary layers (notably, the MfE deforestation tracking layer).

Grassland upgrade

Activity 5 created a separate grassland layer at three different dates (2016, 2012, and 2008) to provide a New Zealand-wide grassland classification backdrop for LUM. As such, they more than cover that area mapped as grassland in the LUM and so, wherever LUM presently maps grassland, the grassland layers will have a confirming (or new) classification. The grassland layers classify grassland into high-producing and low-producing in greater detail than does the 2012 LUM. Further, they sub classify the grasslands into grazed dairy land, grazed non-dairy land and un-grazed land based on CoreLogic and other evidential data.

This activity involves incorporating the Activity 5 grassland classifications (and sub classifications) into the LUM, replacing the present grassland expression.

The New Zealand-wide modelled grassland classifications (at 2016, 2012, and 2008) were created in a raster environment (15 x 15 metre cells). To create a vector representation of grassland areas for insertion into LUM the raster layers was summarised into NZLRI polygons by areal dominance, and assigned one of three broad grassland classes as described in Manderson, et. al. 2018. The three dates were then combined into a single layer with three attributes for the classifications and polygons < 1ha eliminated from the result.

Areas from the LUM, classified as high- or low-producing grassland at 2016, 2012, or 2008 were then extracted. These classifications of grassland, were then replaced by new classifications (and sub-classifications) from the modelled results. The following consistency rules were applied to the new grassland classification and its historical sequence:

- If the 1990 and 2016 classifications (LUC ID) match, set 2008 and 2012 to the same class
- If the 2008 and 2016 classifications (LUC ID) match, set 2012 to the same class
- If the sub-classification (SUB LUC) is Dairy at any date, set class (LUC ID) to high-producing and set all subsequent dates to high-producing/dairy unless they go to un-grazed
- If the class is high-producing at 1990 and low-producing at 2008 AND 2008 sub-class (SUBLUC_ID) is either 'Grazed – dairy' or 'Grazed - non-dairy', then set 2008–16 class (LUC_ID) to high-producing
- If the class is high-producing at 1990 and low-producing at 2008 AND 2008 sub-class (SUBLUC_ID) is 'Ungrazed', then set 1990 class (LUC_ID) to low-producing

All unnecessary boundaries were dissolved out and then slivers under 1 ha were also eliminated from the result. Note that all these steps used only the extracted LUM areas that included grassland, so other polygons in the LUM were not impacted.

A variety of other attributes were updated for the now modified parts of the LUM that included grassland. These were:

- Unique Identifier (FEATURE_ID) – retained original where possible
- Modified By (MOD_ORG) – set to Landcare Research Limited
- Modified Date (MOD_DATE) – set to 31/08/2018
- Area (ha) (AREA_HA) – set to new actual area
- Mapping Method (LUM_METH_ID) – 2017 IDA Grassland (32)

The now modified parts of the LUM that included grassland were then used to replace those original areas in the LUM. Finally, topology checks were performed on the updated LUM.

3.7 Project management and quality control

The project team comprised image processing scientists, geographic information system specialists, and image analysts experienced in land-use and land-use change mapping from satellite imagery. The core of this team has successfully delivered three dates of LUCAS land-use mapping and two dates of New Zealand land cover database mapping, and has conducted developmental research to prototype methods and processes in support of such work. The technical lead of the project team is also a project manager with successful experience in large mapping and IT projects. Workflows mainly used proven or prototyped processes on the same or similar data types as before, so resourcing and throughput could be estimated with reasonable confidence.

Progress against timelines was managed using conventional project management tools, utilising both electronic (MS Project) monitoring and whiteboard progress tracking visible to all the team. Mapping decision-making and problem-solving was both collaborative and collective so that standards and decisions were consistent across all GIS analysts.

Monthly teleconferences were conducted between project managers from MWLR and the Ministry for the Environment, including technical staff as appropriate.

A data acceptance checklist including a data quality standards and consistency table were completed for each region before delivery (Appendix 5).

4 Results

Summary statistics of land use and land use change from all mapping activities except the grassland integration, are presented below (Table 2). The grassland integration was excluded from this analysis because it was more an improvement within the areas mapped as grassland rather than a change activity (despite its effect of altering the balance between high and low-producing grassland at each date). Final statistics will be compiled by MfE as part of New Zealand's national reporting obligations.

Table 2: Summary area statistics from the 2016 LUCAS Land Use Map (Totalled for North, South, Stewart and Chatham Islands and nearby islands)

	2016 Land Use												
2012 Land Use	Natural forest	Pre-1990 planted forest	Post-1989 forest	Grassland-with woody biomass	Grassland-high producing	Grassland-low producing	Cropland-perennial	Cropland-annual	Wetland-open water	Wetland-vegetated non forest	Settlements	Other	Total (ha)
Natural forest	7,790,921.6	25.7		654.1	537.4	830.8		15.9	0.5		26.7	285.9	7,793,298.7
Pre-1990 planted forest		1,451,857.7		1,451.4	13,028.1	7,974.6	5.4	119.9	91.4	116.3	38.5	439.9	1,475,123.3
Post-1989 forest			662,548.8	663.4	3,822.3	1,606.3		93.1	0.4	2.1	35.8	73.1	668,845.4
Grassland-with woody biomass	61.0	314.0	1,748.1	1,326,044.5	3,145.4	5,846.0	14.2	9.9	15.8	0.4	96.1	255.4	1,337,550.7
Grassland-high producing		36.1	779.6	115.9	5,806,833.8		1,091.2	28.7	320.3	16.1	2,939.3	101.1	5,812,262.0
Grassland-low producing	22.5	316.6	8,874.9	702.0	721.5	7,443,339.5	1.8		296.4		173.7	271.5	7,454,720.4
Cropland-perennial					10.2		103,136.6		8.3		156.0	1.6	103,312.7
Cropland-annual					5.0			371,153.1	58.3		220.5	25.2	371,462.1
Wetland-open water					1.6	7.3			533,630.9	1.4	2.9	10.2	533,654.3
Wetland-vegetated non forest				1.3	100.8	3.0			6.5	174,575.3			174,686.9
Settlements											230,628.6		230,628.6
Other			2.5	19.8	14.7	108.5			25.9		90.7	895,308.6	895,570.7
Total (ha)	7,791,005.2	1,452,550.2	673,953.9	1,329,652.4	5,828,220.7	7,459,716.1	104,249.1	371,420.6	534,454.7	174,711.6	234,408.9	896,772.5	26,851,116.0

