Preliminary findings from the information synthesis for land use information classification

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# Introduction

New Zealand currently lacks widespread adoption of a comprehensive land use information system. Consequently, there has been a lack of consistent definition or approach to mapping land use at the national and regional levels. If we consistently understood land use across New Zealand and over time, we would have the opportunity to better understand the impacts of land use and land use change on ecosystem services, support the modelling of the impacts of climate change, and help profile natural disaster risks among other benefits.

# Background

Land use is recognised as a critical driver of environmental change and is underpinned by regional council and national reporting on several facets. However, there are several recognised inconsistencies in land-use classification practice within and between councils (see Cavanagh et al. 2017; Cavanagh et al, 2020, Stevenson et al 2020), industry, and research entities.

Greater consistency in land-use categorisation (across institutions, and time) is recognised as a high priority to inform on:

* Soil quality monitoring
* Wetland delineation
* Land degradation
* Land management
* Greenhouse gas emissions
* Carbon sequestration
* Urban development
* Transportation
* Changes in primary industry
* Natural disaster risk management
* Freshwater quality

Cavanagh and Whitehead (2022) provide a detailed review of different land use categorisations and previous efforts to develop land use classifications in New Zealand.

What are the vocabularies available, and what do they mean? How does the meaning deviate between councils, regions, applications and data?

# Glossary

‘Land use’, ‘land cover’ and ‘land management’ are often (erroneously) used interchangeably in discussions about land use. This erroneous use seems to largely stem from a lack of awareness of the distinct meaning of each of these terms. The following definitions, which have been drawn from the Australian Department of Agriculture, Water and the Environment, help to make explicit the differences.

* **Land use** means the purpose to which the land is committed, including the production of goods (such as crops, timber, and manufactures) and services (such as defence, recreation, biodiversity, and natural resources protection)
* **Land management practice**means the approach taken to achieve a land-use outcome – the 'how' of land use (e.g., cultivation practices such as minimum tillage, direct drilling, and choices around stocking rate density).
* **Land cover**refers to the physical surface of the earth, including various combinations of vegetation types, natural bare surfaces (e.g., exposed rock or gravel, permanent snow and ice, etc.), and water bodies as well as anthropogenic elements, such as agriculture, transport infrastructure and built environments. Land-cover classes can usually be distinguished by characteristic patterns using remote sensing.
* **Land use classification** provides additional information on land cover, and the types of human activity involved in land use. It may also facilitate the assessment of environmental impacts on, and potential or alternative uses of, land. (United Nations, 1997)

Other common terms:

* **Geographic unit** means the geographic entity or entities to which a land use classification (or relevant attributes) may be attached. Many land use classification systems attempt to classify parcels of land; the parcel is therefore the geographic unit. They may range from plot, to field, to farm to catchment to region. The geographic unit may not be a specific type of geographic object that a person may recognise; it may be a small, arbitrary raster or DGGS cell or perhaps areas that appear sufficiently homogenous from a remote sensing perspective to be treated as a group.
* **Land use classification system**
* **Land use information system** means a collection of software and tools that are designed for the specific task of classifying land use. This often requires the integration of large amounts of geospatial data and the development of complex classification rules. MWLR has developed several pieces of software that could contribute to land use information systems, including LUMASS[[1]](#footnote-2) and PyLUC[[2]](#footnote-3) (which are open source; LGPL and GNU Public License, respectively) and LUIS (which is not currently open source).
* **Land use classification framework** is loosely taken to refer to a wider system of guidelines and governance around a land use classification system. For example, the framework of review that is applied to the Australian Land Use and Management Classification system, the guidelines for how ALUM itself is structured (e.g. that is should be hierarchical, general-purpose, and that it may record ancillary uses as well as a prime use), the decision to conform the classification to the Australian Spatial Data Infrastructure (ASDI) standard for land use datasets, and to publish an environmental vocabulary service to make the classification system machine interpretable. The framework may determine how to record information that is ancillary to the land use information itself, i.e. a data schema that goes beyond a vocabulary. This may include provenance information, commodities, management practices, and how to present confidence and geographic scale to end users of the land use data product.

Other potential dimensions of land information (for example, land tenure) are frequently included within land use classification systems, but have important distinctions:

