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Towards consistent land-use and management mapping: methodology and gap analysis for a pilot land-use map

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Summary

Project and client

- The Ministry for the Environment (MfE) contracted Manaaki Whenua – Landcare Research to develop a pilot national land-use map derived from existing information layers and based on the methodology used to produce a land-use map of the Northland region in 2024.
- This contracted work included making improvements to the Protected Areas Network of New Zealand (PAN-NZ) mapping layer and incorporating these into this pilot land-use map.

Objectives

- To develop a pilot national land-use map derived from existing information layers and based on the methodology used to produce a land-use map of the Northland region.
- To address the issues raised by a previous review of PAN-NZ, as much as practicable, and provide the improved PAN-NZ layer for inclusion in the pilot national land-use map.
- To document the methodology used to prepare the pilot land-use map and supply this to MfE, alongside the pilot map layer.

Methods

- We compiled lists of publicly accessible data to identify the sources of information. Configuration was written to describe these (including IUCN[1] categories for PAN-NZ inputs), as well as any necessary transformations of source data and rules to aggregate the data sets.
- Spatial data were aggregated using a discrete global grid system, which aligns and quantises input data for computationally efficient aggregation.

Results

- Using publicly available data sets we have developed two spatial data sets (note that the second uses the first as an input).

1 **Protected areas (PAN-NZ)**: the completeness of this layer reflects the availability of protected area data that are publicly available via national and regional data providers, and that are currently licensed for reuse. Each protected area as part of the layer will have an IUCN protected-areas category attached where the area's associated legislation has been previously mapped to an IUCN category. The tools to create this layer will be built in a manner that ensures they are reusable to underpin future PAN-NZ releases.

2 **National land-use map v0.3**: this is (nominally) for 2024/25, at 1:50,000 scale or better, depending on the availability of appropriate public data sets that conform to the New Zealand Land Use Map (NZLUM) classification system (secondary level). All land with a territorial authority within New Zealand is within scope (i.e. mainland New Zealand and the Chatham Islands, but not the subantarctic islands).

[1] International Union for Conservation of Nature.

- This report (and an associated oral presentation) documents the production of these data sets and the validation exercise, and includes a gap analysis to highlight potential next steps. The data are delivered in a standard vector geospatial format, adhering to spatial data quality standards, including the presence of metadata in a standard format (ISO 19115-3).
- Feature-level validation of the NZLUM resulted in eight classes with an accuracy over 80% (20 were below this threshold); 24 classes are more than 50% accurate. Although there are no formal acceptance criteria for NZLUM, these validation results do not satisfy the accuracy specification for ALUM (see Australian Bureau of Agricultural and Resource Economics and Sciences 2011).
- The validation results reflect inadequate accuracy, and therefore the need to acquire more information and continue to consider the method and rules of classification before putting these data into widespread use.

Conclusions and recommendations

- The PAN-NZ data set has known data gaps, and attempts are already underway to address these by contacting local and regional government and requesting the publication and appropriate licensing of more reserve data. This effort should be appropriately resourced, given that PAN-NZ data are a necessary but independent layer of information for the wider land-use map.
- The validation results for the wider land-use map should be used to determine which thematic information is presently inadequate. Obtaining better validation results in the future may involve more or better data, or improved logical rules for data aggregation, or both. Additional data aimed at improving the classification of one class will have a concomitant effect on the accuracy of other classes.
    - Of particularly high value is obtaining access to consenting information for various activities, such as dairy effluent consents, and forestry. We have incorporated a small amount of this information at a territorial level; there is significantly more that could be used if it is discoverable, appropriately licensed, and possibly subject to some standardisation.
    - The PAN-NZ catalogue has thoroughly documented many relevant license gaps in existing data; these are 'low-hanging' fruit for inclusion in PAN-NZ, and their inclusion may improve the overall validation of the land-use dataset as many low-confidence (mis-)classifications in a number of classes may simply be protected land.
- We recommend using this pilot data set as a demonstration of the NZLUM classification system itself. It should now be considered for its taxonomic structure and suitability for end-users, with its inherent accuracy a secondary consideration due to the presence of large, known data gaps.
- A governance group should be formed to make decisions about whether and how the classification system itself should be adjusted to better reflect the needs of end-users, and how to enhance the usability of the output data.
- Existing examples of public-facing dashboards of land-use information, as used in Australia, should be considered as examples of good practice for the dissemination of land-use data.

1 Introduction

Nationally consistent records of land use over time have been identified as a data priority for New Zealand in the Government Data Investment Plan.[2] New Zealand lacks a comprehensive national-scale land-use map (a spatial data set) to support effective infrastructure development, planning for natural hazards, environmental management, policy-making, and tracking how land use changes over time. The production of such a data set would inform decisions related to land use by making a wider range of natural and built environment information easily accessible, comparable, and discoverable in one place.

The vision for a fully realised land-use information system (of which such a national map is a component) is to make land-use information available in a standard form and at appropriate spatial and temporal scales. The representation of 'use' within the classification system may be quite broad, ranging from agricultural to urban and residential, but could also reflect other values, such as cultural importance, historical value, or mauri.

During the last financial year researchers developed a draft land-use classification (New Zealand Land Use Management classification system, NZLUM) along with a description of a land-use classification framework that encompasses principles, attributes, and other associated specifications to ensure the longevity of this land-use information system (Law et al. 2024). Definitions for both extractive and non-extractive land uses, as well as te ao Māori perspectives, were included. This work was a necessary precursor to producing a national land-use data set. It is available to read on online at https://github.com/manaakiwhenua/nzsluc. It builds upon prior thought that has gone into land use classification system design for New Zealand over several decades, particularly: Rutledge et al. 2008; Ledgard 2013; Anastasiadis et al. 2014;

The Protected Areas of New Zealand information layer (PAN-NZ) has a complementary vision to enable aggregation of all the various legal protections into a national map. The PAN-NZ project contributed to the background work for NZLUM, and a portion of this project has supported the PAN-NZ initiative to enhance the accessibility of protected area data specifically. This is important, both for national and international reporting on legal protection, and to inform policy that guides development (such as resource management reform) and supports market-based funding of biodiversity (such as biodiversity markets).

2 Methodology

We used the New Zealand Standard Land Use Classification (NZSLUC) framework, which defines principles and best practices for the development and maintenance of land-use classification systems, and NZLUM to develop the draft land uses. The development of both the classification framework and this classification system is described in a prior report (Law et al. 2024).

There is currently no provision for governance to adapt and maintain this draft classification system. However, this pilot map may serve to guide, inform, and inspire a governance group to

[2] https://www.data.govt.nz/assets/Leadership/Government-Data-Investment-Plan-2022.pdf

organise and maintain the land-use classification system, at which point it may be sensible to produce a revised map that implements the agreed classification at the tertiary level.

1	Conservation and minimal use of natural environments
1.1.0	**Nature Conservation**
1.1.1	Strict nature reserve
1.1.2	Wilderness area
1.1.3	National park
1.1.4	Natural feature protection
1.1.5	Habitat or species management area
1.1.6	Protected landscape
1.1.7	Other conserved area
1.2.0	**Cultural and natural heritage**
1.3.0	**Minimal use from relatively natural environments**
1.3.6	Defence land
1.4.0	**Unused land and land in transition**

2	Production agriculture and plantations
2.1.0	**Plantation forests**
2.2.0	**Grazing modified pasture systems**
2.3.0	**Short-rotation and seasonal cropping**
2.4.0	**Perennial horticulture**
2.5.0	**Intensive horticulture**
2.6.0	**Intensive animal production**
2.7.0	**Water and wastewater**
2.8.0	**Land in transition**

3	Built environment
3.1.0	**Residential**
3.2.0	**Public recreation and services**
3.3.0	**Commercial**
3.4.0	**Manufacturing and industrial**
3.5.0	**Utilities**
3.6.0	**Transport and communication**
3.7.0	**Mining**
3.8.0	**Waste treatment and disposal**
3.9.0	**Vacant and transitioning land**

Figure 1. Selected land-use classes (from NZLUM v0.3) included in the pilot land-use map. The aim of the pilot was to achieve classification at the secondary level. Some tertiary classes were also included, namely classes under 1.1.0 (Nature Conservation) and 1.3.6 (Defence land). Classes under 1.1.0 were mapped through inclusion of the PAN-NZ dataset using IUCN categories.

The production of a land-use data set can be organised as a top-down or bottom-up method. A top-down classification is where the land-use classes are defined *a priori*, and then spatial information is combined such that the output fits this classification. A bottom-up classification inverts this process: differentiated classes are identified *a posteriori* from the available information. The use of NZSLUC implies the use of top-down classification, because it posits that it is possible and appropriate to identify suitable and useful land-use classes without regard to whether the available information supports the distinctions between these identified classes. Recognising this, we have implemented the second level of the hierarchical classification as a demonstration of the classification system itself (Figure 1), leaving the third level of the hierarchy to future work. This would necessarily involve the creation, curation or relicensing of data that do not currently exist or are unavailable for reuse.

2.1 Land Use Information System (LUIS)

We have previously described a method of combining diverse spatial data sets using a discrete global grid system (DGGS, Law & Ardo 2023, 2025). For in-depth technical information regarding implementation, please refer to the papers mentioned in these documents. In brief, a wide range

of input spatial data are combined through transformation to one common, spatial grid known as a DGGS. We used the H3 DGGS at resolution 11 (static, addressable hexagons with an average edge length of 28.7 m, and an average area of 2149 m^2 at this resolution). Logical rules were developed (expressed in SQL[3]) that allow any part of this grid to be classified as any of the NZLUM classes.

Alongside this identification of a DGGS grid cell as belonging in a particular class, the process records a qualitative confidence value for that identification, plus the combined recency and geographical scale of the relevant input data sets. All records are then sorted by preferring (in this order): higher confidence, more recent input data, and higher precision information. This ensures that the output retains only the most appropriate class identification. As well as the assignment of a land-use class, the output is made to conform to the data schema defined by NZLUM. For instance, in its recording of commodity and land management practice information using strictly predefined sets of terms. The current version of the schema (NZLUM v0.3) is re-presented in Table 1.

Table 1. NZLUM data schema (v0.3)

Attribute	Type	Example	Notes
`lu_code_primary`	integer	`1`	Numerical land use code (primary use) at the primary level
`lu_code_secondary`	integer	`2`	Numerical land use code (primary use) at the secondary level
`lu_code_tertiary`	integer	`3`	Numerical land use code (primary use) at the tertiary level
`lu_code`	string	`1.2.3`	Complete land use code (primary use)
`lu_description`	string	`Natural Heritage`	Land use class label (primary use)
`lu_code_ancillary`	(sorted set of) string	`2.2.0,3.2.1`	Land use code (ancillary uses), multiple uses are to be specified with comma separation with optional whitespace characters
`commod`	(sorted set of) string	`sheep,cattle beef`	Commodity type; multiple commodities are to be specified with comma separation with optional whitespace characters
`commod_ancillary`	(sorted set of) string	`pulpwood`	Commodity type(s) relating to the ancillary land use code(s)
`manage`	(sorted set of) string	`irrigation spray,organic`	Management practices; multiple practices are to be specified with comma separation with optional whitespace characters
`manage_ancillary`	string	`free standing`	Management practices relating to the ancillary use code(s)
`land_estate`	string	`freehold`	Estate type

[3] SQL – Structured Query Language, a domain-specific language used to manage data.

Attribute	Type	Example	Notes
land_status	(hierarchically-organised) string	`Crown Entities,Statutory Entities,Autonomous Crown entities,Heritage New Zealand Puhere Taonga`	[TBD] Land status type (public–private continuum; terminology to be determined)
water	string	`lake`	[TBD] Water type (null for non-water)
zone	string	`Large format retail zone`	[TBD] District plan zone; terminology to be taken from the Zone Framework Standard (National Planning Standards, 2019)
permeability	string	`sealed`	[TBD] Permeability type (sealed or unsealed)
confidence	integer	`3`	Confidence 1-4, a qualitative assessment relating to the overall operator confidence in the assigned classification
luc_date	date	`2024-05-26`	Date of land use classification, "last modified"
source_data	(sorted set of) string	`DVR,NRC,LCDB v5,field mapping`	Primary source data (e.g. field mapping, local knowledge, ancillary dataset, air photo, imagery). Often, multiple sources of information are combined to come to a conclusion; to a reasonable extent, all should be specified.
source_data_doi	(set of) uri	`doi:10.26060/W5B4-WK93`	Optional (i.e. when available) DOI or HTTP URI for source data
source_date	string (date range)	`[2011-05-02,2025-01-03)`	Combined date range of spatial features (e.g. image date, ancillary photo date, last edited date) in primary source data, at feature (preferentially) or dataset level, using interval notation for inclusive and exclusive endpoints
source_scale	string (integer interval)	`[10,60]`	Combined integer (interval)[https://en.wikipedia.org/wiki/Interval_(mathematics)] indicating the precision of source data, in the CRS units (metres)

The logical rules for combining data are sometimes simple rules of priority, but in many cases, they are convoluted and hard to express. Identification of class membership is through topological relationships (expressed in set theory using DGGS cells), primarily intersection and disjunction. Overlapping data provide either necessary or superfluous evidence for the identification of land as being of a particular class. The recorded confidence value (expressed on a 1–12 range, where 1 is most confident) is a qualitative, ordinal value rather than a quantitative probability.

To take an abbreviated example, dairy (pastoral farming) land use is recorded in the District Valuation Roll at the property scale. Where there is also a dairy effluent discharge consent which notes an animal count of some number of animals, this provides extremely good complementary

evidence; thus we may assign the highest confidence (1) for such a place to be assigned class 2.2.0 ('Grazing modified pasture systems'), and note the commodity information (cattle dairy). However, where other evidence shows there is not a "compatible" land cover, or if some other incompatibility is identified, then we may modify the confidence value with an appropriate "penalty" (e.g. +2 or more), or assign a lower baseline confidence value (8), or simply reject the assignment as class 2.2.0 entirely. (Remember that a higher confidence value is worse.) We may also be able to use supplementary evidence to append to the commodity list, in addition to providing additional confidence, e.g. noting a winter grazing crop. If the class assignment is rejected entirely, then an alternative class may be assigned based on other evidence, as defined by the implementation of that alternative class.

Classification rules are applied deterministically. This allows for the transparent, stable reproduction of the output data, but it does not necessarily offer protection from errors or imprecision carried by input data into the output data. The classification rules are written as text (SQL) files, with comments in relevant parts of the queries for clarification of intention. These SQL files are, however, somewhat complex: they include the use of advanced features of SQL, specifically those available within the PostgreSQL relational database system. This includes features such as temporary views, table partitioning, regular expressions, user-defined functions, custom types, range types, text search types, and the combination of multiple SQL files through use of the psql commands.

There are a very large number of possible ways the same logic could be expressed in SQL. For example, abstractions can be applied to make the code shorter, modular, and therefore more maintainable, but these techniques can often come at some cost to clarity. It is the very complexity of these rules that precludes their robust, directly-human-readable description in this report, as their exact application can depend on subtle factors such as the order of SQL joins. However, it is acknowledged that some form of human-readable overview is necessary, so an attempt at doing so is included as Appendix G, but it should not be considered definitive for any class.

The full set of input data is presented as Appendix A. The (SQL) rules used to combine them are available at https://github.com/manaakiwhenua/luis-config-nzlum. These take the form of configuration files for MWLR's (proprietary) LUIS. This has two major parts.

1 *Enumeration and configuration of inputs from various sources, mostly geospatial APIs[4] (YAML format)*

- Licences are noted throughout. Data must be appropriately licensed for inclusion. The major caveat is that the present land-use data set derives data from the District Valuation Roll, a pilot data set maintained by Land Information New Zealand (LINZ), and which is used under permission from MfE; the pilot data set is not openly licensed.
- Configuration includes the definition of various derived variables and database indices, which are intended to make classification rules somewhat simpler to write and maintain, but also more efficient to process computationally.

2 *Classification rules (YAML format)*

[4] API – Application Programming Interface.

- Data views: this is how disparate sources of data that describe the same thing are combined and abstracted. Examples include simple unions of mainland and Chatham Island land-cover information, or more complicated unions of regional consenting information, which are made to artificially share a common data schema by harmonising attributes and data types.
- Classes: this is where the actual expression of combinatorial logic is recorded for the implementation of each class with reference to specific input data sets. These vary in complexity, from very simple inheritances of information from PAN-NZ for most of the classes for legally protected land, to more complicated rules for identifying horticultural or vacant land, while also correctly recording commodities where these are present.

Although the LUIS itself cannot be shared as open-source software, it is described in, and the complete classification configuration is available on, GitHub, which itself vastly exceeds the size of LUIS in terms of lines of code. It is available at https://github.com/manaakiwhenua/luis-config-nzlum. This repository includes in its 'README' an example of data configuration and a sample class definition for class 1.3.6 ('Defence land'), with additional explanation that will help a technical reader reasonably proficient in SQL to interpret the other class definitions.

The land-use class and output data schemata are available online at https://github.com/manaakiwhenua/nzsluc/tree/main/classification-systems/nzlum. This is the definitive version. It also directs interested readers to give collaborative, public feedback into the structure and definition of the classification system.

As part of this programme of work to produce a pilot national land-use map, we identified a need for dedicated attention to PAN-NZ (further detail in the next section). A pilot of a PAN-NZ data set was produced in parallel to the wider land-use classification. The present NZLUM pilot inherits information from the present version of PAN-NZ, such that the definitions of classes under class 1.1.0 Nature Conservation in this pilot land-use map appear to be very simple. In reality, the complexity is 'pushed down' to the independent definition of PAN-NZ classes and to its entirely separate data integration process. This is a separation of concerns, as PAN-NZ comprises stand-alone information and is not sufficient on its own to fulfil the protected area classes, such as whether there is competing, supplementary or contradictory evidence from another source, or what to do with overlapping legal protections.

2.2 PAN-NZ

The Protected Areas Network of New Zealand (PAN-NZ) is a mapping layer, developed by MWLR, that aggregates and combines all (published) legally protected areas in New Zealand. It is used for various purposes, including identifying threatened environments and assessing the extent of legal protection.