Note: This table represents area changes resulting from the LUM 2016 map production process which created version 4 of the LUM 2016 data set. Subsequent mapping improvements will change these figures.

Of the 635,000 polygons in the LUM, over 6,800 underwent land use change between 2012 and 2016.

More than 36,000 polygons were affected by boundary edits during mapping, either because of land use change or polygon refinements to more accurately delineate land features.

Most of the processes used in this round of LUM mapping had been proven in earlier work, so no unforeseen challenges were encountered.

Editing of the LUM was made easier (though sometimes longer) by MfE removing the constraint of former years on altering (or deleting) existing polygon boundaries. This allowed analysts to refine polygon delineation before undertaking the land use change, resulting in a much more legible and accurate result.

5 References

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Appendix 1. LUCAS Land Use Classes and sub-classes used for 2016 land use mapping

<table>
<tr><th>Land Use Class</th><th>Definition</th><th>Sub-classes (sub-classes in grey not maintained in this project)</th></tr>
<tr><td>71 - Pre-1990 natural forest</td><td>Areas that, on 1 January 1990, were and presently include:
tall indigenous forest
• self-sown exotic trees, such as wilding pines and grey willows, established before 1 January 1990
• broadleaved hardwood shrubland, mānuka–kānuka (Leptospermum scoparium–Kunzea ericoides) shrubland and other woody shrubland (≥30 per cent cover, with potential to reach ≥5 metres at maturity in situ under current land management within 30–40 years)
• areas of bare ground of any size that were previously forested but, due to natural disturbances (e.g., erosion, storms, fire), have temporarily lost vegetation cover
• areas that were planted forest at 1990 but are subsequently managed to regenerate with natural species that will meet the forest definition
• roads and tracks less than 30 metres in width and other temporarily unstocked areas associated with a forest land use.</td><td>0 - Unknown
120 - Shrubland
121 - Tall Forest
122 - Wilding trees</td></tr>
<tr><td>72 - Pre-1990 planted forest</td><td>Areas that, on 1 January 1990, were and presently include:
• radiata pine (Pinus radiata), Douglas fir (Pseudotsuga menziesii), eucalypts (Eucalyptus spp.) or other planted species (with potential to reach ≥5 metre height at maturity in situ) established before 1 January 1990 or replanted on land that was forest land as at 31 December 1989
• exotic forest species that were planted after 31 December 1989 on land that was natural forest
• riparian or erosion control plantings that meet the forest definition and that were planted before 1 January 1990
• harvested areas within pre-1990 planted forest (assumes these will be replanted, unless deforestation is later detected)
• roads, tracks, skid sites and other temporarily unstocked areas less than 30 metres in width associated with a forest land use
• areas of bare ground of any size that were previously forested at 31 December 1989 but, due to natural disturbances (e.g., erosion, storms, fire), have lost vegetation cover.</td><td>0 - Unknown
201 - Pinus radiata
202 - Douglas fir
203 - Unspecified exotic species</td></tr>
<tr><td>73 - Post-1989 forest</td><td>Includes post-1989 planted forest, which consists of:
• exotic forest (with the potential to reach ≥5 metre height at maturity in situ) planted or established on land that was non-forest land as at 31 December 1989 (e.g., radiata pine, Douglas fir, eucalypts or other planted species)
• riparian or erosion control plantings that meet the forest definition and that were planted after 31 December 1989
• harvested areas within post-1989 forest land (assuming these will be replanted, unless deforestation is later detected).
• Includes post-1989 natural forest, which consists of:</td><td>0 - Unknown
122 - Wilding trees
201 - Pinus radiata
202 - Douglas fir
203 - Unspecified exotic species
204 - Regenerated natural species</td></tr>
</table>

	• forests arising from natural regeneration of indigenous tree species as a result of management change after 31 December 1989 • self-sown exotic trees, such as wilding conifers or grey willows, established after 31 December 1989. Includes areas within post-1989 natural forest or post-1989 planted forest that are: • roads, tracks, skid sites and other temporarily unstocked areas associated with a forest land use • areas of bare ground of any size that were previously forested (established after 31 December 1989) but, due to natural disturbances (e.g., erosion, storms, fire), have lost vegetation cover.	
74 - Grassland with woody biomass	Includes: • grassland with matagouri (*Discaria toumatou*) and sweet briar (*Rosa rubiginosa*), broadleaved hardwood shrubland (e.g., māhoe – *Melicytus ramiflorus*), wineberry (*Aristotelia serrata*), *Pseudopanax* spp., *Pittosporum* spp.), mānuka–kānuka (*Leptospermum scoparium–Kunzea ericoides*) shrubland, coastal and other woody shrubland (<5 metres tall and any per cent cover) where, under current management or environmental conditions (climate and/or soil), it is expected that the forest criteria will not be met over a 30- to 40-year-period • above-timberline shrubland vegetation intermixed with montane herbfields (does not have the potential to reach >5 metres in height *in situ*) • grassland with tall tree species (<30 per cent cover), such as golf courses in rural areas (except where the Land Cover Database has classified these as settlements) • grassland with riparian or erosion control plantings (<30 per cent cover) • linear shelterbelts that are >1 hectare in area and <30 metres in mean width • areas of bare ground of any size that previously contained grassland with woody biomass but, due to natural disturbances (e.g., erosion, fire), have lost vegetation cover.	0 - Unknown
75 - High producing grassland	Includes: • grassland with high-quality pasture species • linear shelterbelts that are <1 hectare in area or <30 metres in mean width (larger shelterbelts are mapped separately as grassland – with woody biomass) • areas of bare ground of any size that were previously grassland but, due to natural disturbances (e.g., erosion), have lost vegetation cover.	0 - Unknown 501 - Winter forage 502 - Grazed - dairy 503 - Grazed - non-dairy 504 - Ungrazed
76 - Low producing grassland	Includes: • low-fertility grassland and tussock grasslands (e.g., *Chionochloa* and *Festuca* spp.) • mostly hill country • montane herbfields either at an altitude higher than above-timberline vegetation or where the herbfields are not mixed up with woody vegetation • linear shelterbelts that are <1 hectare in area or <30 metres in mean width (larger shelterbelts are mapped separately as grassland – with woody biomass)	0 - Unknown 501 - Winter forage 502 - Grazed - dairy 503 - Grazed - non-dairy 504 - Ungrazed