* **Land tenure** refers to ways of holding land, e.g. fee simple, customary title, leasehold, life estate, etc. Related information, such as whether the land is owner-occupied, may be captured in a classification system for land tenure, which may be valuable information alongside land use. Whether land is publicly owned is often an important dimension of a hierarchical classification of land use, but strictly relates to land tenure.
* **Land use intensity** refers to the amount of a thing per unit area, and may refer to attributes such as stocking rates, fertiliser application, or population density.
* **Land value** refers to the fiscal value of the land and is formally defined in the Ratings Valuation Act 1998. Value of improvements specifically relates to the added value that improvements give to land. Improvements, in relation to land, refers to all work done, or material used on or for the benefit of land by the expenditure of capital or labour.
* **Land use capability –** Land use capability primarily evaluates the productive capacity depending on physical qualities of the land, soil and environment. Key factors assessed are the susceptibility to erosion, steepness of slope, climate, susceptibility to flooding, liability to wetness or drought, salinity, and depth, texture, structure and nutrient supply of the soil.
* **Land use suitability -** Land use suitability can be broadly defined as the ‘fitness’ of a given piece of land for a defined land use. The process of land suitability classification is the appraisal and grouping of specific areas of land in terms of their absolute or relative suitability for a defined use as determined by a specified set of diagnostic criteria – in this regard land-use capability can be considered as one version of a land use suitability assessment. Other NZ work has focused on land use suitability with regards to impact on catchment water quality.

Not all conflations of land use, cover and other dimensions are erroneous, but rather come about due to pragmatic reasons when there are specific justifications for the production of land use information. For example, because the purpose of a land use classification was to satisfy the needs of the NPS-FM Science Programme at Environment Southland, Pearson & Couldrey (2016) devised a system of land use and land cover classification that had classes that allowed for analysis ordered towards this end. That this classification may be more generally useful was incidental, and the distinction between land use and land cover was crucial.

## Land Use Classification/Information Systems

Rutledge et al. (2009) conducted a fundamental and wide-ranging review of geospatial land use classification systems for application in New Zealand. This drew a distinction between four types of land-use classification systems, increasing in complexity:

* Categorical approaches with discrete classes with no relationships between classes.
* Hierarchical approaches with nested sets of classes, where high level classes (e.g. urban) become divided into more specific sub-classes (e.g. residential, commercial).
* Multidimensional approaches store information about attributes for unit areas and these are. recombined to generate different sets of land use classes for particular applications.
* Semantic classifications where land use is described using rich vocabularies and a formal grammar, from which classifications can be derived.

International practice is typically to construct hierarchical classifications and many countries adopt official versions of such classifications. However multidimensional approaches have been practiced, such as The American Planning Association’s (APA) LCCS, SIOSE in Spain, and LENZ in New Zealand (for physiography).

Rutledge et al. (2009) noted **four** distinct attempts to develop a land-use classification; none of these were officially adopted, however the process of land valuation in New Zealand does include a de facto land use classification system that is perhaps the most successful implementation in terms of nationally consistent adoption by multiple practitioners. It is (perhaps wryly) observed by Rutledge et al. (2009) that it is typical for reviews of previous land-use classification systems to conclude by the proposition of a new classification system. It is therefore self-evident that there are some fundamental limitations in the development and application of land-use classifications that lead to this outcome.

It is because of such limitations, and despite a lack of proven semantic classification implementations, that Rutledge et al. (2009) recommended the adoption of a semantic approach to land use classification. This is not incompatible with the idea of a hierarchical or even categorical land use classification; rather it recognises that no single hierarchical classification may ever be satisfactory to all users and therefore what is crucial is to record information about land and geographic objects in landscapes in such a way that multiple interpretations of land use can be constructed.

Rutledge et al. (2009) reviewed three historical attempts to develop an official land use classification in New Zealand that failed, and two that have seen implementation:

1. **Survey and classification for land in New Zealand: a basis for planning (Cumberland, 1944).** Cumberland’s suggestion was to adopt a system developed by the Tennessee Valley Authority (an American organisation similar to the former catchment boards). It is an extremely comprehensive multidimensional classification system where relevant attributes are organised into five broad groups, and then each attribute has categorical or ordinal values that are represented by digits which are then assembled into a distinct identifier. An implementation of this system at wide geographic scale would be challenging due to the richness of the information to completely fulfill the classification (e.g. “amount of land rendered unproductive by weeds”); much of the information was presumably intended to be captured laboriously through fieldwork. However, as a demonstration of a multidimensional land use classification system, it is richly illustrative. Each dimension is clear and based on observable criteria.
2. **Draft New Zealand Land Use Classification (Department of Statistics, 1984).** A committee was formed in 1981 to provide a standard system for recording land use activities. A hierarchical classification system was created, which was informed by existing classifications: manufacturing classes from the NZ Standard Industrial Classification, and the others from the Auckland Regional Authority. The classification had four levels, and approximately 1000 total categories. It was encoded as a four-digit code, therefore each level was limited to 10 categories (0-9). The classification was never formally adopted or used.
3. **Australia and New Zeeland Land Use Codes (ANZLUC) (Standards Australia and Standards New Zealand, 1999).** Similar to the 1984 classification, ANZLUC was a 4-level hierarchical classification consisting of 1,132 classes at Level 4. A set of 23 auxiliary codes organised into three categories (general, agriculture, mining, or extractive industries) provided information on manner of use, such as owner-occupied, extensive agriculture, or bore hole (i.e. mining). The standard recommended associating more than one code for areas exhibiting multiple uses spatially (e.g. service and recreation or multiple level buildings), temporally (e.g. rotating crops), or both. It was not implemented.
4. **Land-use New Zealand (LUNZ) (MWLR, 2004).** A rural land use dataset for NZ, formed by combining data from AgriBase (Sanson, 2005), LCDB (v2), LENZ and Ministry of Agriculture and Fisheries monitor farm types. The unit of observation is sub-farm areas: a homogenous plot of land on a specific farm with a unique land cover type. Implementation issues were apparent due to the deficiencies of AgriBase data, and a probabilistic model was used to infer likely land use in the presence of missing input data. Regional notations were part of the classification schema, in a similar fashion to Beef + Lamb NZ’s classification of farms which draws regional distinctions.
5. **LINZ rating valuation rules (2008).** Under the ratings valuations rules 2008 (LINZS30300) (Sullivan, 2010), which stemmed from the property rating rules prepared under the Ratings Valuations Act of 1998, LINZ includes assessments of land use which are recorded for every rating unit. A multidimensional classification framework that captures multiple attributes for a defined geographic unit (rateable land), information is included about land use as activity, but also permitted activities (council zone), and details about the principal building situated on the rating unit (e.g. age, condition, construction materials, etc.). Perhaps due to the power of the Valuer-General and the standard promulgated by LINZ, this is necessarily implemented by valuers. However, obtaining this information as useful geospatial data can be expensive, as local governments typically contract third parties (such as QV or Opteon) to manage their District Valuation Roll (DVR). LINZ has a role in auditing DVRs. Companies including CoreLogic and Headway Systems standardise and commercially sell a collective DVR for New Zealand. Valuation is performed every three years, but as this happens via mass appraisal, it typically does not involve an on-site re-evaluation of the recorded land use, which means that recorded land uses in DVRs actually have an indeterminate date. The classification schema does not effectively represent mixed land use at the secondary level of the classification; for instance, where multiple rural industry activities occur within the same rating unit, a rating unit is assigned the category 10 “Multi-use within rural industry”. This actually represents a loss of information relative to simply recording multiple uses individually. It is still, however, incredibly valuable information, particularly as there is some assurance that a human has assessed land use at some point.

**Why have classification systems been left unimplemented?**

When proposing a globally applicable (agricultural) land use classification, Mücher et al. (1993, cited in Rutledge et al., 2009) argued that there are several common “drawbacks” of existing classifications that Rutledge et al. propose as reasons for the failure of classification systems to be adopted. Perhaps it is pertinent to be aware of these when designing another classification system:

* The lack of a sound definition of the units of analysis: these may range from field to farm to region and are too often confused with the mapping unit.
* Overlapping land-use classes because of poorly defined criteria. Most hierarchical classifications are only comprehensive for their scope of interest at the first hierarchical level; however they are often far from comprehensive at lower hierarchical levels.
* Subjective assignment of land use to a specific class due to the nearly ubiquitous absence of quantitative class boundaries, for example, critical or threshold values of included criteria.
* The combination of land use with other features such as climate characteristics that may influence land use but are not inherent features of land use.
* Objectives of land-use classification are often closely tied to regional or disciplinary focus.