Note that the primary difference between the NZLUM classification system v0.1 (initial draft) and v0.3 (revised draft, adopted in this report) is in the definition of protected areas under class 1.1.0 Nature Conservation (including subclasses thereof), which were modified from definitions regarding degrees of biodiversity protection to instead correspond directly to IUCN classes. This allows NZLUM to adopt the same classification system as PAN-NZ for protected areas.

In 2023 MfE commissioned a review of PAN-NZ because it was outdated and incomplete, making it unsuitable for policy and regulatory purposes. The review, which focused on the current state of the map and future directions, revealed data gaps and inconsistencies.

As part of the pilot national land-use mapping contract, MWLR has carried out some improvements to PAN-NZ to address these identified issues. The completeness of the protected areas layer reflects the availability of protected area data that are publicly accessible, appropriately licensed for reuse, and discoverable.[5] Each protected area in the final layer includes an IUCN-protected area category, where the associated legislation has previously been mapped to an IUCN category, with most unmapped data contributing to class 1.1.7 (other conserved area). The tools and processes developed to create this layer have been designed for reusability, ensuring they can support future PAN-NZ releases.

A Python-based tool was developed to aggregate national and regional protected area data sets. The tool ingests data into a DuckDB database, whereby SQL queries are executed to identify gaps, resolve inconsistencies, and determine which data should be included in the final PAN-NZ product. Appendix C includes a diagram summarising the tool's functionality.

The tool was designed for flexibility and future scalability. Like LUIS, it is configured using YAML files, which allow new data and rule updates (such as IUCN mapping rule changes) to be incorporated without modifying the source code. While the tool has been developed with reusability in mind, the primary focus has been on producing a national data set. In its current state the tool serves as a proof of concept and proves the success of the logic in aggregating the data sets. For the tool to be considered production-ready and operationalised, a product road map should be developed and the required investment sought.

For a data set to be included in the aggregation process it needs to be:

- publicly accessible on the internet and available for self-download;
- licensed for reuse, with clear licensing information provided at the point of access.

Ideally, a data set would also contain information describing the nature of the protection, such as the legislative act and section under which an area is legally protected. This information facilitates mapping to the IUCN-protected area categories. Where such details are not provided, efforts are made to populate them using the LINZ NZ Parcels data set (Land Information New Zealand 2025b) (see section 2.2.2).

The protected areas data sets that were included in the final product are listed in Appendix D. Further detail on PAN-NZ data sources and standards can be found at https://github.com/manaakiwhenua/PAN-NZ-data-catalogue-and-guidelines, funded by a separate but related procurement.

[5] Note that data under the licence CC BY 4.0 No Derivatives, while open, is unusable, because both PAN-NZ and NZLUM pilot data set are derivative data sets.

2.2.1 Aggregation data

National data

The primary data sets included for compilation in PAN-NZ were national-level data sets sourced from central government agencies. A catalogue of these sources is available online.[6] Central government data sets are characterised by their widespread availability under open licences, their ease of access, and their national coverage of central government-managed land. Some of these data sets contained overlapping records with identical spatial and descriptive attributes. To manage duplication, the data set configuration (as part of the aggregation tool) incorporates a priority property, allowing the aggregation tool to automatically select the record with the highest priority while excluding duplicate entries.

The overall priority of data sets was determined based on their completeness and utility, ensuring the most comprehensive and authoritative data sets were included in the final aggregation. While a level of generalisation was applied in detecting duplicate spatial extents, it was found that some areas had small differences greater than the threshold of generalisation and were not detected as duplicates. In some of these cases it is expected that these data sets were intended to describe the same protection. Future versions of this tool should run quality control procedures to flag such features with potential duplication for manual review.

Local and regional data

Local government data sets are those concerned with describing protected areas managed by local government entities. Local government data sets were included in two primary categories:

- parks and reserves
- significant natural areas (SNAs).

A catalogue of these sources is available online.[7] The quality and completeness of parks and reserves data varied significantly across different councils. Some data sets closely conformed to PAN-NZ requirements, containing essential attributes such as park names, the relevant legislative act, and section details. However, the majority still lacked legislative details, or even park names, providing only spatial extents.

This raises the question of the intent of some of these data sets. In the case of Auckland this is stated explicitly in their metadata:

> ... this dataset DOES NOT represent the legal status of the land, i.e. whether the land is gazetted under the Reserve Act, subject under the Local Government Act or other statutory provisions. The polygons represent the maintenance extent on the land.
>
> Purpose: This data is primarily used by council and its contractors in identifying the location of the asset.

[6] manaakiwhenua.github.io/PAN-NZ-data-catalogue-and-guidelines/national_datasets_catalogue/index.html

[7] manaakiwhenua.github.io/PAN-NZ-data-catalogue-and-guidelines/regional_datasets_catalogue/index.html

This suggests that these Auckland data sets may not be suitable for inclusion in PAN-NZ, but it is the only public data set that includes the extents of Auckland's regional parks (parks under the Local Government Act 2002, §139). The data set includes a field (*AssetGroup*) that allows for filtering on the text 'Regional', which allows for the aggregation tool to extract these parks (Listing 1 shows how this data set is configured for filtering with the aggregation tool). Such methods of filtering had to be applied to many local data sets, often to exclude data due to a lack of clarity about how certain types mapped to legal protection frameworks. With more time and resourcing it would be possible to carry out a deeper analysis of these data sets to develop more refined filtering logic and capture a broader set of relevant protected areas. However, given current constraints, the gap-filling approach described in the following section was adopted as a more expedient solution.

Listing 1. Demonstration of PAN-NZ data source configuration, including filtering.

```
auckland_regional_parks:
    license: "CC-BY-4.0"
    download_path: "https://data-aucklandcouncil.opendata.arcgis.com/datasets/p
ark-extents/explore"
    geofile_path: "protected_areas/data/regional/Auckland/park-extents.gpkg"
    dggs_path: "protected_areas/DGGS/h3/11/Auckland/park-extents"
    priority: 3
    schema_mapping:
           h3_id: "h3_11"
           source_id: "OBJECTID"
           source_protection_type: "AssetGroup"
           source_protection_name: "SITEDESCRI"
           source_legislation_act: NULL
           source_legislation_section: NULL
           source_reserve_purpose: NULL
           source_start_date: NULL
           source_end_date: NULL
           last_updated: NULL
           source_status: NULL
    filter_field: "source_protection_type"
    filter_explicit_list:
           - "Regional"
    default_values:
           source_legislation_act: "LOCAL_GOVERNMENT_ACT_2002"
           source_legislation_section: "S139_REGIONAL_PARK"
```

2.2.2 Data gap filling

Since many local government authorities do not provide data on local-government-managed protections, the LINZ NZ Primary Parcels (Land Information New Zealand 2025b) layer was parsed to extract legal information associated with property parcels. This layer includes all of New Zealand's land parcels with statutory actions attached. A statutory action is an action that is authorised by a specific part or section of an act.

The statutory actions captured in the LINZ parcels layer data set are varied and not all relate to legal protections (see example 3 in Appendix E). Of those that do relate to legal protections, there

are inconsistencies in how they are captured (e.g. scenic reserve descriptions, examples 4 to 6 in Appendix E. To extract the relevant protected area legislation from these statutory actions, regular expressions were developed to handle the inconsistencies while mapping the many actions to legislative acts and sections (Listing 2). A configuration file was produced whereby the regular expressions were stored alongside their mapping to legislative acts and sections. This file allows for new rules to be easily added, and is also self-documenting, providing an explanation of how the statutory actions are mapped to legislation.

Listing 2. Demonstration of PAN-NZ data source configuration showing the use of regular expressions (regex) to determine reserve types.

```
Local Purpose Reserve (Water supply and protection of indigenous flora and faun
a):
    act: RESERVES_ACT
    section: S23_LOCAL_PURPOSE_RESERVE
    reserve_purpose: Water supply and protection of indigenous flora and fauna
    regex: |-
        '(?i).*Local Purpose Reserve \(Water supply and protection of indigenou
s flora and fauna\).*'

Wildlife Management Area:
     act: CONSERVATION_ACT
     section: S23B_WILDLIFE_MANAGEMENT_AREA
     regex: '(?i).*Wildlife Management Area.*'
```

The extraction of protections from LINZ's NZ Primary Parcels data results in PAN-NZ including many locally managed protected areas that would otherwise be missed if we were to rely solely on local government data. This process is, however, considered 'gap filling' and local government data are prioritised, for the following reasons.

- The statutory actions do not capture all legal actions. For example, no references to regional parks under the Local Government Act 2002 are present in the data set.
- Many councils do not lodge all their reserves directly under legislation captured in the LINZ NZ Primary Parcels data set and instead use other instruments, including lodging them in their district plans, which means they are not captured as statutory actions. (For an example, see Figure 2.)
- An in-depth understanding of the inconsistencies of the information recorded by the statutory actions is required so as not to miss any of the parcels that map to protected area legislation. For example, a local purpose reserve with the purpose 'Esplanade' was found to be recorded as 'Local Purpose Reserve (Esplanade)', 'Local Purpose (Esplanade) Reserve' or 'L.P (Esplanade)'. If one of these was not explicitly mapped, it would not be included.
- Not all parcels with a statutory action are relevant (e.g. '[Create] Fee Simple Title New Zealand Gazette 2018 In 3495 Balance Land'). Understanding and capturing exactly those that should (and shouldn't) be included is onerous and prone to error.

Not all actions reference legislation, and for these cases it is not always clear what legislation a statutory action should be mapped to. For example, considering the following '[Create] Water Supply Catchment & Conservation New Zealand Gazette 1967 p 2206', the gazette notice was

found, and 'Water Supply Catchment & Conservation' was mapped to the Public Works Act 1981, §20. There was not the time to review all gazette notices with the same text, so based on this mapping it is now implicitly assumed that *all* statutory actions with text 'Water Supply Catchment & Conservation' relate to the Public Works Act 1981, §20.

- The NZ Primary Parcels data set may not include all statutory actions. This is based on the metadata of the related NZ Statutory Actions List data set stating, 'Historic actions are only available in this data set since the beginning of Landonline operations (about 2000)' (Land Information New Zealand 2025a). However, we note that there *are* many actions in the LINZ NZ Primary Parcels data set from before this date; LINZ should be questioned about this discrepancy.
- The statutory action field can have multiple entries with each entry starting on a new line. The layer's data dictionary (Land Information New Zealand 2025a) shows the lines starting with either '[Extinguished]', '[Create]' or '[Referenced]'. For this work, the tool just reviews the *last* entry, which appears to be sufficient in most cases, but it may be useful to explore more sophisticated parsing of this information in the future that considers *all* lines and not just the last.

For the above reasons, local government data sets are prioritised and valued over the statutory actions gap-filling method. This is because they also often provide a protection name, and ideally their protection information is explicit, removing the ambiguity sometimes related to parsing the LINZ NZ Primary Parcels layer. However, many local government data sets lack explicit legislative details, and until these are stated, NZ Primary Parcels statutory actions parsing will remain an important part of PAN-NZ layer production.

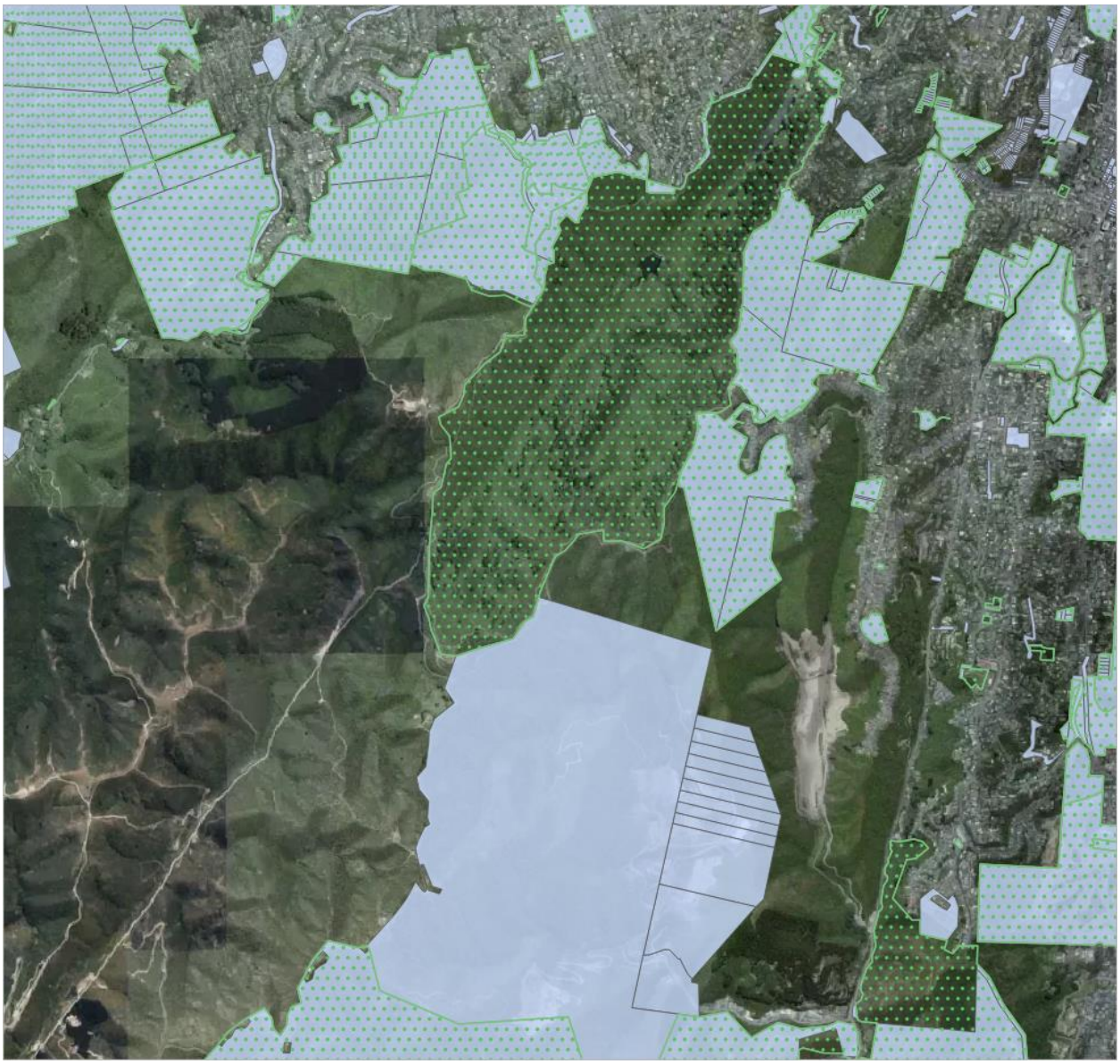

Figure 2. Many councils do not lodge all their reserves in the LINZ NZ Primary Parcels data set and instead may lodge them in their district plans and so they are not captured as statutory actions. In this example of parts of Wellington, light blue shows the LINZ NZ Primary Parcels that have statutory actions, green boundaries with a transparent green pattern represent the extents of the parks in the Wellington parks and reserves data set. The large reserve in the centre is Zealandia Te Māra a Tāne; note that it has no statutory action.

2.2.3 IUCN mapping

Once legislation information—both the legislative act and the relevant section—has been attributed to each feature, it is used to assign an IUCN category. These assignments are based on the mappings provided by the Department of Conservation as part of their work with the World Database on Protected Areas and are detailed in Appendix F. Where it is unclear whether legislation has been evaluated for IUCN categorisation, the feature is assigned the label 'Not Mapped'. If the legislation has been assessed and determined not to meet the criteria for any IUCN category, it is assigned 'Not IUCN'. It is important to note that MfE is currently commissioning

additional work to evaluate more legislative frameworks in relation to IUCN categories. The outcomes of this work are expected to inform future PAN-NZ releases.

Undertaking the PAN-NZ implementation, particularly extracting features from LINZ NZ Primary Parcels, has shown what legislation has been used to protect land. This includes legislation not previously documented in prior work, as well as legislation that has been repealed. For those areas associated with repealed legislation there is no indication in the LINZ NZ Primary Parcels layer as to what legislation replaces the repealed acts (if any). It is expected in many cases that by reviewing the repealed legislation and investigating modern legislation it may be possible to understand what the repealed act and sections have been replaced with, although this project did not allow the time for this. A subset of these legislative acts, and a view of the configuration created to map legislation to IUCN categories, can be seen in Listing 3 below.

Listing 3. Sample of PAN-NZ configuration for mapping legislation to IUCN categories.

```
- designation: "Wildlife Refuge"
  iucn_category: "IV"
  legislation_act: WILDLIFE_ACT_1953"
  legislation_section: S14_WILDLIFE_REFUGE"
- designation: "Wellington Town Belt"
  iucn_category: "Not Mapped"
  legislation_act: WELLINGTON_TOWN_BELT_ACT_2016"
  legislation_section: NA
- designation: "Burial Ground Massey"
  iucn_category: "Not Mapped"
  legislation_act: BURIAL_GROUND_MASSEY_BURIAL_GROUND_ACT_1925
  legislation_section: NA
- designation: "State Forest"
  iucn_category: "Not Mapped"
  legislation_act: FOREST_ACT_1949(REPEALED)
  legislation_section: S18_STATE_FOREST
- designation: "Wairarapa Moana Reserve"
  iucn_category: "Not Mapped"
  legislation_act: TE_ROHE_O_RONGOKAKO_JOINT_REDDRESS_ACT_2022
  legislation_section: S27_WAIRARAPA_MOANA_RESERVE
```

2.2.4 Results for PAN-NZ

This work has not allowed for substantial quality control. However, consistency checks have been made by comparing the results to the source data sets to ensure the rules are being applied correctly. Future efforts should build automated quality checks into the database to allow records that may negatively affect quality to be flagged for manual review.

IUCN rankings also underwent checks to ensure they were being mapped as expected. This was primarily by visualising each class (Figure 3) and then inspecting specific records. This showed that records are being mapped as expected.