	• other areas of limited vegetation cover and significant bare soil, including erosion and coastal herbaceous sand-dune vegetation.	
77 - Perennial cropland	Includes: • all orchards and vineyards • linear shelterbelts associated with perennial cropland.	0 - Unknown
78 - Annual cropland	Includes: • all annual crops • all cultivated bare ground • linear shelterbelts associated with annual cropland.	0 - Unknown
79 - Open water	Includes: • lakes, rivers, dams and reservoirs • estuarine–tidal areas including mangroves.	0 - Unknown 901 - Naturally occurring 902 - Human induced
80 - Vegetated wetland	Includes: • herbaceous and/or non-forest woody vegetation that may be periodically flooded. Includes scattered patches of tall tree-like vegetation in the wetland environment where cover reaches <30 per cent • estuarine–tidal areas including mangroves.	0 - Unknown
81 - Settlements	Includes: • built-up areas and impervious surfaces • grassland within 'settlements' including recreational areas, urban parklands and open spaces that do not meet the forest definition • major roading infrastructure • airports and runways • dam infrastructure • urban subdivisions under construction.	0 - Unknown
82 - Other land	Includes: • montane rock and/or scree • river gravels, rocky outcrops, sand dunes and beaches, coastal cliffs, mines (including spoil), quarries • permanent ice and/or snow and glaciers • any other remaining land that does not fall into any of the other land use categories.	0 - Unknown

Appendix 2. 2012–2016 Land Use Change: matrix of mapping impact

2012 (columns); 2016 (rows)

LUC_ID		71	72	73	74	75	76	77	78	79	80	81	82
		Natural forest	Pre-1990 planted forest	Post-1989 forest	Grass-land w. woody biomass	Grass-land - high	Grass-land - low	Cropland-perennial	Cropland – annual	Wetland - open water	Wetland - veg non forest	Settlement	Other
71	Natural forest												
72	Pre-1990 planted forest		LCDB NF/Exotic update										
73	Post-1989 forest			LCDB Woody update	Derived mainly from MPI afforestation mapping								
74	Grassland w. woody biomass				LCDB Woody update								
75	Grassland - high	Deforestation: 2013 and 2014 deforestation mapped from MfE targets 2015 and 2016 deforestation mapped from initial destock detection (Deliverable 2) after field confirmation by another contractor.				Grassland update based on Deliverable 4		Updates to Canterbury, Hawke's Bay and Southland from LCR regional cropland mapping			LCDB4/WONI update		
76	Grassland - low										LCDB4/WONI update		
77	Cropland - perennial										LCDB4/WONI update		
78	Cropland - annual										LCDB4/WONI update		
79	Wetland - open water										LCDB4/WONI update		
80	Wetland - veg non-forest										LCDB4/WONI update		
81	Settlement											LCDB4 update	
82	Other										LCDB4/WONI update		

Key:
- Illegal change
- No change
- Change mapped from imagery
- Change unlikely to be identified
- Possible where forest present at 1990
- Improvement derived from LCDB4
- Localised updates near LCDB4 update areas
- LCR regional cropland mapping

Appendix 3. LUM 2012 dataset schema

LUM 2012 [Improvements] Schema (greyed out attributes do not require editing)