## Summary of selected land classification systems

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Classification System | Year | Type | Context | Summary |
| Australian Land-Use and Management Classification (ALUM)  [ABARES] | 1999-(v8: 2018) | Land use | Australia | A three-tiered hierarchical land use classification system. Structured by the degree of modification relative to natural land cover. Version 8 includes fields to collect commodity and land management practice information. |
| Land Cover Classification System (LCCS)  [FAO] | 2000? | Land cover | Global | A systematic, hierarchical, unambiguous, and internally consistent multiapproach to land cover classification that seeks to avoid the situation where land cover cannot be classified as one of a set of pre-determined classes. LCCS describes land properties based only on land cover types, disregarding land use in most instances. |
| Land-Based Classification Standards (LBCS)  [APA] | 2000- | Land use | USA | A multidimensional approach to land use classification with dimensions: activities, functions, building types, site development character, and ownership constraints. Each dimension has its own hierarchical classification system. |
| High Resolution Land cover/Land use  Information System in Spain (HR SIOSE) | 2005- | Land use/land cover | Spain | A multidimensional classification system where polygons (cadastral boundaries) are attributed and related to other objects. Within polygons, land covers are noted as percentage values. |
| Land Use and  Carbon Analysis System (LUCAS) Land Use Map (LUM)  [MfE] | 2008- | Land use / Land cover | NZ | A land use/land cover map with particular attention to temporal consistency to enable analysis of change over time, relative to a 1989 baseline. Justified by New Zealand being signatory to the United Nations Framework Convention on Climate Change and commitments for the Kyoto Protocol and the Paris Agreement. |
| Land Ise in Rural New Zealand (LURNZ)  [MOTU] | 2012?- | Land use / land cover | NZ | An econometric model with associated non-hierarchical land classification system with 11 classes focused on the major rural industry types (forestry, dairy, sheep and beef, horticulture, etc.) |
| New Zealand Forestry and Agricultural Regional Model (NZ-FARM)  (Daigneault et al 2018)  [MWLR] | 2017?- | Land use / land cover | NZ | An econometric model intended to predict land use change over time at a catchment scale. Does not entail a particular land use classification system but choice of classes depends on available information e.g., regarding revenue and profit. Consequently, inherits classifications such as those used by Beef + Lamb NZ for sheep and beef farms. |
| Farm classes  [Beef + Lamb NZ] |  | Production systems | NZ (sheep and beef farms) | Classification of New Zealand sheep and beef farms into eight classes. Used for publishing aggregate statistics, and then by farmers to compare their operations to those of their peers. |
| Farm Production Systems  [Dairy NZ] |  | Production systems | NZ (dairy farms) | Classification of dairy farm production systems by allocation of imported feed balance into five classes, primarily to balance feed supply and demand. |
| Environment Southland (bespoke) | 2016 | Land use / land cover | NZ (Southland) | A property-scale two-tier hierarchical land use classification for Southland. Intended for use setting catchment-scale freshwater policy. The data also includes attributes giving the extent of various land covers in hectares. A “technical layer” was also produced that included ancillary data on physiography and freshwater management units (FMUs) to make it easier to use for its intended application. |
| Land Environments of New Zealand (LENZ) | 2003- | Physiography / Land use capability | NZ | A multidimensional classification with 15 dimensions (or attributes) related to climate, landform, and soil. Ultimately manifested as a hierarchical classification of four levels and 500 distinct classes (land environments), the underlying design was non-hierarchical. Distinct groups were determined *a posteriori* by using a multivariate clustering process. |
| Waikato Integrated Scenario Explorer (WISE)  (Rutledge et al, 2016) | 2006- | Land use / Land use change | NZ (Waikato) | A future scenario evaluation tool developed for the Waikato region. One component of this is future land change, which requires a land use classification, and a map of present-day land use. Land use change is modelled using cellular automata, on a 25 m² grid, with 25 classes of land use (32 would have been the technical limit). Land use classes are organised into three types: vacant states, functions, and features. The type determines how the land use is treated in the modelling; features are static, but functions are dynamic and dependent on market conditions. |
| Horizons Regional Council Land Use Map  (HORLUC)  (Herzig et al, 2020) | 2020 | Land use / Land cover | NZ (Manawatu-Whanganui) | A “primary” land use classification was designed, and classes assigned to parcels. A “secondary” classification or hierarchical level was achieved by applying a geospatial union between parcels and the LCDB. The classification had 33 classes at the secondary level; structured under 11 classes at the primary level. It was designed to support Horizons Regional Council to evaluate the opportunities and constraints on intensive land-use expansion within the region. Auxiliary land resource information was provided at the parcel scale: NZLRI (land use capability and fundamental soil layer), Māori land, ownership information, and water management zones. |

# Manaaki Whenua – Landcare Research’s previous projects and research

## Refinement of Land-use categorisation for State of the Environment Soil quality monitoring

Land use is recognised as a critical driver of environmental change, and regional council SOE soil quality monitoring underpins national reporting on land use (e.g. *Our Land 2021* (MfE 2021)). However, there are a number of recognised inconsistencies in land-use classification used for State of the Environment Soil quality monitoring between councils (see Cavanagh et al. 2017; Cavanagh et al, 2020, Stevenson et al 2020). To address this issue, Cavanagh and Whitehead (2022, 2023) undertook review and evaluation of land-use categories used and collaborated with regional councils through LMF to more clearly define land-use categories, as well as specify key attributes and information that should be captured during the SOE soil quality Monitoring. This information in turn was used to develop a prototype tool that allows for the automated categorization of land Ause based on information captured. Cavanagh and Whitehead (2023) also provide a preliminary mapping of the refined SOE soil quality land use categories with categories used in some other New Zealand land-use/land cover classification schemes. An overview of the agreed land use categories, their relationship to the land use types specified in the National Environmental Monitoring Standard for Soil Quality and Trace Elements (NEMS) is provided in Table x.

Table. Summary of land-use category definitions for state of the environment soil quality monitoring, and attributes used to confirm land use. Italics indicates land uses that were discussed but are currently not incorporated into the model. (Adapted from Cavanagh and Whitehead 2023)