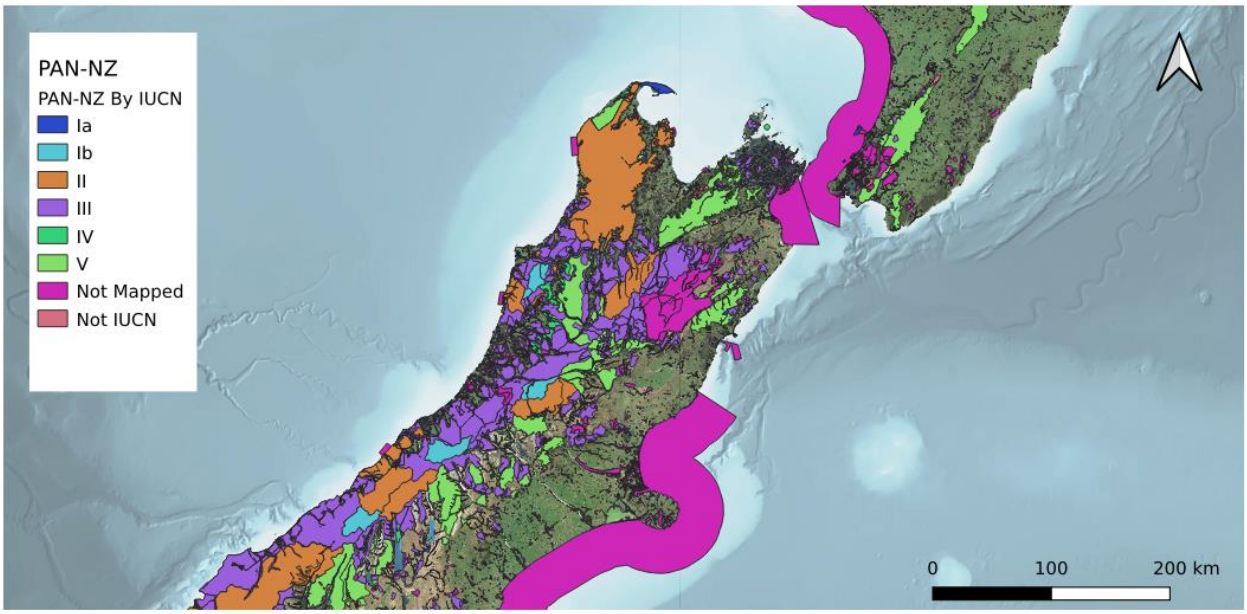

Figure 3. A subset of the PAN-NZ layer produced for this work, as styled by mapped IUCN category.

2.2.5 Summary of PAN-NZ mapping

This project has delivered a proof-of-concept national protected areas data set (PAN-NZ) by developing and applying a systematic approach for aggregating disparate spatial data sets under a unified classification framework. Despite limitations in the available data, the work has demonstrated the feasibility of assembling a consistent, reusable, and scalable data set to support national land-use mapping.

The approach combines national and local government data sets with statutory actions from the LINZ NZ Primary Parcels layer, addressing critical data gaps and revealing inconsistencies in legislative coverage and documentation. A Python-based aggregation tool was developed to streamline this process, with built-in flexibility to accommodate future updates and refinements. While not yet production-ready, the tool proves that automated, logic-driven aggregation is both viable and valuable.

Importantly, this work reveals key insights into the challenges of protected area data integration in New Zealand, such as inconsistencies in local data sets, ambiguous legislative references, and limitations in statutory action metadata. These insights, captured throughout this report, lay the groundwork for future investment and development.

The PAN-NZ layer produced here should be treated as a pilot. It is not the final word on national protection mapping, but a critical step towards a more robust, transparent, and comprehensive data set. Temporally, it supersedes existing PAN-NZ datasets, but as it has known data gaps we recommend it is used with discretion. As additional resources become available this foundation can be strengthened through enhanced quality assurance, deeper engagement with data custodians, expanded legislative mapping, and ongoing refinement of classification rules.

3 Results of the land use mapping

3.1 Land use data set (NZLUM schema)

Our primary output is a spatial data set adhering to a predefined classification schema (NZLUM v0.3). Because it is based on a DGGS it can be produced at any appropriate refinement level. Here we have opted for H3 resolution 11 as an appropriate scale for a national data set, which allows for a reasonable trade-off between processing time and fidelity to the actual geographical scale of many inputs, which are produced at a nominal 1:50,000 geographical scale (e.g. Land Cover Database and LINZ Topo50 1:50,000 scale map series data).

The NZLUM defines 95 classes at the tertiary level of the classification, 21 at the secondary level, and 3 at the primary level. The pilot aimed to implement all 21 secondary classes but ultimately extended to map class 1.1.0 ('Conservation and minimal use of natural environments – Nature conservation') at the tertiary level due to the inclusion of PAN-NZ. This is because the intention of the class 1.1.0 tertiary classes is largely to correspond to PAN-NZ's record of IUCN categories, which we had available as output of the PAN-NZ workstream. In addition, class 1.3.6 ('Defence land') was mapped specifically, in addition to a broader class 1.3.0, because defence land is largely readily identifiable. Thus, the pilot data set includes data fulfilling 28 classes: 20 secondary classes (all but 1.1.0), as well as the seven protected tertiary classes 1.1.1–1.1.7, and class 1.3.6, as shown in Table 2

Table 2. Subset of NZLUM v0.3 classes that have been realised in the land-use map.

Level 1	Level 1 Name	Level 2	Level 2 name	Level 3	Level 3 name
1	Conservation and natural environments	1.1.0	Biodiversity protection	1.1.1	Strict Nature Reserve
				1.1.2	Wilderness Area
				1.1.3	National Park
				1.1.4	Natural Feature Protection
				1.1.5	Habitat or Species Management Area
				1.1.6	Protected Landscape
				1.1.7	Other Conserved Area
		1.2.0	Cultural and natural heritage		
		1.3.0	Minimal use from relatively natural environments		
				1.3.6	Defence Land
		1.4.0	Unused land		
2	Production agriculture and plantations	2.1.0	Plantation forests		
		2.2.0	Grazing modified pasture systems		
		2.3.0	Short-rotation and seasonal cropping		
		2.4.0	Perennial horticulture		
		2.5.0	Intensive horticulture		

Level 1	Level 1 Name	Level 2	Level 2 name	Level 3	Level 3 name
		2.6.0	Intensive animal production		
		2.7.0	Water and wastewater		
		2.8.0	Land in transition		
3	Built environment	3.1.0	Residential		
		3.2.0	Public recreation and services		
		3.3.0	Commercial		
		3.4.0	Manufacturing and industrial		
		3.5.0	Utilities		
		3.6.0	Transport and communication		
		3.7.0	Mining		
		3.8.0	Waste treatment and disposal		
		3.9.0	Vacant and transitioning land		

With respect to the data structure of NZLUM, see https://github.com/manaakiwhenua/nzsluc/tree/main/classification-systems/nzlum#data-structure with the data schema also presented in Table 1.

All attributes meet the v0.3 specification, excluding:

permeability, which is excluded because there was no identified source for this information, and producing it was out of scope.

commod_ancillary and ***manage_ancillary***, which were excluded because at this stage ancillary uses are treated superficially, if at all, partly due to lack of information that could indicate ancillary uses, and partly because a robust method for processing evidence for the presence of legitimately mixed land uses has not been developed (as opposed to handling competing evidence for alternative uses); *lu_code_ancillary* has been used in limited cases, where possible.

source_data_doi, which is excluded because almost no published data set incudes a DOI, and stable UUIDs[8] at the feature level are non-existent in all sources.

water, ***zone*** and **land_*status*** do not have stable definitions in v0.3; these have been given values but there is no fixed list of terms.

- ***confidence***, which is on a 1-12 scale instead of a 1-4 scale, for additional detail. This can be collapsed to a 1-4 range by dividing by 3 with a ceiling function: $y = \left\lceil \frac{x}{3} \right\rceil$

The output of the process is shown in Figure 4. It is a spatial data set with H3 DGGS cell boundaries visible, albeit adjacent cells with identical attributes are combined by taking the spatial union to present groups of cells as coherent spatial features. DGGS cell IDs are not recorded in the output.

[8] UUID – Universal Unique Identifier

All data that are configured for use in the classification process are downloaded (entirely: unclipped and unfiltered) and archived (though unpublished) alongside the output data for future reclassification, if necessary. Intermediate data are not useful and so are not included in the archive.

The 'region of interest' is defined by the layer 'Urban Rural 2025' (version UR2025_V1_00),[9] which is one of the current geographical boundaries maintained by StatsNZ. This was chosen because it was considered possible that land-use maps using different DGGS resolutions may subsequently be provided for urban and rural areas, and this region of interest would permit such a division. Although the urban-rural division was not performed, the entirety of the Urban Rural 2025 layer provides a robust definition of New Zealand including many outlying islands, and the 12-mile territorial marine area itself.

[9] Unclipped, to include marine areas out to the 12-mile territorial sea outer limit, large parts of which are variously protected or used for aquaculture.

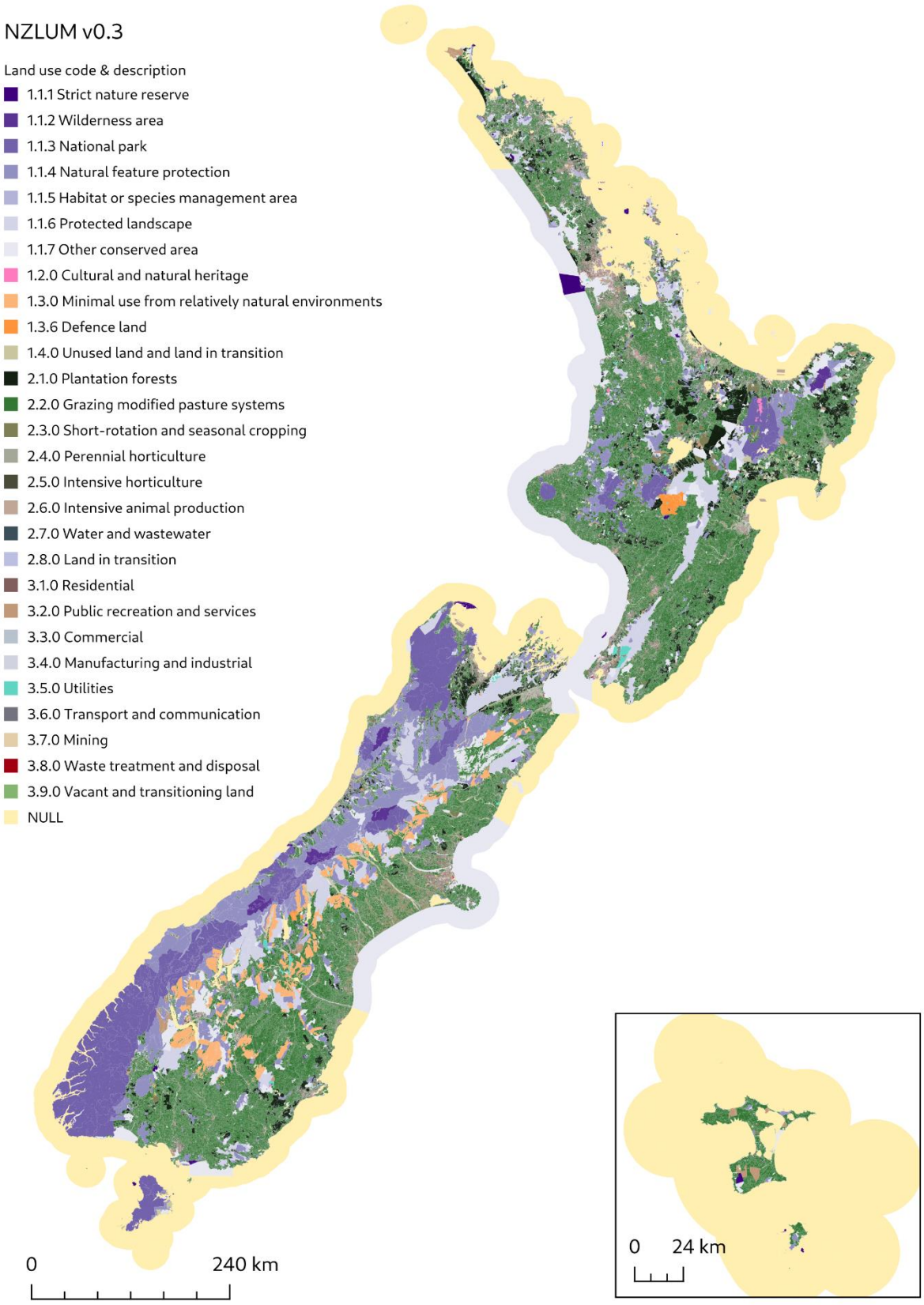

Figure 4. Map of assigned land-use classes in the NZLUM classification system v0.3.

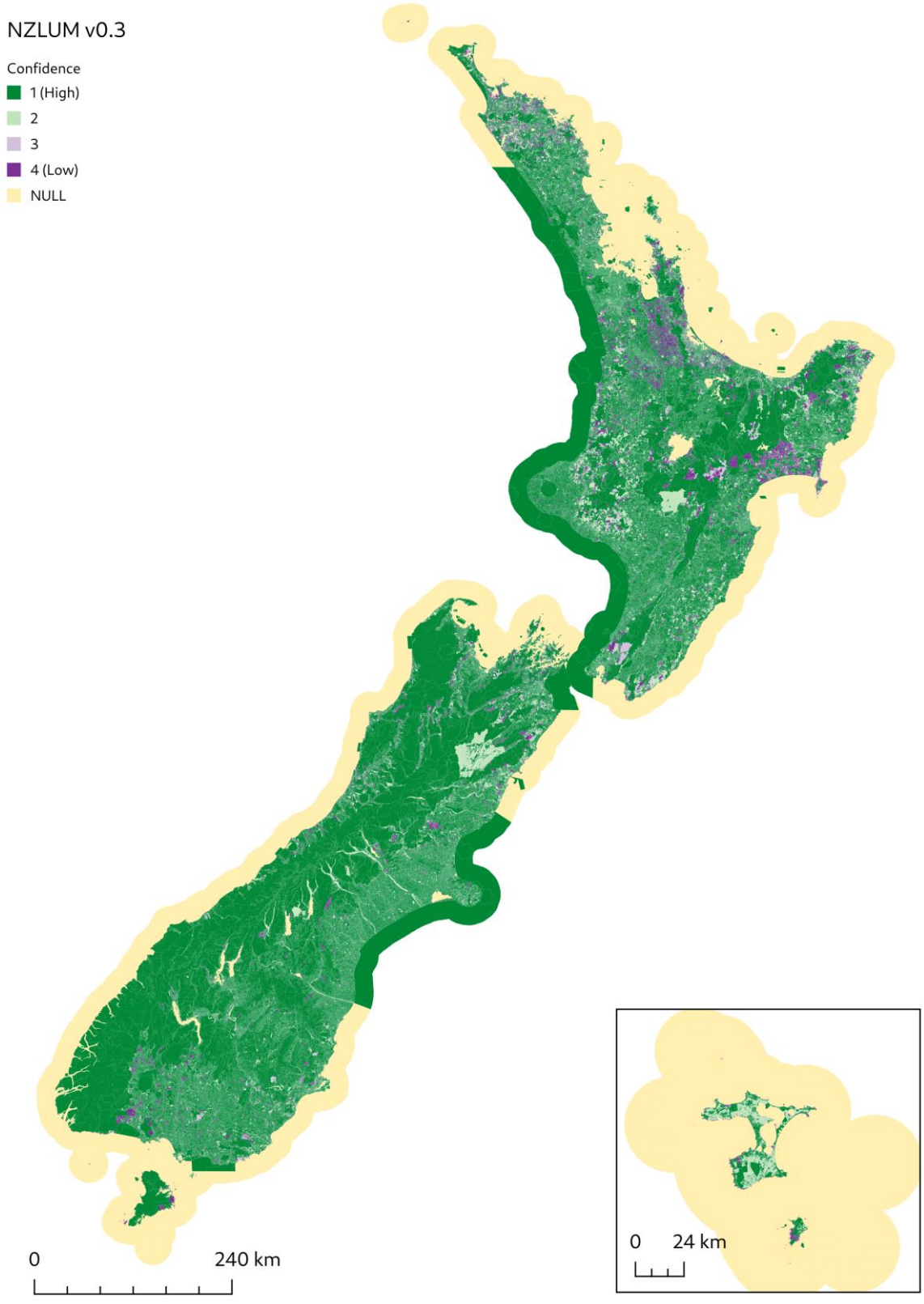

Figure 5. Map of the assigned confidence value corresponding to the classes in Figure 4. Areas with no assigned land-use class have a null confidence.

Note that values in a range 1–12 are mapped to a 1–4 range using the formula [x/3].

Figure 6, Figure 7, and Figure 8 demonstrate different ways the data can be visualised with respect to the class-wise confidence of the classified data. Note the following points.

- By total area, as is apparent spatially in Figure 5 and graphically in Figure 8, there is overall high confidence assignment.
- By class, classes 2.5.0 ('Intensive horticulture'), 3.5.0 ('Utilities'), 3.6.0 ('Transport and communication'), and 3.9.0 ('Vacant and transitioning land') are classified with relatively lower confidence. This indicates where additional data are required to further improve the land-use classification implementation. Or, if validation of these classes shows they are in fact accurate despite relatively low confidence scores, then the classification rules could be revised to assign higher confidence to the existing classification without other changes.
- Class 1.4.0 ('Unused land and land in transition') is an outlier and is naturally difficult to classify, but also to validate accurately by examining aerial imagery. Its definition can include vacant property that may not be possible to validate as such without ground-truth information.