	Field	Alias	2012 Land Use Map Attribution	Comment
	OBJECTID	OBJECTID		Automatically generated.
	shape	SHAPE		Automatically generated.
Land Use Class Attributes	**FEATURE_ID**	Unique Identifier	Managed by LUM Attribute Tool	Automatically generated. This provides a unique reference to a polygon which remains fixed across each version of the land use map. This field is used by the CRA to uniquely tag deforested polygons.
	LUC_ID	Current Land Use Classification [2012]	Land use as at 31 December 2012	This is the best-known land use as at 31 December 2012 . Note: LUC_ID is sub-classified by new field "SUBID_CUR". Allowed values are given by domain 'LUC'.
	IS_IMPROVEMENT	Improvement	Not used	This field serves as a gate, reserved for use by "locked" versions of the LUM Attribute Tool. Allowed values are given by domain 'BOOLEAN'.
	IMPR_LUC_ID	2008 Land Use Classification	Land use as at 1 January 2008	This is the best-known land use as at 31 December 2007. Allowed values are given by domain 'LUC'.
	SUB_LUC_ID	2008 Sub Class	Sub-classification of 2008 land use	This field is the land use sub-class of IMPR_LUC_ID (2008 Land Use Classification). Allowed values are controlled by subtyping on the value of IMPR_LUC_ID and are given by the domains: 'Grassland', 'Natural Forests', 'Open Water', 'Planted Forests', 'Post-1989 Forests', 'Other LUC'.
	PREV_LUC_ID	1990 Land Use Classification	Land use as at 31 December 1989	This field is the best-known land use as at 31 December 1989. Allowed values are given by domain 'LUC'. Note that the value "Post-1989 Forest" is invalid by definition.
Change Tracking Attributes	**DOCUMENT_ID**	Document Store References	Not updated	This field provides MfE change control document IDs relating to improvement projects (comma delimited). Document IDs are appended with "C" (Changed) or "R" (Reviewed, but not changed).
	MOD_ORG_ID	Modified By	Updated automatically	This is the organisation which made the most recent modification to the polygon information (automatically calculated by LUM Attribute Tool). Edits done outside of the LUM Attribute Tool will have MOD_ORG_ID attributed by subsequent bulk updates. Allowed values are given by domain 'ORGANISATION'.
	MOD_DATE	Modified Date	Updated automatically	The date/time of the last modification (automatically calculated). Edits done outside of the LUM Attribute Tool will have MOD_DATE attributed by subsequent bulk updates.
Location Attributes	**lum_reg_id**	Region	Not updated	This field identifies the New Zealand LUM region to which the polygon belongs. Each region is self-contained and polygons may not straddle a regional boundary. Allowed values are given by domain 'LUM_REGION'.
	lum_island	Island	Not updated	This field identifies the island to which the polygon belongs. Allowed values are given by domain 'LUM_ISLAND'.
	area_ha	Area (ha)	Updated automatically	This field gives the area of the polygon in hectares (automatically calculated by LUM Attribute Tool).
Original Mapping Attributes	**lum_year**	Mapping Year	Not updated	This field is the year associated with the mapping. The nominal mapping date is 31 December 2012.
	MAP_LUC_ID	Mapped Land Use Classification	Not updated	This field records the land use classification as first mapped for the LUM_YEAR map. This attribute is frozen once it has been created. Allowed values are given by domain 'LUC'.

	Field	Alias	2012 Land Use Map Attribution	Comment
	LUM_METH_ID	Mapping Method	Set to either: 'LCDB4 data'; 'LCR Regional Cropland Mapping'; 'Manual Image Interpretation'; 'WONI data'; or remains unchanged	This field indicates the mapping method used to determine the polygon's land use at 2012. Where polygons have been modified based on LCDB 4.x data: LUM_METH_ID = 'LCDB4 data'. Where polygons have been modified based on LCR Regional Cropland Mapping data: LUM_METH_ID = 'LCR Regional Cropland Mapping'. Where polygons have been modified from manually interpreting imagery: LUM_METH_ID = 'Manual Image Interpretation'. Where polygons have been modified based on WONI (wetland) data: LUM_METH_ID = 'WONI data'. Where the polygon has **not** been modified, LUM_METH_ID remains unchanged. Allowed values are given by domain 'LUM_METHOD'.
	LUM_ORg_id	Mapping Organisation	Not updated	This field records the organisation which performed the original mapping. Allowed values are given by domain 'ORGANISATION'.
	LUM_date	Mapping Date	Not updated	This is the date the original 2012 mapping was completed.
Deforestation and harvesting attributes	**IS_DEFORESTED**	Deforested	Set = 1 if post-2007 deforestation.	This flag indicates if the polygon has been deforested since 31 December 2007 (i.e. during a commitment period). This flag is not applicable to pre-2008 deforestation. **Suspected Deforestation:** For areas **outside** the MfE-supplied deforestation mapping that meet the forest definition **suspected** of being deforested post-2007; set this flag to 1. However, do **not** change DEF_YEAR or IS_DEF_YR_KNOWN attributes. The land use classifications should remain set to forest; deforestation will be confirmed by another party. Allowed values are given by domain 'BOOLEAN'.
	IS_DEF_METH_ KNOWN	Deforestation Method Known	Not used	This field is not used. It applies to polygons for which the IS_DEFORESTED flag is set true. It indicates if the deforestation method is known. Allowed values are given by domain 'BOOLEAN'.
	DEF_METH_ID	Deforestation Method	Not used	This field is not used. It applies to polygons for which the IS_DEF_METH_ KNOWN flag is set true. It provides the method of deforestation. Allowed values are given by domain 'DEF_METHOD'.
	IS_DEF_YR_ KNOWN	Deforestation Year Known	Not updated	This field only applies to polygons for which the IS_DEFORESTED flag is set true. It indicates that a deforestation year is required. **Suspected Deforestation:** **Without** a confirmed deforestation target polygon, do **not** change this attribute. Allowed values are given by domain 'BOOLEAN'.
	DEF_YEAR	Deforestation Year	Not updated	This field only applies to polygons for which the IS_DEF_YR_KNOWN flag is set true. It provides the calendar year of deforestation and is attributed from the DSTOCK_YR field in MfE deforestation polygon targets.
	IS_PL_YR_KNOWN	Planting Year Known	Not updated	This field only applies to post-1989 Forest polygons for which the IS_DEFORESTED flag is set true. It indicates that a planting year is required. Allowed values are given by domain 'BOOLEAN'.
	PLANT_YEAR	Planting Year	Not updated	This field only applies to polygons for which the IS_PL_YR_KNOWN flag is set true. It provides the estimated year of planting.
	IS_STK_KNOWN	Stocking Known	Not used	This field is not used. It applies to polygons for which the IS_DEFORESTED flag is set true. It indicates whether the stocking rate is known. Allowed values are given by domain 'BOOLEAN'.
	STOCKING	Stocking	Not used	This field is not used. It applies to polygons for which the IS_STK_KNOWN flag is set true. It provides the stem rate of stocking.
	IS_HARVESTED	Harvested	Not used	This field is not used. The function has been superseded by the Destocking Tracking map. It indicates if a forest polygon has been harvested post-2007. Allowed values are given by domain 'BOOLEAN'.