| Category | NEMS class | Potential  sub-groups | Definition |
| --- | --- | --- | --- |
| Conservation and natural environments | Indigenous vegetation | Forest | Native forest, tussock, shrubland, and scrub dominated by indigenous species. Undisturbed or unfertilised in recent decades. May include cut-over forest. |
|  | Scrub and shrubs |
|  | Native grassland |
| Plantation forestry | Exotic forest | Exotic forestry | Plantations of exotic tree species grown for pulp and timber production, generally radiata pine, but can include other exotic species (e.g. redwood, Douglas fir). Usually harvested using clear-felling methods.a |
| Perennial horticulture | Horticulture | Tree crops | Permanent tree, vine or berry cropsa |
|  | Vine crops |
|  | Berry fruit |
| Short-rotation croppingb | Cropping | Arable and mixed cropping | Predominantly grain, seed or fodder crops; over time may include short-term (c. 1–3 years) pasture and livestock rotations, and/or vegetable rotations. Pasture and livestock rotations may occur up to 50% of the time. Includes maize, barley, wheat, peas, other grain and seed crops, and fodder crops. May be used for dairy support.c |
|  | Vegetable cropping | Predominantly rotations of vegetable crop grown for human consumption; may include livestock rotations but less likely. |
| Dairy | Dairy | Bovine | Dairy is the area on which milking cows are grazed during the milking season. Dairy may include rotations of grazed forage crops and maize for silage, and dry-stock grazing. Where the land is permanently used for dry-stock grazing it should be classified under dry-stock land use.d |
|  |  | *Non-bovine* | *Land used for raising non-bovine stock for milking. Non-bovine dairy may include areas of grazed forage crops and maize for silage.* |
| Dry stock | Dry stock | Flat–rolling | All other (non-milking platform) pasture, including dry-stock farms for sheep, beef, deer, goats, horses, dairy support,d and cut and carry. Includes slope <15°. May include rotations for arable or vegetable crops.d |
|  | Hill country | As above for flat–rolling, but designates land on a slope >15°, and anthropogenic inputs are anticipated to be reduced. High-country farming will be captured under production for relatively natural systems. |
| Recreation and culture | Urban open space | Urban open space – grassland | Open areas of grass in urban areas, including parks, school grounds and playgrounds |
| Rural residentiale |  | *With agriculture*  *Without agriculture* | Residential properties with low-intensity (non-commercial) land management practices (e.g. hobby farm, on land in rural or peri-urban areas). |
| Production from relatively natural environments |  | Grazing | This captures high-country farming with domestic stock grazing on native vegetation where there has been limited or no deliberate attempt at pasture modification. Some change in species composition may have occurred. |
|  | *Other* | *Could include indigenous forestry, honey production.* |
| *Carbon farming* |  | *Exotic trees* |  |
|  | *Indigenous* |  |
| *Land in transition* |  | *Native plantings* |  |
|  | *Natural regeneration / unmanaged* | *Vegetation cover could be exotic or indigenous* |

a Based on the NEMS-SQ definition.

b NEMS-SQ description for cropping: annual crops, usually grown on a rotational system that can include a short-term (c. 1–3 years) pasture rotation. Includes maize, barley, wheat, peas, other grain and seed crops, fodder crops, and commercial vegetables (includes market gardens).

c Modified from NEMS-SQ definition; see Table 1 for original definition.

d Dairy support is land that is used to support non-lactating dairy stock (dry cows, heifers & calves). It will include any feed required, and will often include winter crops and potentially summer crops (location/irrigation dependent), along with cereal crops, such as maize, barley, wheat. It can also include feed that is cut and carried to the milking platform.

5The rural residential categorisation is based partly on the rural/lifestyle block description from the user guide for the NES for soil contaminants (MfE 2012), where rural residential land use is applicable to the residential vicinity of farmhouses but not the productive parts of agricultural land. The descriptions from the Australian Land Use and Management classification[[3]](#footnote-4) for rural residential may also be useful, specifically being rural allotments with houses built (or being built) and agricultural activity at the sub-commercial and/or hobby scale (excluding backyard/domestic garden areas or livestock as pets). An option for rural residential without agriculture is also used, along with a land area size cut-off. Rural residential is considered to apply to a land area of 2 ha or less; land area larger than this should be classified under a different category relevant to the land use occurring at the site

## ALUM—Australian Land-Use and Management Classification

The ALUM deserves particular attention due to its widespread adoption in Australia, and that MWLR recently implemented this classification system for a regional land use map of Northland. MWLR has not had a role in designing any aspect of it.

The Australian Land Use and Management (ALUM) Classification system provides a nationally consistent method to collect and present land use information for a wide range of users across Australia. The latest version (Version 8) of the classification conforms to the Australian Spatial Data Infrastructure (ASDI) standard for land use datasets and is also available as an environmental vocabulary service or glossary.

The framework for assigning attributes addresses the following:

* **Level of intervention** - the degree of modification to the 'natural' landscape. Precedence is also given to the modelling capabilities of data over monitoring capabilities, and monitoring capabilities over descriptive uses.
* **Generality** - the classification is designed for users who are interested in both processes (e.g. land management practices) and outputs (e.g. commodities).
* **Hierarchical structure** - facilitates and promotes aggregation/ disaggregation of related land uses, the addition of levels or classes and relevance at a range of scales.
* **Prime use/Ancillary use** - some land can be subject to a number of concurrent land uses. Land use class allocations are based on the primary land management objective of the nominated land manager. Ancillary or secondary uses can also be recorded.