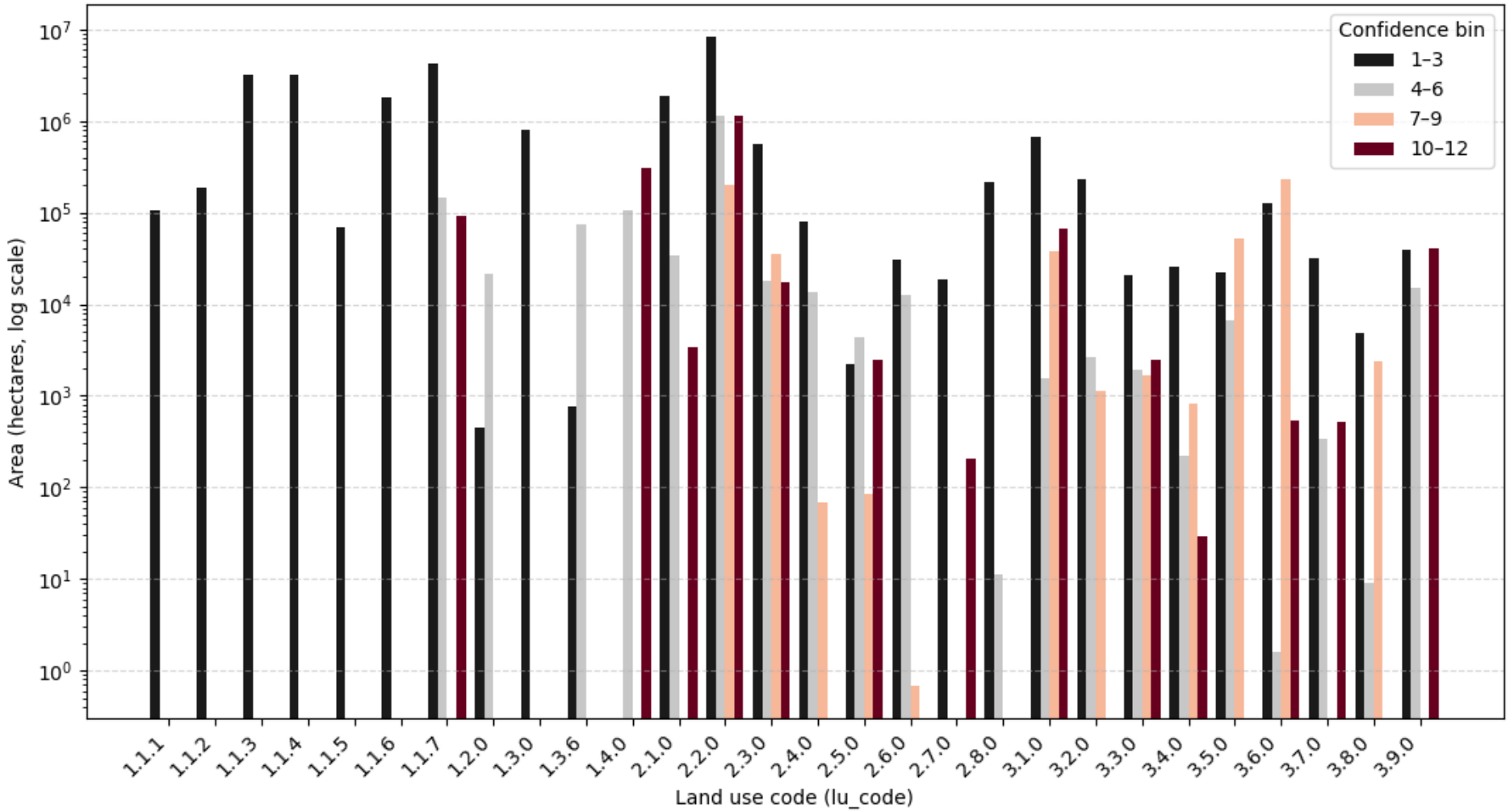

Figure 6. Graph of land-use code according to confidence, using logarithmic scale.

Notes: The height of each bar represents how much area (in hectares, on a logarithmic scale) there is assigned to each class within each confidence bin. More land assigned to lower confidence values (1 is most confident) is better. Not all possible class-confidence value combinations are present in the data.

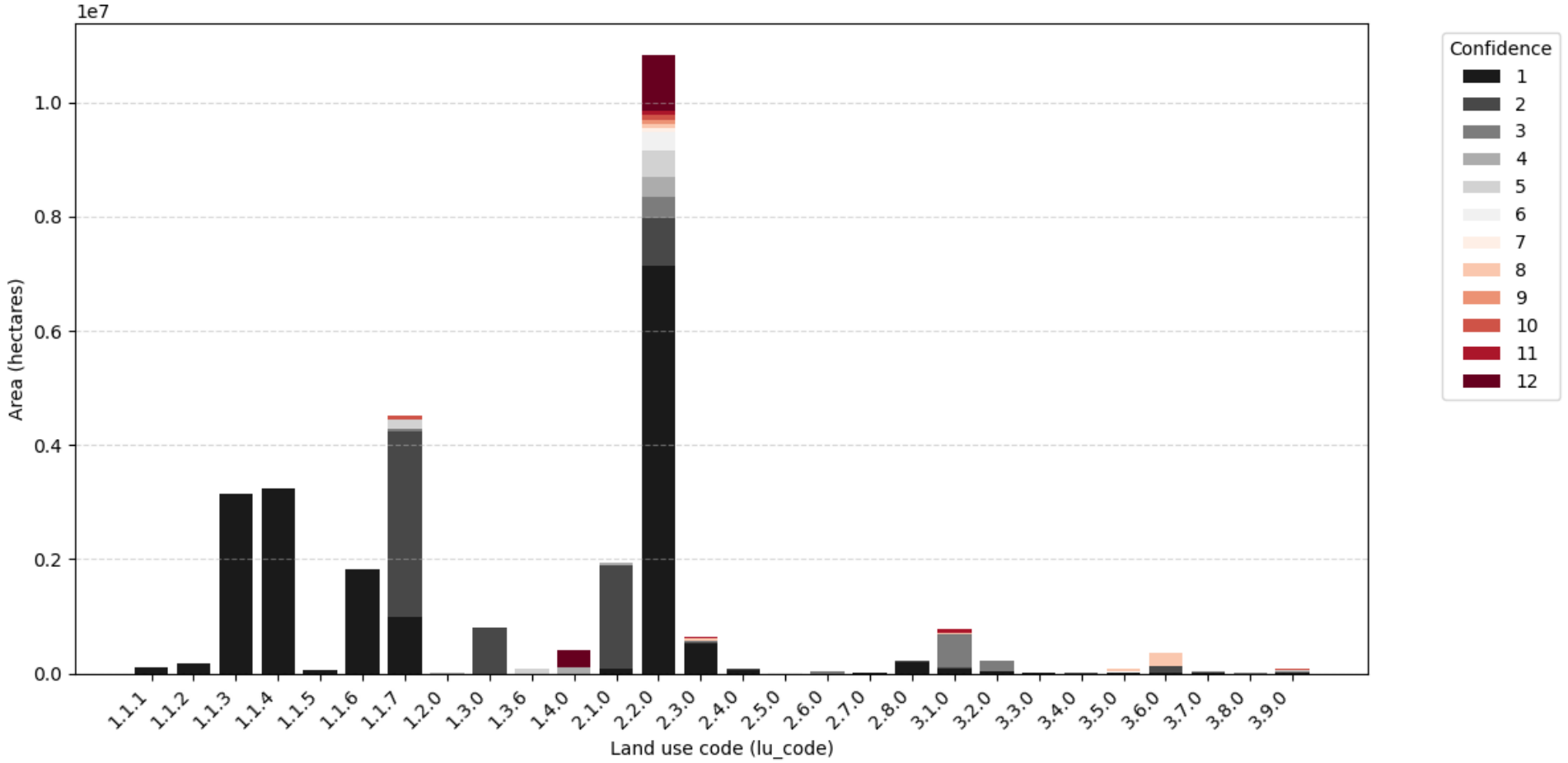

Figure 7. Graph of land-use code according to confidence, but on a linear scale.

Notes: Each column is now stacked (which was not sensible on a logarithmic scale). The total area of class 2.2.0 ('Grazing modified pasture systems') is about 15,000,000 ha, or about 57% of the total area of New Zealand.

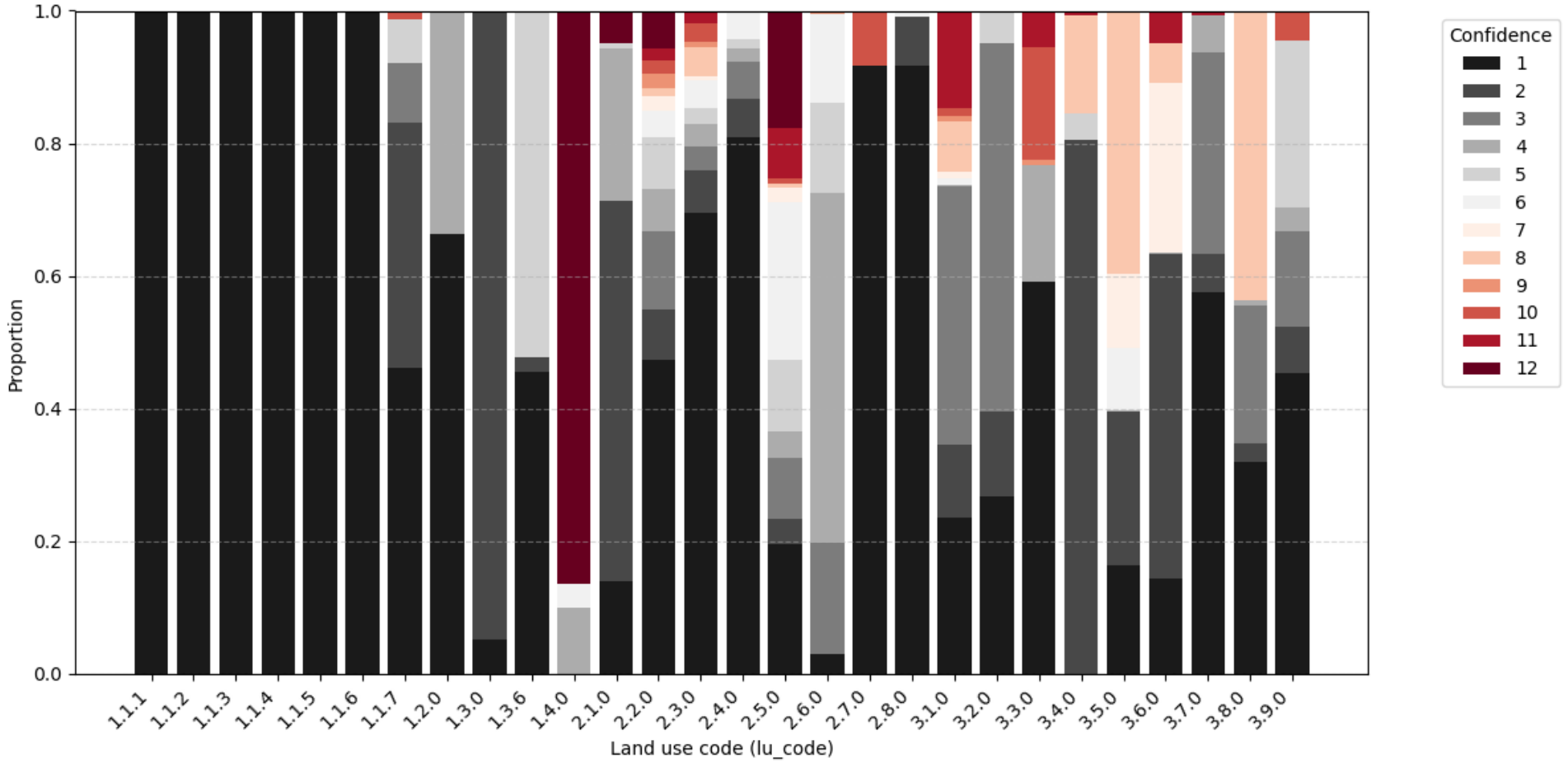

Figure 8. Graph of land-use code according to confidence, shown as a proportion of the total individual geographical features assigned to each class.

Notes: This does not account for the area of each feature, unlike the preceding figures.

In addition to a map of the primary land-use class, other attributes can be visualised. Appendix B demonstrates the visualisation of the commodity and management practice attributes: these provide some structured information about commodities and management practices related to the assigned land use. Maps of land status, water attribute, other commodities, management practices and combinations of these are easily rendered using filtering expressions.

3.2 Validation

3.2.1 Validation methodology

A continuous series of first-pass map validations was performed informally throughout the production of the land-use map. The use of a DGGS for combining many geospatial data sets made it feasible to produce innumerable small sample maps, which were interactively examined for sense and errors as the development of the classification rules progressed. The redefinition of a class rule can result in non-linear outcomes; that is, an apparently small change to a rule, such as an adjusted filter or confidence value, can possibly result in dramatic changes to the output classified map. The challenge of writing classification rules is to ensure that any changes are made with due consideration, and that outputs are examined throughout the process.

At the point of producing a national data set, formal validation can begin. True validation of a land-use data set requires ground-truth data, which is not possible in this instance if the goal is to achieve a representative sample of locations representing all classes. Instead, validation was performed against a 40 cm aerial imagery LINZ base map, with the most recent available imagery for New Zealand.

The validation was conducted as a stratified random sample of contiguous features in the output map, biased towards larger areas by using (log-transformed) geometry area as a weight. The sample was not stratified or weighted by any other factor, such as the assigned confidence score. To achieve a 95% confidence value and a 10% margin of error, a sample size of approximately 2,700 features was required. A constant random seed (itself randomly chosen) was applied to the sample so that the sample can be reproduced, but different seeds were used in each round of validation to take different samples.[10] Some sampling error is to be expected.

These 2,700 features were split evenly between two independent human validators (spatial analysts at MWLR), who were tasked with assessing whether the class assigned to each feature was 'logically consistent' with what they could see in aerial imagery. Responses could be coded 'yes', 'maybe', or 'no', along with the ability to record comments. This test for logical consistency rather than strict correctness was used because it is not possible for certain classes to be assessed for accuracy based on imagery alone (for example, the legal boundary of a nature reserve may not correspond with visible land cover), and there is no other hold-out information available with which to conduct an assessment.

[10] A Python implementation of this stratified sampling methodology is available at https://gist.github.com/alpha-beta-soup/b18a8ff2c869b17bfc3f839bfe11c3f5

The first round of formal validation results was used to make further adjustments and corrections to classification rules. A new national map was produced following revisions responding to this validation, and a second round of formal validation was then carried out.

3.2.2 Validation results

Class-wise validation results are presented in Figure 9. The same results are presented again in Figure 10, broken down by the assigned confidence score. Please note the following:

1 The validation result for the null class (unclassified space, the majority of which by area is marine) is not particularly meaningful. A 'no' result indicates that the operator considered the unclassified space classifiable, a 'yes' result that it is correct to consider it unclassifiable for some reason. A poor result for this class would be expected, given that it directly identifies data gaps or gaps in logical rules.

2 The worst-performing class after the first round of validation was class 2.5.0 ('Intensive horticulture'): 40% was assigned 'no' by the validators. This information was used to guide attention to the implementation of this class, and the following changes were made to improve it. By adjusting the confidence attributable to different evidence, some places will have a class 2.5.0 confidence that is sufficiently low that a different class will become the most confident class at that location. Others may be assigned a higher or lower confidence, but without entailing a different class assignment (e.g. due to lack of evidence for an alternative class). Still others may be excluded from consideration as class 2.5.0 entirely (e.g. due to a land-cover incompatibility).

   a A stronger baseline confidence was placed on Gisborne District Council's summer crop survey for various types of plant nursery (extremely favourable evidence from an in-person survey).

   b Considerably less confidence was placed on the District Valuation Roll property 'category' attribute (which is the valuer's opinion of what a property *would* be sold for, if it were to be sold, but which does not necessarily identify actual use).

   c Land cover was used to exclude any land that had an obviously incompatible land cover for intensive horticulture. This is helpful, because property-scale information from the District Valuation Roll may be correct in identifying intensive horticulture as the primary economic use of a property, but it may still only occupy a very small part of a property parcel.

   d Similarly, a land area threshold was applied, with a confidence penalty applied for properties over 15 ha and a smaller penalty for remaining properties over 10 ha in size.

   e The use of zoning information was reconsidered, including the use of 'special purpose' and 'lifestyle' zones as positive indicators, rather than doing so only for 'rural' zones.

3 The second round of validation used a new sample for validation. The worst-performing class from the first round of validation (2.5.0) was observed to have an improved accuracy after the second round: 'yes' increased from 22% to nearly 60%, and 'no' fell from 40% to 20%. Because this improved accuracy was achieved with the use of no newly obtained data, it demonstrates that there are still opportunities to significantly improve the accuracy of the classification *without* obtaining additional data.

4 The worst-performing category after the second (final) round of validation is class 2.8.0 ('Land in transition'). The 'transition' classes (2.8.0 and 3.9.0) are very difficult to assess and classify, so this is not unexpected. A vacant property does not necessarily have any visual indication that could support its classification as transitionary; neither does a completed new building, even if the data used to support its classification are correct but not sufficiently recent.

   a The information used to assign these classes comes largely from the District Valuation Roll's indication of property vacancy, which is reliable but not necessarily timely. These classes are particularly difficult to use, since there is no general relationship between the assigned confidence and the validation score: both classes assigned high confidence to areas that were validated negatively.

5 Apart from the 'transition' classes, classes 2.3.0 ('Short rotation and seasonal cropping') and 3.5.0 ('Utilities') had validation scores of 'no' above 35%.

   a Class 2.3.0 is difficult to validate using single-date imagery, so uncertainty in its validation is high.

   b Both 2.3.0 and 3.5.0 face classification difficulties due to the use of property-scale information, whereby the primary use at the property scale may be correctly assigned, but the entire property is not used for the assigned purpose. This is common for utility infrastructure (e.g. water treatment), where a territorial local authority may only use a small portion of a large property parcel for this purpose. Further data to supplement the District Valuation Roll would be needed to improve this classification, or better use of high-resolution land-cover information.