	Field	Alias	2012 Land Use Map Attribution	Comment
	IS_HARV_YR_KNOWN	Harvest Year Known	Not used	This field is not used. It applies to polygons for which the IS_HARVESTED flag is set true. It indicates if the year of harvesting is required. Allowed values are given by domain 'BOOLEAN'.
	HARV_YEAR	Harvest Year	Not used	This field is not used. It applies to polygons for which the IS_HARV_YR_ KNOWN flag is set true. It provides the post-2007 year of harvesting.
	INDEX_SITE	Site Index	Not used	This field is not used. It provides the planted forest mean top height in terms of the Site Index model. Allowed range controlled by domain 'Site Index'.
	INDEX_300	300 Index	Not used	This field is not used. It provides the planted forest volume productivity in terms of the 300 Index model. Allowed values are given by domain '300 Index'.
New field	**SUBID_CUR**	Current Sub Class [2012]	Sub-classification of 2012 land use	This field is the land use sub-class of LUC_ID (Current Land Use Classification [2012]). Land uses that are sub-classified are *Natural Forest; Post-1989 Forest*, *Grassland - High producing*, *Grassland - Low producing* and *Wetland - Open water*. In the case of *Natural Forest*, *Wetland - Open water* and *Grassland*, "Unknown" is a valid attribute, if another sub-classification is not relevant. The sub-classification for all other land uses is set to "Unknown". WARNING: subtyping controls do not apply; appropriate attributes are manually selected from the catch-all domain 'LUC sub_class'.
	SHAPE_Length	SHAPE_Length	Not updated	Automatically generated; value is in metres.
	SHAPE_Area	SHAPE_Area	Not updated	Automatically generated; value is in square metres.

Appendix 4. LUM 2016 dataset schema

LUM 2016 Schema (greyed out attributes do not require editing)

	Field	Alias	2016 Land Use Map Attribution	Comment
	OBJECTID	OBJECTID		Automatically generated.
	shape	SHAPE		Automatically generated.
Land Use Class Attributes	**FEATURE_ID**	Unique Identifier	Managed by LUM Attribute Tool	Automatically generated. This provides a unique reference to a polygon which remains fixed across each version of the land use map. This field is used by the CRA to uniquely tag deforested polygons.
	LUC_ID	Current Land Use Classification [2012]	Land use as at 31 December 2012	This is the best-known land use as at 31 December 2012. Note: LUC_ID is sub-classified by new field "SUBID_CUR". Allowed values are given by domain 'LUC'.
	IS_IMPROVEMENT	Improvement	Not used	This field serves as a gate, reserved for use by "locked" versions of the LUM Attribute Tool. Allowed values are given by domain 'BOOLEAN'.
	IMPR_LUC_ID	2008 Land Use Classification	Land use as at 1 January 2008	This is the best-known land use as at 31 December 2007. Allowed values are given by domain 'LUC'.
	SUB_LUC_ID	2008 Sub Class	Sub-classification of 2008 land use	This field is the land use sub-class of IMPR_LUC_ID (2008 Land Use Classification). Land uses that are sub-classified are *Natural Forest; Post-1989 Forest*, *Grassland - High producing*, *Grassland - Low producing* and *Wetland - Open water*. In the case of *Natural Forest*, *Wetland - Open water* and *Grassland*, "Unknown" is a valid attribute, if another sub-classification is not relevant. The sub-classification for all other land uses is set to "Unknown". WARNING: subtyping controls no longer apply; appropriate attributes are manually selected from the catch-all domain 'LUC sub_class'.
	PREV_LUC_ID	1990 Land Use Classification	Land use as at 31 December 1989	This field is the best-known land use as at 31 December 1989. Allowed values are given by domain 'LUC'. Note that the value "Post 1989 Forest" is invalid by definition.
Change Tracking Attributes	**document_id**	Document Store References	Not updated	This field provides MfE change control document IDs relating to improvement projects (comma delimited). Document IDs are appended with "C" (Changed) or "R" (Reviewed, but not changed).
	MOD_ORG_ID	Modified By	Updated automatically	This is the organisation which made the most recent modification to the polygon information (automatically calculated by LUM Attribute Tool). Edits done outside of the LUM Attribute Tool will have MOD_ORG_ID attributed by subsequent bulk updates. Allowed values are given by domain 'ORGANISATION'.
	MOD_DATE	Modified Date	Updated automatically	The date/time of the last modification (automatically calculated). Edits done outside of the LUM Attribute Tool will have MOD_DATE attributed by subsequent bulk updates.
Location Attributes	**lum_reg_id**	Region	Not updated	This field identifies the New Zealand LUM region to which the polygon belongs. Each region is self-contained and polygons may not straddle a regional boundary. Allowed values are given by domain 'LUM_REGION'.
	lum_island	Island	Not updated	This field identifies the island to which the polygon belongs. Allowed values are given by domain 'LUM_ISLAND'.
	area_ha	Area (ha)	Updated automatically	This field gives the area of the polygon in hectares (automatically calculated by LUM Attribute Tool).
Original Mapping Attributes	**LUM_YEAR**	Mapping Year	2016	This field is the year associated with the mapping. The nominal mapping date is 31 December 2016.
	MAP_LUC_ID	Mapped Land Use Classification	2016 LUC as first mapped in 2016 LU Mapping.	This field records the land use classification as first mapped for the LUM_YEAR map. This attribute is frozen once it has been created. Set MAP_LUC_ID = LUCID_2016 at the conclusion of mapping. Allowed values are given by domain 'LUC'.