The classification has six primary classes of land use that are distinguished in order of generally increasing levels of intervention or potential impact on the natural landscape.

1. **Conservation and Natural Environments**: Land is used primarily for conservation purposes, based on the maintenance of essentially natural ecosystems already present.
2. **Production from Relatively Natural Environments**: Land is used mainly for primary production based on limited change to the native vegetation.
3. **Production from Dryland Agriculture and Plantations**: Land is used mainly for primary production, based on dryland farming systems.
4. **Production from Irrigated Agriculture and Plantations**: Land is used mainly for primary production, based on irrigated farming.
5. **Intensive uses**: Land is subject to substantial modification, generally in association with closer residential settlement, commercial or industrial uses.
6. **Water**: Although primarily land cover types, water features are regarded as essential to the classification.

The ALUM Classification version 8 includes fields to collect commodity and land management practice information. These fields allow consistent recording of more detailed information about crops, livestock and management techniques which can be determined at the time of mapping. This information allows further distinction within a land use class such as separating tree fruits into bananas and mangoes. It is also particularly useful in responding to or preparing for biosecurity incidents.

In producing a land use map for Northland Regional Council, Law and Ardo (2023) elected to adopt ALUM v8 rather than develop (another) bespoke classification system. Minor adaptations were made to allow for intended use cases, but these were able to be captured within the accepted schema of ALUM (e.g., using the “comments” field to capture some additional cover information for riparian vegetation on farms). Although some limitations for the application of ALUM in New Zealand were noted, the benefits of having a stable classification system, including a controlled list of terms for commodities and management practices, and a means to capture some information about classification confidence and provenance (source and date), were immense. Particularly, the ability to quickly adopt a published standard for land use information meant that more attention was paid to preparing and combining data in useful ways to improve the accuracy and detail of the data product rather than spending time debating the hierarchy of classes.

The ALUM classification as operated by the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES, the science and economics research division of the Department of Agriculture, Fisheries and Forestry), has been developed iteratively and is currently in version 8, which included the ability to describe agricultural and mineral commodities and management practices. Its scope extends beyond the terminology itself, to defining the minimum spatial unit, data schema, and governance arrangements. Its wide and consistent adoption and revision is considered aspirational for an equivalent system for application in New Zealand. In particular, the intention to revise the system over time in a backwards-compatible manner.

## Dairy NZ

For benchmarking, Dairy NZ has a simple system of classification of dairy farms into five classes, based on the importation of feed:

|  |  |
| --- | --- |
| System | Description |
| System 1: All grass self-contained, all stock on the dairy platform | No feed is imported.  No supplement fed to the herd except supplement harvested off the effective milking area, and dry cows are not grazed off the effective milking area. |
| System 2: Feed imported, either supplement or grazing off, fed to dry cows | Approx. 4–14% of total feed is imported. Large variation in %, as in high rainfall areas and cold climates such as Southland most of the cows are wintered off. |
| System 3: Feed imported to extend lactation (typically autumn feed) and for dry cows. | Approx. 10–20% of total feed is imported.  Westland: feed to extend lactation may be imported in spring rather than autumn. |
| System 4: Feed imported and used at both ends of lactation and for dry cows. | Approx. 20–30% of total feed is imported onto the farm. |
| System 5: Imported feed used all year, throughout lactation and for dry cows. | Approx. 25–40% (but can be up to 55%) of total feed is imported. |

## Beef + Lamb NZ

For benchmarking and statistical reporting, Beef + Lamb NZ has a system of classifying commercial sheep and beef farms according to multidimensional criteria, the broadest of which is geographic region:

|  |  |  |
| --- | --- | --- |
| Farm class | Description | Estimated farms (2019-20) |
| 1. South Island high country | Extensive run country located at high altitude. These farms run a diverse mix of operations which include breeding sheep, often fine wooled, breeding cows and deer. Stocking rate is typically up to three stock units per hectare. Located mainly in Marlborough, Canterbury and Otago. | 200 |
| 2. South Island hill country | Traditionally store stock producers with a proportion sold prime in good seasons. Carrying between two and seven stock units per hectare, they usually have a significant proportion of beef cattle. | 620 |
| 3. North Island hard hill country | Steep hill country or low-fertility soils with most farms carrying 6–10 stock units per hectare. While some stock are finished, a significant proportion are sold in store condition. | 920 |
| 4. North Island hill country | Easier hill country or higher-fertility soils than Class 3. Mostly carrying between 7 and 13 stock units per hectare. A high proportion of sale stock sold is in forward store or prime condition. | 3,055 |
| 5. North Island intensive finishing farms | Easy-contour farmland with the potential for high production. Mostly carrying between 8 and 15 stock units per hectare. A high proportion of stock are sent to slaughter and replacements are often bought in. | 1,045 |
| 6. South Island finishing-breeding farms | A more extensive type of finishing farm, also encompassing some irrigation units and frequently with some cash cropping. Carrying capacity ranges from 6 to 11 stock units per hectare on dryland farms and over 12 stock units per hectare on irrigated units. Mainly in Canterbury and Otago. This is the dominant farm class in the South Island. | 1.820 |
| 7. South Island intensive finishing farms | High-producing-grassland farms carrying about 10–14 stock units per hectare, with some cash crop. Located mainly in Southland, south and west Otago. | 1,040 |
| 8. South Island mixed cropping and finishing farms | Located mainly on the Canterbury Plains. A high proportion of their revenue is derived from grain and small seed production as well as stock finishing. | 465 |