Although we did not use the same validation methodology, and still lack formal acceptance criteria, the Australian Land Use and Management (ALUM) classification guidelines use 80% overall accuracy as a guideline for the lower bound of the 90% confidence interval for the validation of each class as the threshold for meeting their accuracy standard. If any class's accuracy upper bound is less than 50%, then the map fails validation, although there is an allowance for flexibility due to some unavoidable confusion between certain classes (see Australian Bureau of Agricultural and Resource Economics and Sciences 2011). **By this measure, the delivered map does not presently meet the ALUM accuracy specification.**

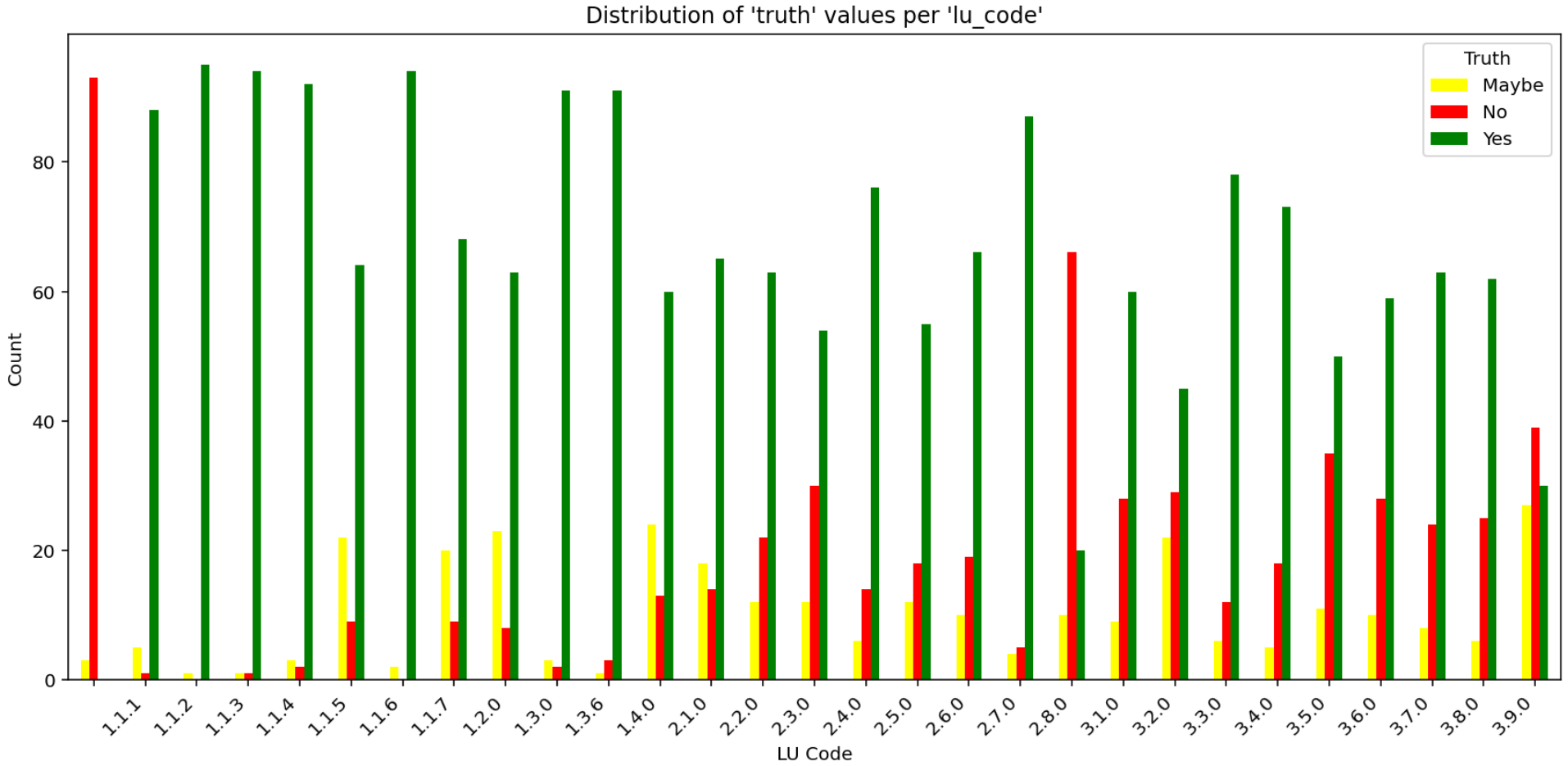

Figure 9. Class-wise validation results. This figure shows the number of features in the land-use map that were validated per class, divided into "yes" (green), "maybe" (yellow), and "no" (red) according to the validator's opinion regarding the consistency of the class assignment with aerial imagery. The group on the left corresponds to the "null" class assignment. The total sample size was approximately 2,700 features.

Note: the y axis shows the feature count.

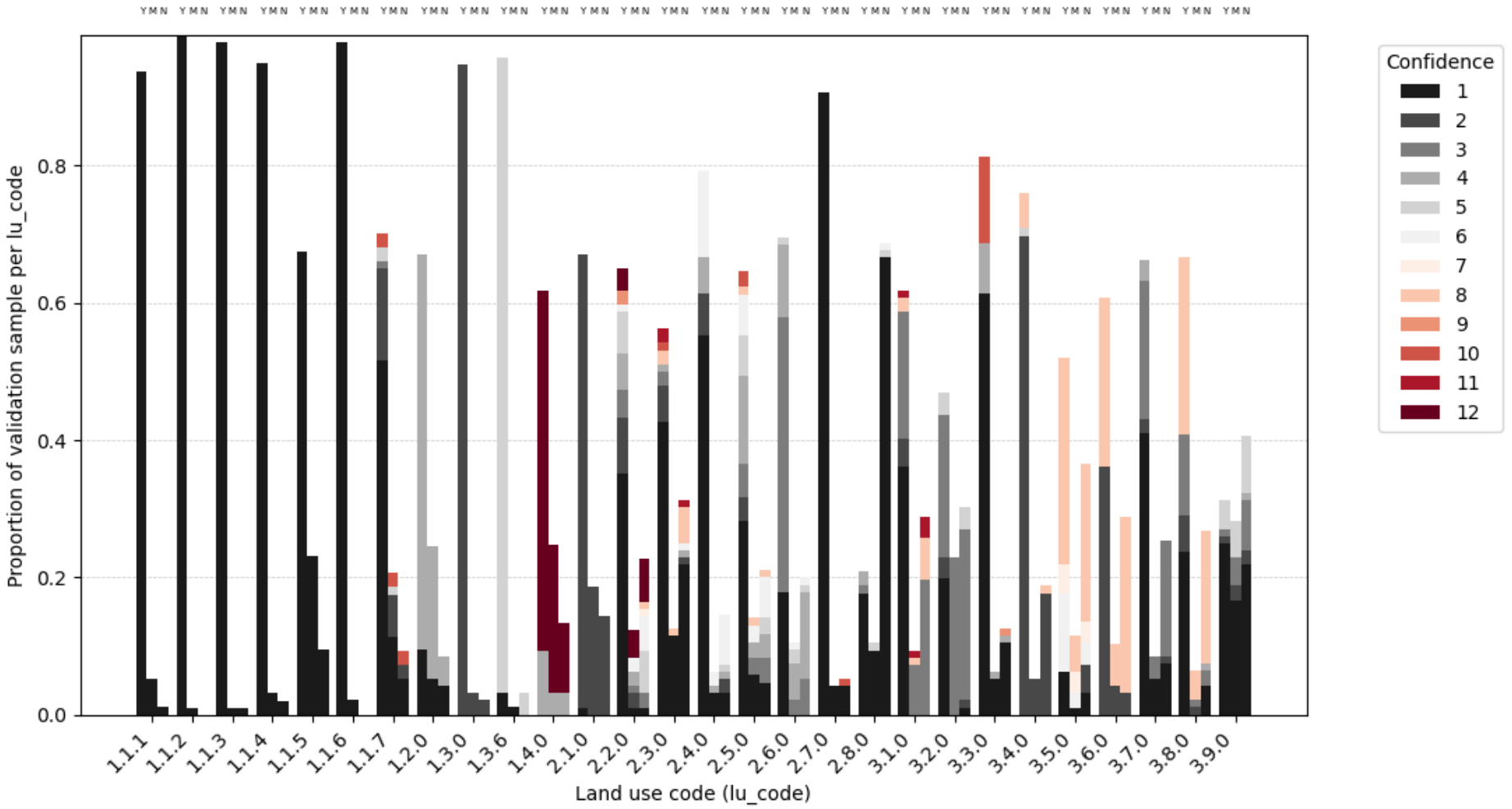

Figure 10. Class-wise validation results, as in Figure 9 but the information is broken down further by considering the assigned confidence score (which is not considered when sampling and is independent of the validation exercise).

Note: This demonstrates, for example, that class 2.8.0 ('Land in transition') is a particularly unreliable class, as its most common validation result was 'no' (the right column in each group of three columns), and yet the assigned confidence is very high. Therefore, it is confidently assigned but often wrong. A more positive pattern is shown for class 3.2.0 ('Public recreation and services'), where confidence generally corresponds to validation performance.

4 Gap analysis

4.1 Local government data

Local authorities across New Zealand hold and manage their own geospatial data sets, tailored to their specific regulatory, operational, and planning needs. As stated in the Resource Management Act 1991 (RMA), §35, each local authority is responsible for gathering, monitoring, and maintaining information necessary to effectively perform their functions under the act. This includes collecting environmental data, monitoring the state of the environment, assessing compliance with resource consents, and evaluating the efficiency and effectiveness of their policies and plans. To enhance mapping at a regional level we rely on these data sets because they are typically collected with finer spatial resolution and greater specificity than national datasets, and—importantly—are used operationally or have been validated in-person.

Although the RMA does not explicitly require integration with national systems, government initiatives such as the New Zealand Geospatial Strategy 2007 have encouraged aligning geospatial data sets with broader frameworks to promote consistency and accessibility. However, the continued lack of coordinated frameworks or directives between local and central government agencies continues to hinder efforts at data harmonisation. This lack of cohesion poses challenges to developing a seamless, national geospatial data set that can effectively support broader planning and policy objectives.

For the purposes of data integration, LUIS is designed to integrate data from disparate sources. Data published by territorial local authorities is a primary example. It is not always possible to reconcile data sets that nominally represent the same concept, such as dairy consents. One council may maintain effluent discharge consents spatially as point data, where the point is the location of discharge. Another may use addresses (text strings that need geocoding), or farm boundaries (polygons). Reconciling these would be considerably easier if they were more aligned conceptually and schematically. This is challenging but not impossible.

What can present significant barriers to the automatic integration of regional data is the dependence on the stability and longevity of online services for the publication of authoritative geographical data. These services may not be continuously available or handle schema changes with strategies such as version numbering APIs. This situation occurred even within the life-cycle of this pilot programme: summer crop maps published by Gisborne District Council via their ArcGIS REST API were spontaneously discontinued in May 2025. Access to the data was only re-obtained by direct request, and only then as a file and therefore divorced from any further updates.

Each territorial local authority independently decides which data sets to host, resulting in significant variation in types, formats, and availability of data across regions. Data sets are typically hosted on each authority's own platform, often using the ArcGIS Online platform (open data sites usually built with ArcGIS Hub) under all-of-government contracts. Hosted data are made available according to each authority's own discretion and requirements.

The absence of standardised requirements results in significant variability in the data sets provided by different authorities. Inconsistent data formats and unstandardised data structure (e.g. no standardised dictionary or vocabulary in recording water-take consents between authorities) further complicate efforts to ensure interoperability and consistency across data sets from different

councils. This variation extends beyond structural differences to include discrepancies in licensing, completeness, accuracy, update frequency, and accessibility, making integration into a national data set challenging.

Licensing arrangements differ considerably between authorities. Some provide open access under licences such as CC BY-NC 4.0 or CC BY-ND 4.0, while others implement custom licensing that requires formal permission requests or has insufficient information to determine if it can be integrated into a derivative data set. In many cases, incomplete metadata or a complete lack of licensing information further complicates data accessibility.

All these considerations have motivated us to prioritise the inclusion of high-value data sets (such as resource consents, and some region-specific data sets such as a comprehensive summer-cropping map for Gisborne), in preference to low-value data even when we are aware it does exist. We included such high-value regional data sets even if very few local authorities publish them. This pilot data set can thus be used to demonstrate how valuable they are and to act as an impetus for more local authorities to publish, license, collect and standardise similar information.

4.2 PAN-NZ

The development of a PAN-NZ layer was an identifiable, discrete and necessary step to support this pilot land-use map. Due to constrained resources, both the PAN-NZ layer and its associated tools were developed with limited investment, restricting the work to rapid prototyping. This approach aligns with the purpose of the land-use product the PAN-NZ layer supports: it serves as a pilot demonstration, offering a practical example of how a national land-use map can be produced under multiple constraints. This work therefore provides valuable insights and a foundation for the development of higher-quality national products in the future.

As a result, the PAN-NZ product has not undergone the standard quality control processes typically applied to similar outputs. For this reason, it should be considered a pilot, and no guarantees can be made regarding its accuracy. However, validation of PAN-NZ is indirectly captured under the overall land-use data validation described in section 3.1 of this report, given that PAN-NZ is a central input, particularly to class 1.1 of this implementation of NZLUM. Despite these limitations, the work has yielded valuable insights to inform and strengthen future PAN-NZ efforts, particularly if further funding becomes available.

5 Recommendations

1 This pilot land-use data set implemented the NZLUM classification system, which is defined under the NZSLUC classification framework. (For more information about these, see Law et al. 2024). It is intended to be a demonstration product that can be used for users of various interest groups to assess the suitability of NZLUM itself rather than focus on the quality of the implementation in terms of how accurate it is or what input data are used. Critical reflection on the class definitions, hierarchy, use of attributes, data types, etc. is crucial before more effort is made to produce a higher-resolution map at the tertiary level. There will very likely be a significant level of path dependence with whatever decisions are made.

2 A key recommendation in Law et al. 2024 was to form a governance group to manage recommendations and changes for NZLUM and NZSLUC. At an MfE–MWLR joint seminar held in December 2024 with 25 in-person attendees from a range of organisations, as well as online participants, it was agreed that a governance group should be formed for this purpose. However, it has presently remained unformed and un-resourced. We repeat the recommendation here and note especially that it should consider a te ao Māori lens of land use that can inform NZLUM, or perhaps be expressed in a different land-use classification system entirely, but which still adheres to the NZSLUC principles and best practices for land-use classification systems.

   a This group should particularly consider the NZLUM attributes that were not used (e.g. permeability) or are still indeterminate (e.g. zoning) with the objective of developing a more stable v1.0 of NZLUM that should be the result of substantial contribution from end-users.

3 To maintain the PAN-NZ data catalogue, we recommend:

   a Adding new data sources as they are made available, or change, particularly as the result of requests made to territorial local authorities (many of which are currently underway).

   b Removing data from the catalogue as necessary.

   c Continuing to update PAN-NZ with revisions to the mappings between legal protections and IUCN categories, which can then be used as input by the wider land-use map and any other third-party derivative datasets and applications.

4 For peer review, visualisation and public presentation of the present land-use data set, we recommend considering the various state-level examples of how ALUM is used in Australia:

   a See, for example, Queensland's 'Land Use Summary App'[11]. The web application presents the temporal sequence of available land-use maps since 2009, including change maps that indicate where land has changed, and whether the change of use indicates a change to more- or less-intensive categories. Of particular interest in this application is the 'Validation' tab (Figure 11). This shows the results of peer review performed according to the ALUM specification and transparently shows the location of both correct and incorrect classifications. Their land-use data were also put through a peer review process, whereby draft land-use mapping for 2017 was reviewed with a purpose-built web app shared with stakeholders and local experts over a 6-week period. The review app received 656 comments to assist in map production, and they are transparently presented. This is an excellent example of how local knowledge can be used to improve a national data product (especially given that it should increasingly rely on data held by local or regional bodies and be of use to them).

   b A national example is the Applied Agricultural Remote Sensing Centre (AARSC) Industry Engagement Web App.[12] This presents a map of commercial horticulture tree crops across all of Australia, but also provides a mechanism for growers and stakeholders to review the map and contribute feedback via the same web application.

[11] https://qgsp.maps.arcgis.com/apps/MapSeries/index.html?appid=96d3ec168d394bcfaa1d80af5b5182c8

[12] https://experience.arcgis.com/experience/413f33d9b88e4f94b1c4187ea1125c4d

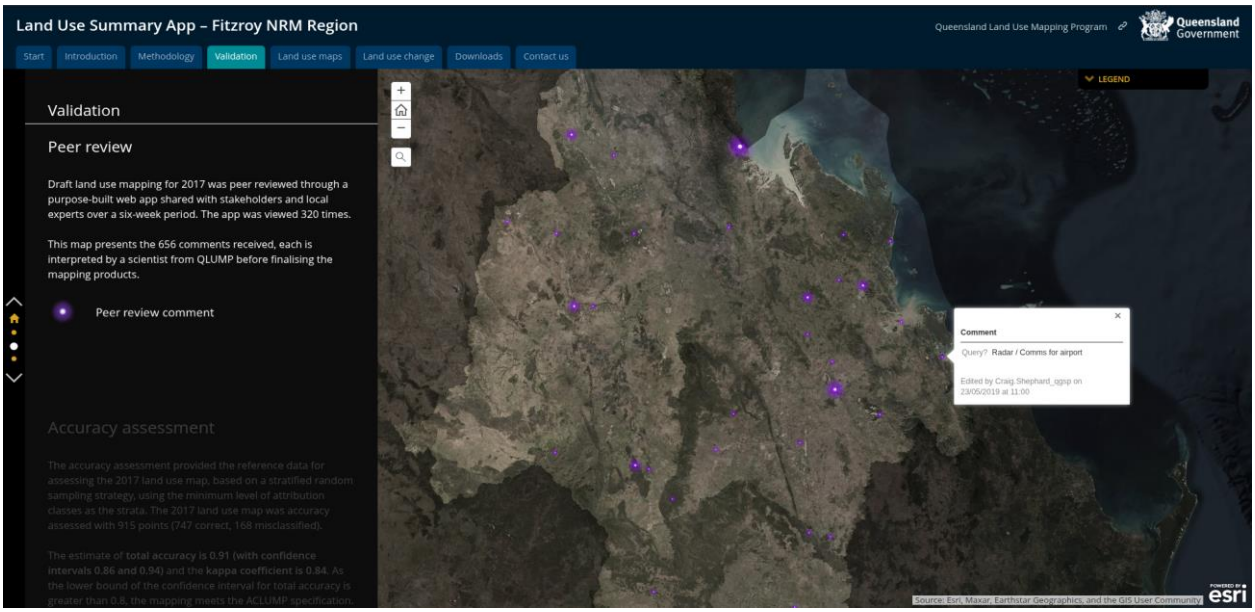

Figure 11. Queensland Land Use Mapping Programme summary app showing the 'Validation' tab.