	Field	Alias	2016 Land Use Map Attribution	Comment
	LUM_METH_ID	Mapping Method	Set to either: ‘2016 Ecosat Process’; ‘2017 IDA Grassland’; ‘MfE Deforestation Mapping’; ‘LCDB4 data’; ‘LCR Regional Cropland Mapping’; ‘Manual Image Interpretation’; ‘MPI Forestry Scheme Mapping’; ‘WONI data’; or remains unchanged	This field indicates the mapping method used to determine the polygon’s land use at 2016. Where confirmed change between 2012 and 2016 was discovered by the Ecosat process: LUM_METH_ID = ‘2016 Ecosat Process’. Where confirmed change between 2012 and 2016 was identified from manually identifying the change in imagery: LUM_METH_ID = ‘Manual Image Interpretation’. Where afforestation is integrated from MfE-supplied MPI forestry scheme data: LUM_METH_ID = ‘MPI Forestry Scheme Mapping’. Where deforestation is integrated from MfE-supplied deforestation polygons with MFE_EVIDNC = ‘MPI scheme information’: LUM_METH_ID = ‘MPI Forestry Scheme Mapping’. Where deforestation is integrated from MfE-supplied deforestation polygons with MFE_EVIDNC <> ‘MPI scheme information’: LUM_METH_ID = ‘MfE Deforestation Mapping’. Where grassland polygons have been modified by the IDA process: LUM_METH_ID = ‘2017 IDA Grassland’. Where polygons have been modified based on LCDB 4.x data: LUM_METH_ID = ‘LCDB4 data’. Where polygons have been modified based on LCR Regional Cropland Mapping data: LUM_METH_ID = ‘LCR Regional Cropland Mapping’. Where polygons have been modified based on WONI (wetland) data: LUM_METH_ID = ‘WONI data’. Where the polygon has **not** been modified, LUM_METH_ID remains unchanged. Allowed values are given by domain ‘LUM_METHOD’.
	LUM_ORg_id	Mapping Organisation	Not updated	This field records the organisation which performed the original mapping. Allowed values are given by domain ‘ORGANISATION’.
	LUM_DATE	Mapping Date	Set LUM_DATE = MOD_DATE	This is the date the 2016 mapping was completed. Set LUM_DATE = MOD_DATE at the conclusion of mapping.
Deforestation and harvesting attributes	**IS_DEFORESTED**	Deforested	Set = 1 if post-2007 deforestation.	This flag indicates if the polygon has been deforested since 31 December 2007 (i.e. during a commitment period). This flag is not applicable to pre-2008 deforestation. **Deforestation Integration:** **With** a confirmed post-2007 deforestation target polygon supplied by MfE, this flag is set to 1. **Suspected Deforestation:** **Without** a confirmed deforestation target polygon, for areas meeting forest definition **suspected** to be deforested post-2007; set this flag to 1. However, do **not** change DEF_YEAR or IS_DEF_YR_KNOWN attributes. The land use classifications should remain set to forest; deforestation will be confirmed by another party. Allowed values are given by domain ‘BOOLEAN’.
	is_def_meth_known	Deforestation Method Known	Not used	This field is not used. It applies to polygons for which the IS_DEFORESTED flag is set true. It indicates if the deforestation method is known. Allowed values are given by domain ‘BOOLEAN’.
	def_meth_id	Deforestation Method	Not used	This field is not used. It applies to polygons for which the IS_DEF_METH_ KNOWN flag is set true. It provides the method of deforestation. Allowed values are given by domain ‘DEF_METHOD’.
	IS_DEF_YR_KNOWN	Deforestation Year Known	Set = 1 with a confirmed post-2007 target	This field only applies to polygons for which the IS_DEFORESTED flag is set true. It indicates that a deforestation year is required. **Deforestation Integration:** **With** a confirmed post-2007 deforestation target polygon supplied by MfE, this flag is set to 1. **Suspected Deforestation:** **Without** a confirmed deforestation target polygon, do **not** change this attribute. Allowed values are given by domain ‘BOOLEAN’.