## Land Cover Database (LCDB)

The New Zealand LCDB dataset is a multi-temporal classification of New Zealand’s land cover. The mainland version consists of 33 different classes (35 if offshore Chatham Islands are included). Currently, LCDB is up to its 5th version (v5.0), while land cover classes have been revised between version 1, 2 and 3 (backwards compatibility is ensured) it has been stable ever since. The classes of LCDB have been used to guide national and regional environmental monitoring, forest and shrubland inventory, biodiversity assessment, trend analysis and infrastructure planning.

The LCDB classification is a top-down hierarchical system that consists of 7 first order classes at the top level and increasing to 33 classes in the lower level. The classes outlined in LCDB classification system are designed to be harmonized wherever possible with the other international land cover initiatives, i.e., the FAO/UNEP Land Cover Classification System (Thompson, 2003). The first order classification is based on physical features of the land cover (i.e. grassland, cropland, water bodies etc.). While the second order classes are based on other characteristics (i.e., geomorphological- Lake or Pond; phenology- Evergreen/Deciduous; or use- Transport Infrastructure).

The classes of the LCDB consists of:

1. Artificial surfaces: Anthropogenic land cover, mainly consisting of use classes – Built-up Area, Uban Parkland/Open Space, Surface Mines and Dumps, and Transport Infrastructure.
2. Bare or lightly vegetated surfaces: Natural surface with little to no vegetation – Sand and Gravel, Gravel and Rock, Landslide, Permanent Snow and Ice, and Alpine Grass/Herbfield.
3. Water bodies: Open water bodies – Lake or Pond, River, and Estuarine Open Water.
4. Cropland: Land that is occupied by crop production – Short-rotation Cropland, and Orchard Vineyard & Other Perennial Crops.
5. Grassland, Sedgeland, Saltmarsh: land where cover is predominantly vegetated by grass, sedges or marshland – High Producing Grassland, Low Producing Grassland, Tall Tussock Grassland, Depleted Grassland, Herbaceous Freshwater Vegetation, Saline water Vegetation, and Flaxland.
6. Scrub and/or Shrubland: land where vegetation is dominated by woody scrubs- Fernland, Gorse and/or Broom, Manuka and/or Kanuka, Matagouri or Grey Scrub, Broadleaved Indigenous Hardwoods, Sub Alpine Shrubland, and Mixed Exotic Shrubland. Chatham Islands classes – Peat Shrubland, Dune Shrubland.
7. Forest: land where cover is predominantly forest cover- Exotic Forest, Forest – Harvested, Deciduous Hardwoods, Indigenous Forest, and Mangrove.

## Land Use and Carbon Analysis System Land Use Map (LUCAS LUM)

New Zealand is a signatory to the United Nations Framework Convention on Climate Change and the Paris Agreement. These agreements require New Zealand to submit an inventory of greenhouse gas emissions, annually and biannually respectively. Underpinning New Zealand’s reporting of greenhouse gas emissions is the Land Use Carbon Analysis System (LUCAS) Land Use Map (LUM). This is a national digital temporal map of land use and land use change compiled for nominal dates beginning at 31 December 1989.

The LUCAS mapping requires land use to be mapped, rather than land cover. However, for its intended purposes, there is a clear entailment between land cover and land use. Land-use maps rely on an understanding of how an area of land is used, or managed, over time. The LUCAS land use map (LUM) has twelve major classes and was developed to provide input on carbon accounting, specifically to underpin New Zealand’s international reporting obligations. To meet this requirement, the LUM’s baseline is 1989. The LUM has had four additional time steps added, nominally 2007, 2012, 2016 and 2020 (due for release April 2024).

A general description of the land-use classes mapped and/or recorded for LUM is shown in table below. The woody land-use classes (namely, Natural forest, Pre-1990 planted forest, Post-1989 forest and Grassland – with woody biomass) are unique to LUM and the definition of these land-use classes is in line with international good practice guidance (IPCC, 2003, chapter 2). Several of these are focused on the status of the forest or on the intention for the land and not necessarily the actual land cover at the time. For instance, a post-1989 forest can exist from the moment the land is ‘designated’ for that use, possibly before any trees are actually planted in the ground. Another example is where infrastructure, transport and utilities (such as roads and tracks less than 30m wide) related to a specific land use type, are often grouped within the same boundary (see definitions in the table below).