Declaration of the use of generative AI/AI-assisted technologies

During the preparation of this report the authors used GPT-4o to produce most of Appendix G, as stated in that appendix.

After using this tool, the content was reviewed and edited as needed by the authors. Landcare Research New Zealand Ltd takes full responsibility for any content in this report that has used the stated technology.

6 References

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Appendix A – Input data sets

id	description	license	attribution	host
lcdb_v5	LCDB v5	CC BY	Sourced from the Land Resource Information Systems (LRIS) Portal and licensed for reuse under CC BY 4.0	https://lris.scinfo.org.nz/services;key={key}/wfs
lcdb_v5_chathams	LCDB v5 [Chatham Islands]	CC BY	Sourced from the Land Resource Information Systems (LRIS) Portal and licensed for reuse under CC BY 4.0	https://lris.scinfo.org.nz/services;key={key}/wfs
nzlri_lowcapability	NZ Land Resource Inventory (NZLRI) Land Use Capability 2021	https://lris.scinfo.org.nz/license/landcare-data-use-licence-v1/	Data reproduced with the permission of Landcare Research New Zealand Limited	https://lris.scinfo.org.nz/services;key={key}/wfs
winter_forage_2022	NZ winter forage 2022	Copyright © MWLR 2025	Sourced from the Land Resource Information Systems (LRIS) Portal and used under permission	https://lris.scinfo.org.nz/services;key={key}/wfs
winter_forage_2023	NZ winter forage 2023	Copyright © MWLR 2025	Sourced from the Land Resource Information Systems (LRIS) Portal and used under permission	https://lris.scinfo.org.nz/services;key={key}/wfs
pan_nz_draft	PAN-NZ Draft H3 12 (2025)	CC BY		https://lris.scinfo.org.nz/services;key={key}/wfs
crosl	The Central Record of State Land (CRoSL) identifies all crown land in New Zealand and provides contextual information on the land such as parcel/title information, ownership information and legislative information.	CC BY	Land Information New Zealand	https://services.arcgis.com/xdsHIIxuCWByZiCB/arcgis/rest/services/CRoSL_Layer_N/FeatureServer
railway_parcels	NZ Parcels (all cadastral parcel polygons) - current, primary, railway	CC BY	Sourced from the LINZ Data Service and licensed for reuse under CC BY 4.0	https://data.linz.govt.nz/services;key={key}/wfs

id	description	license	attribution	host
road_parcels	NZ Parcels (all cadastral parcel polygons) - current, primary, road	CC BY	Sourced from the LINZ Data Service and licensed for reuse under CC BY 4.0	https://data.linz.govt.nz/services;key={key}/wfs
hydro_parcels	NZ Parcels (all cadastral parcel polygons) - current, primary, hydro	CC BY	Sourced from the LINZ Data Service and licensed for reuse under CC BY 4.0	https://data.linz.govt.nz/services;key={key}/wfs
nz_facilities	NZ Facilities	CC BY	Sourced from the LINZ Data Service and licensed for reuse under CC BY 4.0	https://data.linz.govt.nz/services;key={key}/wfs
south_island_pastoral_leases	South Island Pastoral Leases	CC BY	Sourced from the LINZ Data Service and licensed for reuse under CC BY 4.0	https://data.linz.govt.nz/services;key={key}/wfs
unit_of_property	This pilot dataset provides a representation of the boundaries of all known properties in New Zealand.	—	Restricted use: used under permission from MfE	—
national_dvr	This pilot dataset provides a subset of the national collection of District Valuation Roll (DVR) data under open CC BY 4.0 license.	—	Restricted use: used under permission from MfE	—
property_title_reference	Non-spatial relationship between unit_of_property_id and title_no from Landonline (Title ID). Weekly updates. PDMF-compliant link.	CC BY	Sourced from the LINZ Data Service and licensed for reuse under CC BY 4.0	https://data.linz.govt.nz/services;key={key}/wfs
nz_property_titles_list	Records of Title that are live and part-cancelled, including title number, type, status, legal descriptions, owners, and registered rights.	CC BY	Sourced from the LINZ Data Service and licensed for reuse under CC BY 4.0	https://data.linz.govt.nz/services;key={key}/wfs
topo50_land	NZ Coastlines and Islands Polygons (Topo 1:50k)	CC BY	Sourced from the LINZ Data Service and licensed for reuse under CC BY 4.0	https://data.linz.govt.nz/services;key={key}/wfs
topo50_sportsfields	LINZ Topo 1:50k sports fields	CC BY	Sourced from the LINZ Data Service and licensed for reuse under CC BY 4.0	https://data.linz.govt.nz/services;key={key}/wfs

id	description	license	attribution	host
topo50_golf_courses	LINZ Topo 1:50k golf courses	CC BY	Sourced from the LINZ Data Service and licensed for reuse under CC BY 4.0	https://data.linz.govt.nz/services;key={key}/wfs
topo50_chatham_golf_courses	LINZ Topo 1:50k Chatham Island golf courses	CC BY	Sourced from the LINZ Data Service and licensed for reuse under CC BY 4.0	https://data.linz.govt.nz/services;key={key}/wfs
topo50_cemetery	LINZ Topo 1:50k cemeteries	CC BY	Sourced from the LINZ Data Service and licensed for reuse under CC BY 4.0	https://data.linz.govt.nz/services;key={key}/wfs
topo50_chatham_cemetery	LINZ Topo 1:50k Chatham Island cemeteries	CC BY	Sourced from the LINZ Data Service and licensed for reuse under CC BY 4.0	https://data.linz.govt.nz/services;key={key}/wfs
topo50_airports	LINZ Topo 1:50k Airport Polygons	CC BY	Sourced from the LINZ Data Service and licensed for reuse under CC BY 4.0	https://data.linz.govt.nz/services;key={key}/wfs
topo50_chatham_airports	LINZ Topo 1:50k Chatham Island Airport Polygons	CC BY	Sourced from the LINZ Data Service and licensed for reuse under CC BY 4.0	https://data.linz.govt.nz/services;key={key}/wfs
topo50_runways	LINZ Topo 1:50k Runway Polygons	CC BY	Sourced from the LINZ Data Service and licensed for reuse under CC BY 4.0	https://data.linz.govt.nz/services;key={key}/wfs
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topo50_ice	LINZ Topo 1:50k ice	CC BY	Sourced from the LINZ Data Service and licensed for reuse under CC BY 4.0	https://data.linz.govt.nz/services;key={key}/wfs
topo50_lagoon	LINZ Topo 1:50k Lagoon Polygons	CC BY	Sourced from the LINZ Data Service and licensed for reuse under CC BY 4.0	https://data.linz.govt.nz/services;key={key}/wfs
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topo50_lake	LINZ Topo 1:50k Lake Polygons	CC BY	Sourced from the LINZ Data Service and licensed for reuse under CC BY 4.0	https://data.linz.govt.nz/services;key={key}/wfs
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topo50_pond	LINZ Topo 1:50k pond Polygons	CC BY	Sourced from the LINZ Data Service and licensed for reuse under CC BY 4.0	https://data.linz.govt.nz/services;key={key}/wfs

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topo50_swamp	LINZ Topo 1:50k swamp Polygons	CC BY	Sourced from the LINZ Data Service and licensed for reuse under CC BY 4.0	https://data.linz.govt.nz/services;key={key}/wfs
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topo50_mangrove	LINZ Topo 1:50k Mangrove Polygons	CC BY	Sourced from the LINZ Data Service and licensed for reuse under CC BY 4.0	https://data.linz.govt.nz/services;key={key}/wfs
topo50_river	LINZ Topo 1:50k River Centrelines	CC BY	Sourced from the LINZ Data Service and licensed for reuse under CC BY 4.0	https://data.linz.govt.nz/services;key={key}/wfs
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topo50_roads	LINZ Topo 1:50k Road Centrelines	CC BY	Sourced from the LINZ Data Service and licensed for reuse under CC BY 4.0	https://data.linz.govt.nz/services;key={key}/wfs
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topo50_railway	LINZ Topo 1:50k Railway Centrelines	CC BY	Sourced from the LINZ Data Service and licensed for reuse under CC BY 4.0	https://data.linz.govt.nz/services;key={key}/wfs

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topo50_dredge_tailing_centrelines	LINZ Topo 1:50k Dredge Tailing Centrelines (buffered 50 m)	CC BY	Sourced from the LINZ Data Service and licensed for reuse under CC BY 4.0	https://data.linz.govt.nz/services;key={key}/wfs
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topo50_scree_polygons	LINZ Topo 1:50k Scree Polygons	CC BY	Sourced from the LINZ Data Service and licensed for reuse under CC BY 4.0	https://data.linz.govt.nz/services;key={key}/wfs

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topo50_moraine_wall_polygons	LINZ Topo 1:50k Moraine Wall Polygons	CC BY	Sourced from the LINZ Data Service and licensed for reuse under CC BY 4.0	https://data.linz.govt.nz/services;key={key}/wfs
topo50_shingle_polygons	LINZ Topo 1:50k Shingle Polygons	CC BY	Sourced from the LINZ Data Service and licensed for reuse under CC BY 4.0	https://data.linz.govt.nz/services;key={key}/wfs
topo50_chatham_shingle_polygons	LINZ Topo 1:50k Chatham Island Shingle Polygons	CC BY	Sourced from the LINZ Data Service and licensed for reuse under CC BY 4.0	https://data.linz.govt.nz/services;key={key}/wfs
topo50_landfill_polygons	LINZ Topo 1:50k Landfill Polygons	CC BY	Sourced from the LINZ Data Service and licensed for reuse under CC BY 4.0	https://data.linz.govt.nz/services;key={key}/wfs
topo50_residential_areas	LINZ Topo 1:50k Residential Area Polygons	CC BY	Sourced from the LINZ Data Service and licensed for reuse under CC BY 4.0	https://data.linz.govt.nz/services;key={key}/wfs
topo50_reefs	LINZ Topo 1:50k Reef Polygons	CC BY	Sourced from the LINZ Data Service and licensed for reuse under CC BY 4.0	https://data.linz.govt.nz/services;key={key}/wfs
topo50_chatham_reefs	LINZ Topo 1:50k Chatham Island Reef Polygons	CC BY	Sourced from the LINZ Data Service and licensed for reuse under CC BY 4.0	https://data.linz.govt.nz/services;key={key}/wfs
topo50_fish_farms	LINZ Topo 1:50k Fish Farm Polygons	CC BY	Sourced from the LINZ Data Service and licensed for reuse under CC BY 4.0	https://data.linz.govt.nz/services;key={key}/wfs
irrigation_2020	Irrigated land area, raw, 2020 update	CC BY		https://data.mfe.govt.nz/services;key={key}/wfs
lum	LUCAS NZ Land Use Map 2020 v003	CC BY		https://data.mfe.govt.nz/services;key={key}/wfs
lum_chathams	LUCAS Chathams NZ Land Use Map 2020 v001	CC BY		https://data.mfe.govt.nz/services;key={key}/wfs
fenz_lakes	FENZ Lakes	CC BY		https://data.mfe.govt.nz/services;key={key}/wfs

id	description	license	attribution	host
mpi_current_marine_farms	Current Marine Farms	"The data is available to view on a map and can also be downloaded for use in Geographic Information Systems"	Ministry for Primary Industries	https://maps.mpi.govt.nz/wss/service/ags-relay/arcgis1/guest/arcgis/rest/services/MARINE/MARINE_Aquaculture_Marine_Farms/MapServer
urban_rural_2025	Urban Rural 2025	CC BY	Sourced from Statistics NZ Datafinder and licensed under CC BY 4.0	https://datafinder.stats.govt.nz/services;key={key}/wfs
ecan_consented_activities_areas_active	Records of current consented activities in Environment Canterbury RM Act database	CC BY	Sourced from Canterbury Maps and partners under CC BY 4.0	https://gis.ecan.govt.nz/arcgis/rest/services/Public/Resource_Consents_Active/MapServer
ecan_effluent_dairy_discharge_area	Consented Activities - Effluent Dairy Discharge Area (Active)	CC BY	Sourced from Canterbury Maps and partners under CC BY 4.0	https://gis.ecan.govt.nz/arcgis/rest/services/Public/Resource_Consents_Active/MapServer
ecan_braided_rivers	ECAN Braided Rivers Cover Classes	CC BY	Sourced from Canterbury Maps and partners under CC BY 4.0	https://gisbasemap.ecan.govt.nz/arcgis/rest/services/Public/SOE_Braided_Rivers/MapServer
cera_red_zoned_land	CERA Red Zoned Land as shown in the Land Use Recovery Plan	CC BY	Sourced from Canterbury Maps and partners and licensed for reuse under the CC BY 4.0 licence	https://gis.ecan.govt.nz/arcgis/rest/services/Public/LURP/MapServer
fosal_areas_tairawhiti	Future of severely affected land (FOSAL) areas for the Tairāwhiti region. This data is provisional and subject to change.	CC BY	Gisborne District Council	https://services7.arcgis.com/8G10QCd84QpdcTJ9/arcgis/rest/services/FOSAL_Areas_Tairāwhiti/FeatureServer
summer_crop_gdc	Tairāwhiti Gisborne Summer Crops Annual Survey 2007-2025. This is a public view of the data.	CC BY	Gisborne District Council	
winter_crop_gdc	Tairāwhiti Gisborne Winter Crops Annual Survey 2015-21. This is a public view of the data.	CC BY	Gisborne District Council	

id	description	license	attribution	host
hawkes_bay_land_categorisation	This layer shows the Land Categorisation 3 areas within Hawke's Bay Region	CC BY	Hawke's Bay Regional Council	https://services1.arcgis.com/hWByVnSkh6ElzHkf/arcgis/rest/services/Hawkes_Bay_Land_Categorisation/FeatureServer
hbrc_all_consent_polygons	HBRC consents	CC BY	Hawke's Bay Regional Council	https://gis.hbrc.govt.nz/server/rest/services/ExternalServices/Regulatory/MapServer
hbrc_hail_suitable_remediated	HBRC HAIL: Suitable for land use: remediated	CC BY	Hawke's Bay Regional Council	https://gis.hbrc.govt.nz/server/rest/services/HazardPortal/Contaminated_Sites/MapServer
hbrc_hail_suitable_natural_state	HBRC HAIL: Suitable for land use: natural state	CC BY	Hawke's Bay Regional Council	https://gis.hbrc.govt.nz/server/rest/services/HazardPortal/Contaminated_Sites/MapServer
hbrc_hail_risk_not_quantified	HBRC HAIL: risk not quantified	CC BY	Hawke's Bay Regional Council	https://gis.hbrc.govt.nz/server/rest/services/HazardPortal/Contaminated_Sites/MapServer
hbrc_hail_managed_for_land_use	HBRC HAIL: managed for land use	CC BY	Hawke's Bay Regional Council	https://gis.hbrc.govt.nz/server/rest/services/HazardPortal/Contaminated_Sites/MapServer
hbrc_hail_contaminated_for_lu_human	HBRC HAIL: contaminated for land use: human health	CC BY	Hawke's Bay Regional Council	
hbrc_hail_contaminated_for_lu_env	HBRC HAIL: contaminated for land use: environment	CC BY	Hawke's Bay Regional Council	https://gis.hbrc.govt.nz/server/rest/services/HazardPortal/Contaminated_Sites/MapServer
hbrc_hail_background_natural_state	HBRC HAIL: at or below background: natural state	CC BY	Hawke's Bay Regional Council	https://gis.hbrc.govt.nz/server/rest/services/HazardPortal/Contaminated_Sites/MapServer
horizons_reg_act	Horizons RC regulatory activities (polygon only)	CC BY	Horizons Regional Council	https://services1.arcgis.com/VuN78wcRdq1Oj69W/arcgis/rest/services/OpenData_RegulatoryActivity/FeatureServer
es_slu	Environment Southland Selected Land Use Sites (SLUS)	CC BY		https://maps.es.govt.nz/server/rest/services/Public/General/MapServer
es_winter_forage_2017	Environment Southland winter forage 2017	CC BY		https://maps.es.govt.nz/server/rest/services/Public/General/MapServer