	Field	Alias	2016 Land Use Map Attribution	Comment
	DEF_YEAR	Deforestation Year	Set DEF_YEAR = DSTOCK_YR (from targets)	This field only applies to polygons for which the IS_DEF_YR_KNOWN flag is set true. It provides the calendar year of deforestation and is attributed from the DSTOCK_YR field in the MfE-supplied deforestation polygon targets.
	IS_PL_YR_KNOWN	Planting Year Known	Set = 1 for deforested Post 1989 Forest >= 10 ha	This field only applies to Post -989 Forest polygons for which the IS_DEFORESTED flag is set true. It indicates that a planting year is required. **Following deforestation integration, for all deforested Post-1989 Forest >= 10 ha, set this flag to 1**. Otherwise, leave this field unchanged. Allowed values are given by domain 'BOOLEAN'.
	PLANT_YEAR	Planting Year	Deforested Post-1989 >= 10 ha assigned a planting year	This field only applies to polygons for which the IS_PL_YR_KNOWN flag is set true. It provides the estimated year of planting. Estimate post-1989 planting dates by back-casting from imagery. Attribute this field with reference to MfE-supplied forestry scheme layer(s).
	IS_STK_KNOWN	Stocking Known	Not used	This field is not used. It applies to polygons for which the IS_DEFORESTED flag is set true. It indicates whether the stocking rate is known. Allowed values are given by domain 'BOOLEAN'.
	stocking	Stocking	Not used	This field is not used. It applies to polygons for which the IS_STK_KNOWN flag is set true. It provides the stem rate of stocking.
	is_harvested	Harvested	Not used	This field is not used. The function has been superseded by the Destocking Tracking map. It indicates if a forest polygon has been harvested post-2007. Allowed values are given by domain 'BOOLEAN'.
	IS_HARV_YR_KNOWN	Harvest Year Known	Not used	This field is not used. It applies to polygons for which the IS_HARVESTED flag is set true. It indicates if the year of harvesting is required. Allowed values are given by domain 'BOOLEAN'.
	harv_year	Harvest Year	Not used	This field is not used. It applies to polygons for which the IS_HARV_YR_ KNOWN flag is set true. It provides the post-2007 year of harvesting.
	INDEX_SITE	Site Index	Not used	This field is not used. It provides the planted forest mean top height in terms of the Site Index model. Allowed range controlled by domain 'Site Index'.
	INDEX_300	300 Index	Not used	This field is not used. It provides the planted forest volume productivity in terms of the 300 Index model. Allowed values are given by domain '300 Index'.
New fields	**SUBID_CUR**	Current Sub Class [2012]	Sub-classification of 2012 land use	This field is the land use sub-class of LUC_ID (Current Land Use Classification [2012]). Land uses that are sub-classified are *Natural Forest; Post-1989 Forest*, *Grassland - High producing*, *Grassland - Low producing* and *Wetland - Open water*. In the case of *Natural Forest*, *Wetland - Open water* and *Grassland*, "Unknown" is a valid attribute, if another sub-classification is not relevant. The sub-classification for all other land uses is set to "Unknown". WARNING: subtyping controls do not apply; appropriate attributes are manually selected from the catch-all domain 'LUC sub_class'.
	LUCID_2016	2016_LUC	Land use as at 31 December 2016	This is the best-known land use as at 31 December 2016. Allowed values are given by domain 'LUC'.
	SUBID_2016	2016_LUC_SUB_CLASS	Sub-classification of 2016 land use	This field is the land use sub-class of the 2016 Land Use Classification. Allowed values are controlled by subtyping on the value of LUCID_2016 and are given by the domains: 'Grassland', 'Natural Forests', 'Open Water', 'Planted Forests', 'Post 1989 Forests', 'Other LUC'.
	CEF_CLASS	CEF_CLASS	Not updated	This field is the Carbon Equivalent Forest classification.
	CEF_YEAR	CEF_YEAR	Not updated	This field provides the Carbon Equivalent Forest change year.
	CEF_ID	CEF_ID	Not updated	This field provides the Carbon Equivalent Forest MPI application ID.
	SHAPE_Length	SHAPE_Length	Not updated	Automatically generated; value is in metres.
	SHAPE_Area	SHAPE_Area	Not updated	Automatically generated; value is in square metres.

Appendix 5. MfE Data Acceptance Checklist

Attribute Check List		Expected Polygon Count		
Rule ID	Polygon Query	2016 Layer	✔	Description
1	LUCID_2016 < 71	0	✔	
2	LUCID_2016 > 82	0	✔	
3	LUCID_2016 = 73 AND PREV_LUC_ID IN (71,72)	0	✔	
4	LUCID_2016 IN (71,72) AND (IMPR_LUC_ID = 73 OR LUC_ID = 73)	0	✔	
5	LUCID_2016 IN (71,72) AND PREV_LUC_ID NOT IN (71,72)	0	✔	
6	LUCID_2016 <= 73 AND IS_DEFORESTED = 1 AND DEF_YEAR >= 2013	0	✔	
7	SUBID_2016 NOT IN (0,120,121,122) AND LUCID_2016 = 71	0	✔	
8	SUBID_2016 NOT IN (0,201,202,203) AND LUCID_2016 = 72	0	✔	
9	SUBID_2016 NOT IN (122,201,202,203,204) AND LUCID_2016 = 73	0	✔	
10	SUBID_2016 NOT IN (0) AND LUCID_2016 = 74	0	✔	
11	SUBID_2016 NOT IN (0,501) AND LUCID_2016 = 75	0	✔	
12	SUBID_2016 NOT IN (0,501) AND LUCID_2016 = 76	0	✔	
13	SUBID_2016 NOT IN (0) AND LUCID_2016 = 77	0	✔	
14	SUBID_2016 NOT IN (0) AND LUCID_2016 = 78	0	✔	
15	SUBID_2016 NOT IN (0,901,902) AND LUCID_2016 = 79	0	✔	
16	SUBID_2016 NOT IN (0,1001) AND LUCID_2016 = 80	0	✔	
17	SUBID_2016 NOT IN (0) AND LUCID_2016 = 81	0	✔	
18	SUBID_2016 NOT IN (0) AND LUCID_2016 = 82	0	✔	
19	SUBID_2016 IS NULL	0	✔	
20	LUC_ID < 71	0	✔	
21	LUC_ID > 82	0	✔	
22	LUC_ID = 73 AND PREV_LUC_ID IN (71,72)	0	✔	
23	LUC_ID IN (71,72) AND IMPR_LUC_ID = 73	0	✔	
24	LUC_ID IN (71,72) AND PREV_LUC_ID NOT IN (71,72)	0	✔	
25	LUC_ID <= 73 AND IS_DEFORESTED = 1 AND DEF_YEAR <=2012	0	✔	
26	LUC_ID NOT IN (71,72,73) AND IS_DEFORESTED = 1 AND DEF_YEAR >= 2013	0	✔	
27	SUBID_CUR NOT IN (0,120,121,122) AND LUC_ID = 71	0	✔	
28	SUBID_CUR NOT IN (0,201,202,203) AND LUC_ID = 72	0	✔	