Appendix B – NZLUM v0.3 visualisations

Commodity: animals

Cattle dairy

Cattle meat

Deer

Finfish

Goats dairy

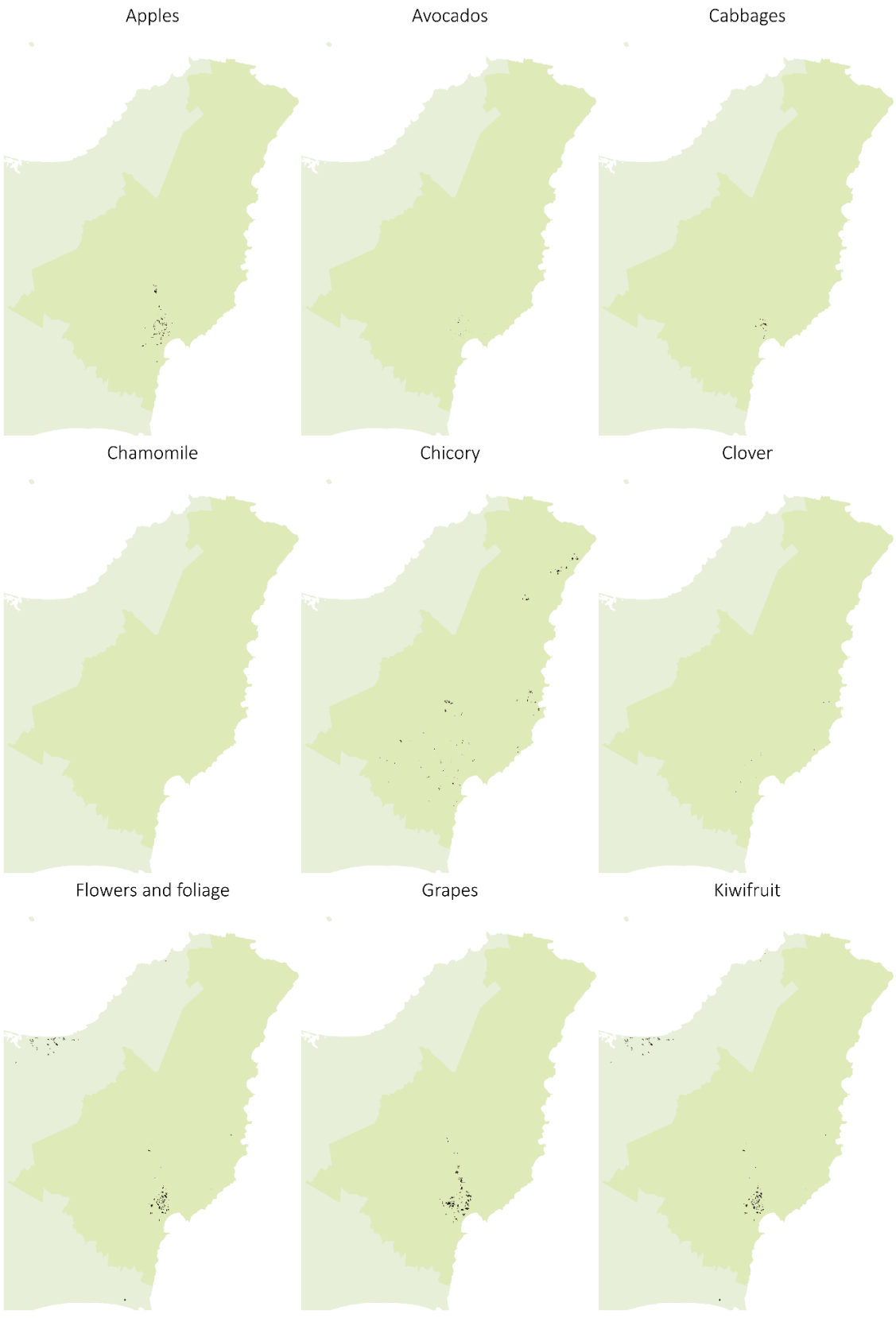
Horses

Mollusc

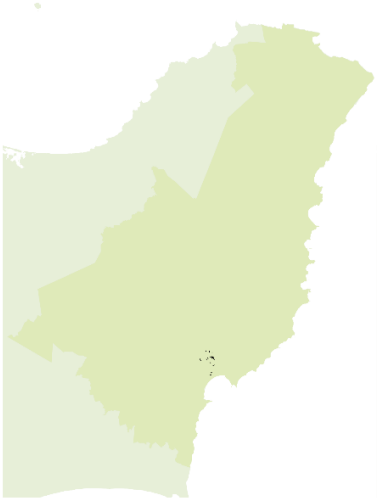
Pigs

Sheep

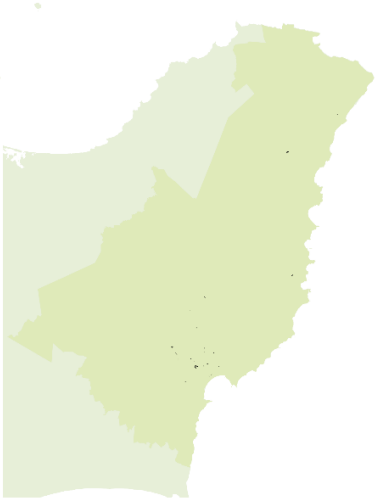
Commodity: crop (shown for Gisborne)



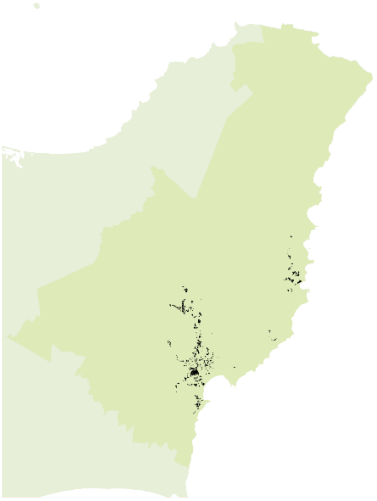
Lettuces



Lucerne



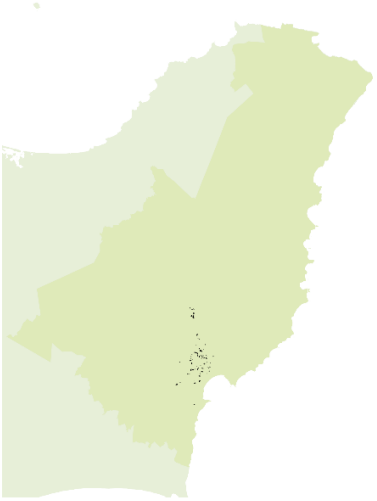
Maize



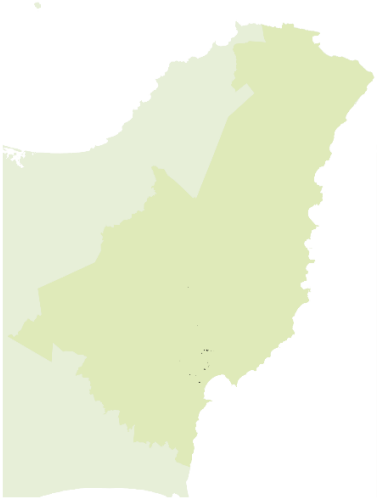
Melons

Olives

Pears

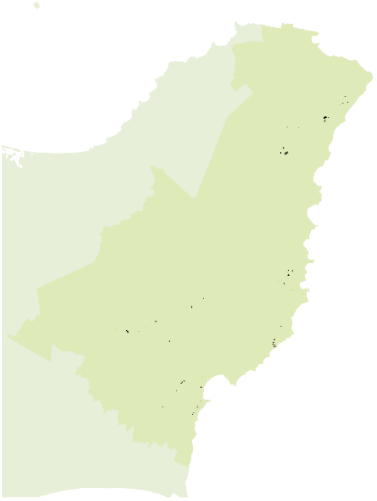


Persimmons



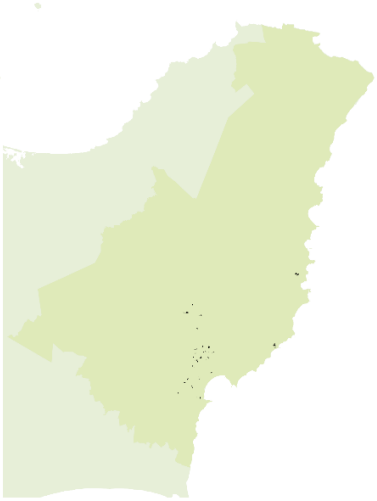
Pinenuts

Plantain

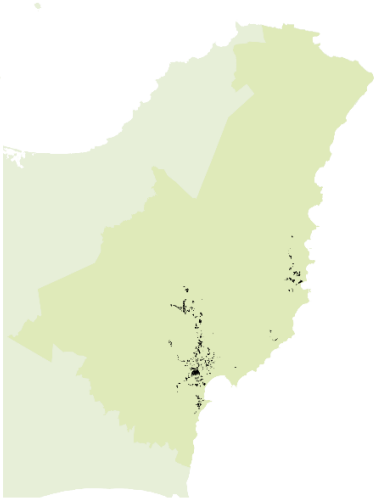


Pomegranate

Pumpkins

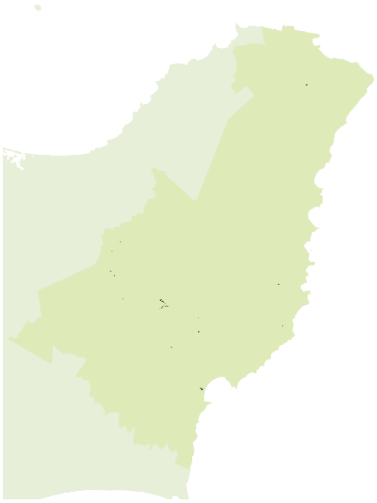


Sweetcorn



Tamarillo

Turnips



Commodity- Minerals

Clay

Coal

Gold

Gravel

Ironsand

Lime

Limestone

Metal

Salt

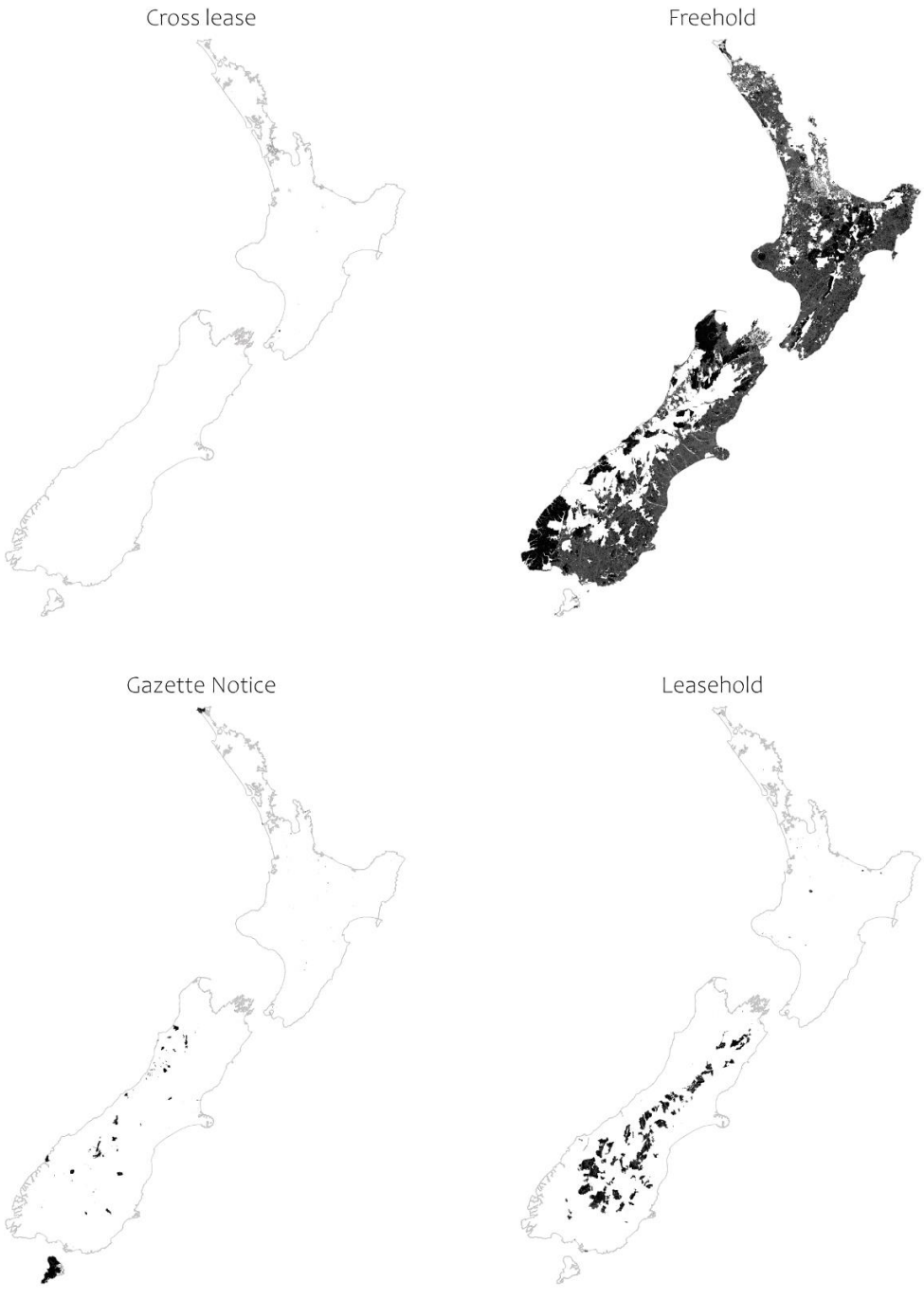
Shingle

Silica sand

Stone

Zeolite

Land Estate



Life Estate

Records Embodied in the Register

Supplementary Record Sheet

Timeshare

Unit Title

Management practices

Irrigation

Crop pasture rotation

Ownership

Council organisations

Crown entities

Mixed ownership model companies

Non-public Service departments

Private

Public Finance Act 1989 Organisations

Public Service

State-owned enterprises

Territorial Local Authorities

Zone

Commercial

Community uses

Designated or zoned reserve land

Industrial

Land in more than one zone or designation

Lifestyle

Other broad zone

Other specific zone

Recreational

Residential

Rural

Appendix C – PAN-NZ overview

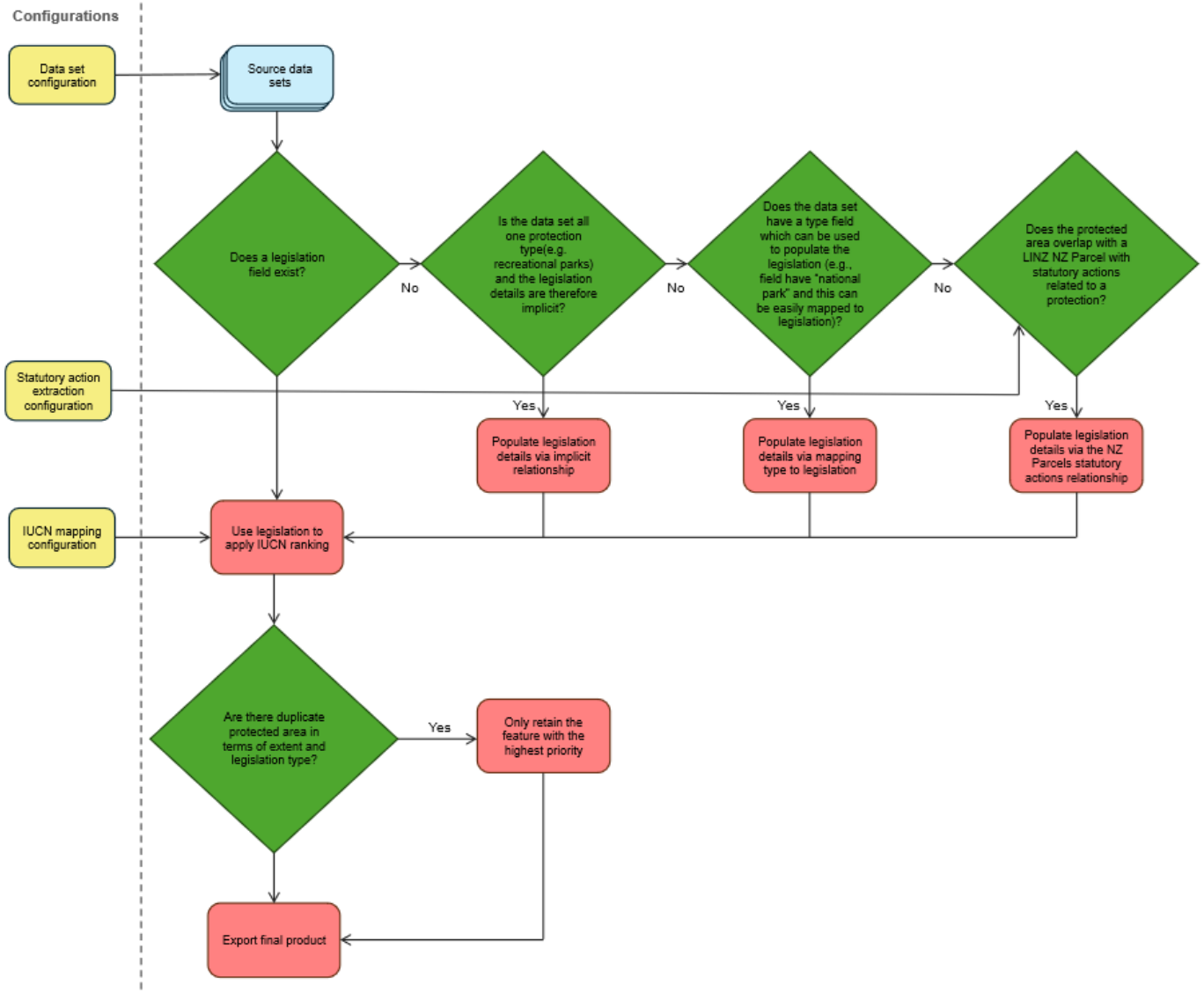


Figure A1. A high-level overview of the key steps performed by the aggregation tool in generating the PAN-NZ layer.