Attribute Check List		Expected Polygon Count		
Rule ID	Polygon Query	2016 Layer	✔	Description
29	SUBID_CUR NOT IN (122,201,202,203,204) AND LUC_ID = 73	0	✔	
30	SUBID_CUR NOT IN (0) AND LUC_ID = 74	0	✔	
31	SUBID_CUR NOT IN (0,501) AND LUC_ID = 75	0	✔	
32	SUBID_CUR NOT IN (0,501) AND LUC_ID = 76	0	✔	
33	SUBID_CUR NOT IN (0) AND LUC_ID = 77	0	✔	
34	SUBID_CUR NOT IN (0) AND LUC_ID = 78	0	✔	
35	SUBID_CUR NOT IN (0,901,902) AND LUC_ID = 79	0	✔	
36	SUBID_CUR NOT IN (0,1001) AND LUC_ID = 80	0	✔	
37	SUBID_CUR NOT IN (0) AND LUC_ID = 81	0	✔	
38	SUBID_CUR NOT IN (0) AND LUC_ID = 82	0	✔	
39	SUBID_CUR IS NULL	0	✔	
40	IMPR_LUC_ID < 71	0	✔	
41	IMPR_LUC_ID > 82	0	✔	
42	IMPR_LUC_ID = 73 AND PREV_LUC_ID IN (71,72)	0	✔	
43	IMPR_LUC_ID IN (71,72) AND PREV_LUC_ID NOT IN (71,72)	0	✔	
44	IMPR_LUC_ID NOT IN (71,72,73) AND IS_DEFORESTED = 1 AND DEF_YEAR >= 2008 AND DEF_YEAR <= 2012	0	✔	
45	IMPR_LUC_ID NOT IN (71,72,73) AND IS_HARVESTED = 1	0	✔	
46	IMPR_LUC_ID <> LUC_ID AND IS_HARVESTED = 1	0	✔	
47	SUB_LUC_ID NOT IN (0,120,121,122) AND IMPR_LUC_ID = 71	0	✔	
48	SUB_LUC_ID NOT IN (0,201,202,203) AND IMPR_LUC_ID = 72	0	✔	
49	SUB_LUC_ID NOT IN (122,201,202,203,204) AND IMPR_LUC_ID = 73	0	✔	
50	SUB_LUC_ID NOT IN (0) AND IMPR_LUC_ID = 74	0	✔	
51	SUB_LUC_ID NOT IN (0,501) AND IMPR_LUC_ID = 75	0	✔	
52	SUB_LUC_ID NOT IN (0,501) AND IMPR_LUC_ID = 76	0	✔	
53	SUB_LUC_ID NOT IN (0) AND IMPR_LUC_ID = 77	0	✔	
54	SUB_LUC_ID NOT IN (0) AND IMPR_LUC_ID = 78	0	✔	
55	SUB_LUC_ID NOT IN (0,901,902) AND IMPR_LUC_ID = 79	0	✔	
56	SUB_LUC_ID NOT IN (0,1001) AND IMPR_LUC_ID = 80	0	✔	
57	SUB_LUC_ID NOT IN (0) AND IMPR_LUC_ID = 81	0	✔	
58	SUB_LUC_ID NOT IN (0) AND IMPR_LUC_ID = 82	0	✔	
59	SUB_LUC_ID IS NULL	0	✔	

Attribute Check List Rule ID	 Polygon Query	Expected Polygon Count 2016 Layer	 ✔	 Description
60	PREV_LUC_ID NOT IN (71,72) AND (IMPR_LUC_ID IN (71,72) OR LUC_ID IN (71,72) OR LUCID_2016 IN (71,72))	0	✔	
61	PREV_LUC_ID = 73	0	✔	
62	LUM_YEAR <> 2016	0	✔	
63	IS_DEFORESTED <> 0 AND IS_HARVESTED = 1	0	✔	
64	IS_DEFORESTED <> 1 AND (((IMPR_LUC_ID < 74) AND (LUC_ID > 73)) OR ((LUC_ID < 74) AND (LUCID_2016 > 73)))	0	✔	
65	IS_DEF_METH_KNOWN IS NOT NULL	0	✔	
66	DEF_METH_ID IS NOT NULL	0	✔	
67	DEF_YEAR < 2008 AND IS_DEF_YR_KNOWN = 1	0	✔	
68	DEF_YEAR IS NULL AND IS_DEFORESTED = 1	??	✔	Probable Deforestation Observed
69	DEF_YEAR > 2016 AND IS_DEF_YR_KNOWN = 1	0	✔	
70	CEF_CLASS NOT IN (1,2) AND CEF_CLASS IS NOT NULL	0	✔	
71	CEF_CLASS IS NULL AND CEF_YEAR IS NOT NULL	0	✔	
72	CEF_YEAR IS NULL AND CEF_CLASS IS NOT NULL	0	✔	
73	CEF_YEAR < 2013 AND CEF_YEAR IS NOT NULL	0	✔	
74	CEF_ID IS NULL AND CEF_CLASS IS NOT NULL	0	✔	
75	PLANT_YEAR < 1960 AND IS_PL_YR_KNOWN = 1	0	✔	
76	STOCKING IS NOT NULL	0	✔	
77	IS_HARVESTED <> 0 AND IS_DEFORESTED = 1	0	✔	
78	HARV_YEAR < 1990 AND IS_HARVESTED = 1	0	✔	
79	HARV_YEAR < 1990 AND IS_HARV_YR_KNOWN = 1	0	✔	
80	INDEX_SITE IS NOT NULL	0	✔	
81	INDEX_300 IS NOT NULL	0	✔	
82	Polygons with AREA_HA <0.05 before mapping	???		
83	Polygons with AREA_HA <0.05 after mapping	???	✔	No extra polygons below 0.05 ha in size should be created by mapping activity.
84	LUC_ID NOT IN (71,72,73) AND IS_DEFORESTED = 1 AND DEF_YEAR >= 2013 AND DEF_YEAR <= 2016	0	✔	

Topology Checklist

2016 Layer	**Expected Result**		**Comment**
Perform Topology Validation on region based on topology rules in LUM regional file geodatabase to ensure the layer contains no gaps or overlaps	Completed with no errors	✔	