Appendix D – PAN-NZ input data sets

Data set	Licence	URL
LINZ Protected Areas	CC-BY-4.0	https://data.linz.govt.nz/layer/53564-protected-areas/
DOC Public Conservation Land	CC-BY-4.0	https://doc-deptconservation.opendata.arcgis.com/datasets/72354ba9bf7a4706af3fdfe60f86eea1_0/
DOC Covenant Areas	CC-BY-3.0	https://doc-deptconservation.opendata.arcgis.com/datasets/e35ba07f91aa47df9651f423f4ff11d0_0/about
DOC Internationally Recognised Areas	CC-BY-4.0	https://doc-deptconservation.opendata.arcgis.com/datasets/f0cbb7544b1f4dae910fba8d8728d72a_0/
QEII Open Space Covenants		https://qeiinationaltrust.org.nz/publications-and-resources/gis-data/
DOC Marine Reserves	CC-BY-4.0	https://doc-deptconservation.opendata.arcgis.com/datasets/0e74f9682502447c9a14d51340512361_0
Nga Whenua Rahui	Custom License "PUBLIC USE"	https://nwr-open-data-nwr.hub.arcgis.com/datasets/3e788355a98a4e949f7baf8027a183cf_0
NZ Parcels	CC-BY-4.0	https://data.linz.govt.nz/layer/51571-nz-parcels/
Auckland Parks	CC-BY-4.0	https://data-aucklandcouncil.opendata.arcgis.com/datasets/park-extents/explore
Waikato SNAs	CC-BY-4.0	https://southwaikatodc-open-data-portal-southwaikatodc.opendata.arcgis.com/maps/583f8bbf5d3147449d49e5c044c30c17/about
South Waikato Reserve Areas	CC-BY-4.0	https://southwaikatodc-open-data-portal-southwaikatodc.opendata.arcgis.com/datasets/0cdbcf77df5049b1999fa683ac36e928/explore
Rotorua SNAs	CC-BY-4.0	https://data-waikatolass.opendata.arcgis.com/datasets/f6d7eac945974ec18b42ad0e3c310726_0/explore
Gisborne Parks	CC-BY-4.0	https://geoportal-gizzy.opendata.arcgis.com/maps/gizzy::parks-and-reserves/about
Hawke's Bay Regional Parks	CC-BY-4.0	https://hub.arcgis.com/datasets/658697bb70c345f48d21cc002ecc0bef_1/explore
New Plymouth Parks	CC-BY-4.0	https://arc-gis-hub-home-arcgishub.hub.arcgis.com/datasets/8db10ed20467482ba215074cefa1bf89_0/explore
Palmerston North Parks	CC-BY-4.0	https://data-pncc.opendata.arcgis.com/datasets/PNCC::pncc-parks-reserves/explore
Wellington City Council Parks and Reserves	CC BY-ND 4.0 License	https://data-wcc.opendata.arcgis.com/datasets/wcc-parks-and-reserves
ECAN Parks	CC-BY-3.0	https://opendata.canterburymaps.govt.nz/datasets/ecan::parks/explore

Appendix E – Property parcels: statutory actions

Examples of the statutory actions captured against property parcels as part of the LINZ NZ Primary Parcel layer (Land Information New Zealand 2025b)

Example #	Example Statutory Action Text
1	[Create] Ecological Area [Opuiaki Ecological Area] New Zealand Gazette 1984 p 4606 [Create] State Forest [Opuiaki Ecological Area] New Zealand Gazette 1925 p 155 [Create] State Forest Park [Opuiaki Ecological Area] New Zealand Gazette 1975 p 2328
2	[Create] State Forest New Zealand Gazette 1954 p 1992 [Referenced] Conservation purposes Section 62(1), Conservation Act 1987 SO 12711 R18/6
3	[Referenced] Fee Simple the, Land Transfer Act 1952 Transfer from Her Majesty The Queen to private individuals - T.10173873.11
4	[Create] Scenic Reserve New Zealand Gazette 2011 p 780 Gaz 1990 p 3432 – Subject to the Reserves Act 1977
5	[Create] Scenic Reserve New Zealand Gazette 1994 p 1634
6	[Referenced] Land set apart as a Scenic Reserve New Zealand Gazette 2017 ln 4238\\Subject to Sec 19(1)(a) of the Reserve Act 1977
7	[Create] Subject to Part IVA Conservation Act 1987 Sec 24 Conservation Act 1987
8	[Create] Subject to Part IVA Conservation Act 1987 Sec 24 Conservation Act 1987 [Referenced] Fee Simple Title Section 87, Rangitane Tu Mai Ra (Wairarapa Tamaki nui-a-rua) Claims Settlement Act 2017 Transferred from HM the King to Iwi
9	[Create] Fee Simple Title New Zealand Gazette 2018 ln 3495 Balance Land
10	[Create] Hot Springs Reserve New Zealand Gazette 1929 p 2500 [Referenced] Revokes hot springs reserve and Vests in Fee Simple. [Te Puia Site pursuant to Sec 70(5) is named Te Puia Local Purpose (Geothermal and Walking Track) Reserve] 70, Ngati Porou Claims Settlement Act 2012 Vests in the Trustee of Te Runanganui o Ngati Porou. Subject to local purpose reserve referred to in Sec 70(3). Subject to conditions referred to in Sec 70(4). Subject to the Reserves Act 1977.
11	[Referenced] Fee Simple Estate the, Ngati Pahauwera Treaty Claims Settlement Act 2012 Pursuant to Sec 81 of the Act - Transfer from HMQ to the Trustees of the Ngati Pahauwera Development Trust - T.10785156.8
12	[Create] Subject to the provision of Esplanade Strips Sec 232 Resource Management Act 1991 [Referenced] Notice of Intention to Take Land for Landfill Site New Zealand Gazette 2007 p 1409 Intention to Take Pt Land Defined as Section 1 SO 382707

Appendix F – DOC: Mapping of legislation to IUCN categories

The legislation to IUCN category mappings as supplied by the Department of Conservation. These were used in this work to rank protected areas in terms of IUCN categories.

DESIG	IUCN_CAT	Updated Query
Conservation Area	III	*Section = 'S7_CONSERVATION_PURPOSES'*
Conservation Park	V	*Section = 'S19_CONSERVATION_PARK'*
Ecological Area	III	*Section = 'S21_ECOLOGICAL_AREA'*
Government Purpose Reserve	Not Reported	*Section = 'S22_GOVERNMENT_PURPOSE_RESERVE' AND "Government_Purpose" IN ('CLIMATIC', 'PRESERVATION_TIMBER', 'PROTECTION_GANNETS', 'WETLAND_MANAGEMENT', 'WILDLIFE_HABITAT', 'WILDLIFE_MANAGEMENT', 'WILDLIFE_REFUGE', 'WILDLIFE_SANCTUARY')*
Local Purpose Reserve	Not Reported	*Section = 'S23_LOCAL_PURPOSE_RESERVE' AND "Local_Purpose" IN ('RIVER_BANK_PROTECTION', 'RIVER_PROTECTION', 'WETLAND', 'WILDLIFE')*
National Park	Ia	*Section = 'S20_NATURE_RESERVE'*
Sanctuary Area	Ia	*Section = 'S22_SANCTUARY_AREA'*
Scenic Reserve	III	*Section IN ('S19_1_A_SCENIC_RESERVE', 'S19_1_B_SCENIC_RESERVE')*
Scientific Reserve	Ia	*Section = 'S21_SCIENTIFIC_RESERVE'*
Stewardship Area	III	*Section = 'S25_STEWARDSHIP_AREA'*
Wilderness Area	Ib	*Section = '20_WILDERNESS_AREA'*
Wildlife Management Area	IV	*Section IN ('S14A_WILDLIFE_MANAGEMENT_RESERVE', 'S23B_WILDLIFE_MANAGEMENT_AREA')*
Wildlife Sanctuary	IV	*Section = 'S9_WILDLIFE_SANCTUARY'*

Appendix G – Classification implementation: summary by class

This appendix provides summaries of the implementation of each class as interpreted by a large language model (GPT-4o). These have been reviewed and adjusted as necessary. However, they remain loose summaries of the implementation, and the actual implementation in SQL should be referred to for reproduction. These are all available at https://github.com/manaakiwhenua/luis-config-nzlum/ and comments are used throughout to aid interpretation. However, these summaries are provided for ease of use and particularly for consideration of those unfamiliar with SQL. The AI is not always aware of limitations of input data and was managed to avoid an overly positive tone.

The overall process involves using a comprehensive SQL-based workflow to produce detailed land-use maps by systematically classifying land into various use classes. This is achieved by leveraging a variety of spatial and property data sources that are indexed using a DGGS and imported into a PostgreSQL database. The system employs a series of abstraction layers and temporary views to manage input data efficiently, allowing the classification logic to focus on high-level rules rather than low-level data intricacies.

Initially, input data are abstracted through data views, which unify and prepare various data sets for analysis. These data sets include geographical and administrative data from LINZ, land-cover data, irrigation records, and more. Temporary tables and views serve to structure and streamline access to this data, facilitating efficient data navigation and ensuring the classification rules can be applied robustly across different data partitions defined by the DGGS.

The core of the process is the classification itself, which is implemented through a series of SQL scripts that define the logic for categorising land into different use classes. Each class is implemented using specific criteria that focus on distinct attributes such as property use, zoning, water features, and modifications to the natural or built environment. Criteria may include indicators of land activity, legal designations, or environmental attributes, and they often incorporate ranking and priority logic to ensure the most appropriate classification.

Attributes such as water, land status, zoning, and land estate are also defined as part of the workflow, providing critical contextual data that supports the classification process, and they are also independently recorded. These attributes help refine the distinctions between different land-use classes by ensuring pertinent geographical and legal contexts are considered in classification decisions.

The result is a map output that provides an intricate overview of land uses. The use of temporary data structures and a clear hierarchical approach to data organisation ensures the overall system remains scalable and adaptable to various data sets, enabling a transparent and efficient mapping process. This structured approach not only supports precise land-use delineation but also facilitates integration with other geospatial analysis and decision-making frameworks.

Class 1.1.1: Strict Nature Reserve

Class 1.1.1 uses the PAN-NZ data set to identify areas classified as 'Ia' in IUCN categories, focusing on strict nature reserves. The SQL prioritises newer records, especially those with specific protection names, ensuring areas with high preservation standards are correctly classified.

Class 1.1.2: Wilderness Area

Implementation for Class 1.1.2 relies on the PAN-NZ data set, targeting entries marked 'Ib' in the IUCN classification. The classifier favours recent records and checks for specific protection names, ensuring accuracy in designating unmodified or slightly modified natural landscapes.

Class 1.1.3: National Park

This class employs PAN-NZ data to capture areas marked as 'II' in IUCN criteria, including special areas like Te Urewera. The SQL design favours the latest data iterations and prioritises those with explicit protection specifications, ensuring robust classification of national park territories.

Class 1.1.4: Natural Feature Protection

Class 1.1.4 utilises the IUCN 'III' category designation from PAN-NZ records. It leverages SQL to prioritise current entries with precise protection titles, effectively compiling a set of natural monuments and features worthy of conservation focus.

Class 1.1.5: Habitat or Species Management Area

Class 1.1.5 targets IUCN 'IV' regions identified in PAN-NZ data. The implementation relies on selecting entries with recent timestamps and well-defined protections, thus establishing classifications based on habitat or species conservation objectives.

Class 1.1.6: Protected Landscape

Through the PAN-NZ data set, Class 1.1.6 identifies 'V' IUCN categories. The SQL set-up values freshly updated records and those with detailed protection names, facilitating the classification of areas known for their landscape interactions with traditional practices.

Class 1.1.7: Other Conserved Area

Class 1.1.7 is implemented using PAN-NZ entries noted as not mapped or not specifically IUCN, leveraging a constructed priority rank focused on legislative designations. This classification extends to areas under alternative conservation governance, not captured under standard IUCN designations.

Class 1.2.0: Cultural and Natural Heritage

The SQL logic for Class 120 aggregates areas designated as historic reserves or Māori reservations, validated through legislation. It cross-references undeveloped land indicators from the Land Cover Database (LCDB) to ensure identification of culturally significant yet minimally developed land.

Class 1.3.0: Minimal Use from Relatively Natural Environments

Class 1.3.0 is determined using New Zealand Defence Force land ownership data and District Valuation Roll (DVR) property use records, excluding built-up areas using LCDB and focusing on

territories with minimal human intervention. The implementation seeks to categorise expanses that embody natural ecosystems with little modification.

Class 1.3.6: Defence Land

This class identifies defence-related lands by utilising New Zealand Defence Force-managed data from the Central Record of State Land (CRoSL) and corroborating with DVR, excluding developed zones. The SQL ensures specific military tracts dedicated to training and defence services are accurately classified.

Class 1.4.0: Unused Land and Land in Transition

Class 1.4.0 employs diverse data sets, from LINZ geographical delineations and LCDB classifications, to recognise unused or transitional landforms, such as braided rivers and scree. The SQL logic incorporates multiple data inputs to categorise lands without active economic output.

Class 2.1.0: Plantation Forests

Class 2.1.0 identifies areas as plantation forests using LUM and LINZ data, further supported by forestry consent records. The SQL configuration verifies data across modules aiming for consistent forest plantation classification, marked by scheduled timber production.

Class 2.2.0: Grazing Modified Pasture Systems

The SQL logic for this class identifies grazing land through the interplay of multiple data sets, such as LINZ, LCDB, and irrigation data. It analyses property uses coded for agriculture and overlays land capability data to categorise areas where modified pastures primarily support livestock grazing. The classification is supported by evidence of irrigation practices or consents as necessary, and additional notes or comments accompany irrigation activities to refine pasture designations precisely. Ranking focuses on priority classification based on agriculture-specific parcel characteristics.

Class 2.3.0: Short-Rotation and Seasonal Cropping

Class 2.3.0 uses LCDB and LUM data to identify cropping lands, cross-validating with DVR and crop rotations from MWLR data for seasonal information. The SQL leverages available cropping records to determine areas dedicated to short-lived but intensive agricultural practices, not excluding pastoral grazing in rotation.

Class 2.4.0: Perennial Horticulture

Implemented through LUM, LINZ, and irrigation analyses, Class 2.4.0 identifies orchard and vineyard areas by examining perennial crop declarations and verifying irrigation as a supportive management practice. The SQL targets established plots with continual yield patterns.

Class 2.5.0: Intensive Horticulture

Class 2.5.0 is defined by the presence of high-intensity cultivation loci such as greenhouses, leveraging data from descriptive source identifications regarding property improvements and irrigation. Implementation highlights advanced horticultural practices underpinned by substantial infrastructure investments.

Class 2.6.0: Intensive Animal Production

Class 260 captures defined animal farming locations using DVR and marine farming-related data sets, supported by recognised commodity types. The SQL distinguishes areas based on property category enhancements for specified intensive animal production.

Class 2.7.0: Water and Wastewater

The implementation of Class 2.7.0 focuses on built water features specifically associated with agricultural use. This includes identifying stock water reservoirs, farm dams intended for livestock drinking-water, effluent ponds linked with dairying, and areas used for effluent land application. The classification uses data from LINZ for natural and artificial water features, leveraging additional data sets such as dairy effluent discharge consents. Irrigation reservoirs and canals dedicated to agricultural purposes are identified by assessing the intersection of land use and documented water management practices. The SQL prioritises records where agricultural and water management data converge, ensuring these areas reflect their role in agricultural water storage, treatment, or distribution.

Class 2.8.0: Land in Transition

Through evaluating multi-source data, Class 2.8.0 identifies transitional areas, delving into crops and rural planning data to identify fluxing zones, prioritising data sets revealing potential transitions in land application and use.

Class 3.1.0: Residential

This class is implemented through a combination of the LINZ property database and auxiliary geographic data sets. It identifies residential areas by assessing property use classifications (e.g. codes beginning with '2' for lifestyle or '9' for residential) and verifying the presence of significant improvements in value. Also, irrigation data are examined to exclude any residential areas that might be involved in non-residential water management. The algorithm prioritises data showing non-vacant use and significant residential zoning to distinguish lived-in areas from vacant land.

Class 3.2.0: Public Recreation and Services

Class 3.2.0 is characterised using data from LINZ and other related data sets to highlight land used for public amenities and recreational services. It detects land-use types that support public infrastructure such as schools, healthcare facilities, and recreational grounds. The SQL implementation cross-references facility data with DVR actual uses and categories to confirm these areas serve a public function, ensuring land is correctly attributed to community-centred activities.

Class 3.3.0: Commercial

Implementation of Class 3.3.0 centres on identifying commercial land uses through the evaluation of databases, including the LINZ DVR. The classification targets areas designated for commercial activity, including retail and office spaces. It evaluates actual property use and improvements to categorise properties as commercial. The SQL logic favours entries with clear commercial descriptors and significant property improvements, aligning with expected commercial characteristics.

Class 3.4.0: Manufacturing and Industrial

Class 3.4.0 categorises areas through the analysis of properties designated for manufacturing and industrial use, primarily using data from the LINZ DVR. The classification examines property uses associated with industrial categories and considers descriptions of improvements and specific use codes. Auxiliary data, such as the Hazardous Activities and Industries List (HAIL), also contribute by identifying sites with historical or current contaminant activities linked with industrial processes. This includes activities such as foundries and metal treatment facilities. The SQL logic integrates these data points to delineate industrial zones, using both explicit industrial categorisations and ancillary contamination records.

Class 3.5.0: Utilities

The SQL framework for Class 3.5.0 identifies utility-related land by coupling LCDB utilities coverage with DVR classifications, targeting electricity, gas, and water infrastructure assets.

Class 3.6.0: Transport and Communication

Class 3.6.0 evaluates transport-specific data inputs such as road and rail networks sourced from DVR and other infrastructure documentation. It secures classifications for areas explicitly tied to transport utilities, supporting vehicular, rail, and communication line operations.

Class 3.7.0: Mining

Class 3.7.0 identifies areas associated with mining and extractive industries by utilising a combination of data sets, including the LINZ DVR and auxiliary spatial data sources. The classification process evaluates properties marked for mining activities, considering actual property use codes that specifically categorise land for mining purposes. This involves recognising regions such as quarries, mines, and tailings by examining land classified for mineral extraction and associated activities.

The SQL implementation further leverages the HAIL data set to detect sites with historical or ongoing environmental contaminant activities, which often align with mining operations. Additional criteria are used to distinguish between active and disused sites, using attributes such as site status and extracted substances, where documented. The classification also cross-references topographical data when available to enhance recognition of physically distinct mining features.

Class 3.8.0: Waste Treatment and Disposal

This class utilises data from LINZ and HAIL data sets to identify areas devoted to waste management processes. SQL queries focus on recognising landfills, recycling facilities, and wastewater treatment zones by examining site zoning, property use, and historical land management data. The classification also incorporates text search on property descriptions indicating facilities handling waste products. The algorithm gives preference to areas consistently documented as waste-related zones across sources.

Class 3.9.0: Vacant and Transitioning Land

Focused on identifying zones of minimal active use, Class 3.9.0 is built from DVR and property use data sets, highlighting areas under positive transition potentials or indefinite vacancy, ensuring accurate recording of partially occupied tracts or yet-to-be repurposed urban spaces.