The LUCAS LUM classification system is fit for the specific purpose for carbon monitoring and accounting, as well as enable reporting on United Nations commitments to the Kyoto Protocol and now, the Paris Agreement. However, this limits the use of this classification system, and it is not intended for use as a general New Zealand land use map.

LUCAS LUM 2020 land use class definitions and sub-classes:

|  |  |  |
| --- | --- | --- |
| **Land Use Class** | **Definition** | **Sub-classes** |
| **71 - Pre-1990 natural forest** | Areas that, on 1 January 1990, were and presently include:   * tall indigenous forest * self-sown exotic trees, such as wilding pines and grey willows, established before 1 January 1990 * broadleaved hardwood shrubland, mānuka–kānuka (*Leptospermum* *scoparium*–*Kunzea* *ericoides*) shrubland and other woody shrubland (≥30 per cent cover, with potential to reach ≥5 metres at maturity *in situ* under current land management within 30–40 years) * areas of bare ground of any size that were previously forested but, due to natural disturbances (e.g., erosion, storms, fire), have temporarily lost vegetation cover * areas that were planted forest at 1990 but are subsequently managed to regenerate with natural species that will meet the forest definition * roads and tracks less than 30 metres in width and other temporarily unstocked areas associated with a forest land use. | 0 - Unknown  120 - Shrubland  121 - Tall Forest  122 - Wilding trees |
| **72 - Pre-1990 planted forest** | Areas that, on 1 January 1990, were and presently include:   * radiata pine (*Pinus radiata*), Douglas fir (*Pseudotsuga menziesii*), eucalypts (*Eucalyptus* spp.) or other planted species (with potential to reach ≥5 metre height at maturity *in situ*) established before 1 January 1990 or replanted on land that was forest land as at 31 December 1989 * exotic forest species that were planted after 31 December 1989 on land that was natural forest * riparian or erosion control plantings that meet the forest definition and that were planted before 1 January 1990 * harvested areas within pre-1990 planted forest (assumes these will be replanted, unless deforestation is later detected) * roads, tracks, skid sites and other temporarily unstocked areas less than 30 metres in width associated with a forest land use * areas of bare ground of any size that were previously forested at 31 December 1989 but, due to natural disturbances (e.g., erosion, storms, fire), have lost vegetation cover. | 0 - Unknown  201 - Pinus radiata  202 - Douglas fir  203 - Unspecified exotic species  204 - Regenerating natural species |
| **73 - Post-1989 forest** | Includes post-1989 planted forest, which consists of:   * exotic forest (with the potential to reach ≥5 metre height at maturity *in situ*) planted or established on land that was non-forest land as at 31 December 1989 (e.g., radiata pine, Douglas fir, eucalypts or other planted species) * riparian or erosion control plantings that meet the forest definition and that were planted after 31 December 1989 * harvested areas within post-1989 forest land (assuming these will be replanted, unless deforestation is later detected).   Includes post-1989 natural forest, which consists of:   * forests arising from natural regeneration of indigenous tree species as a result of management change after 31 December 1989 * self-sown exotic trees, such as wilding conifers or grey willows, established after 31 December 1989.   Includes areas within post-1989 natural forest or post-1989 planted forest that are:   * roads, tracks, skid sites and other temporarily unstocked areas associated with a forest land use * areas of bare ground of any size that were previously forested (established after 31 December 1989) but, due to natural disturbances (e.g., erosion, storms, fire), have lost vegetation cover. | 0 - Unknown  122 - Wilding trees  201 - Pinus radiata  202 - Douglas fir  203 - Unspecified exotic species  204 - Regenerated natural species |
| **74 - Grassland with woody biomass** | Includes:   * grassland with matagouri (*Discaria toumatou*) and sweet briar (*Rosa rubiginosa*), broadleaved hardwood shrubland (e.g., māhoe – *Melicytus ramiflorus*), wineberry (*Aristotelia serrata*), *Pseudopanax* spp., *Pittosporum* spp.), mānuka–kānuka (*Leptospermum* *scoparium*–*Kunzea* *ericoides*) shrubland, coastal and other woody shrubland (<5 metres tall and any per cent cover) where, under current management or environmental conditions (climate and/or soil), it is expected that the forest criteria will not be met over a 30- to 40-year period * above-timberline shrubland vegetation intermixed with montane herbfields (does not have the potential to reach >5 metres in height *in situ*) * grassland with tall tree species (<30 per cent cover), such as golf courses in rural areas (except where the Land Cover Database has classified these as settlements) * grassland with riparian or erosion control plantings (<30 per cent cover) * linear shelterbelts that are >1 hectare in area and <30 metres in mean width * areas of bare ground of any size that previously contained grassland with woody biomass but, due to natural disturbances (e.g., erosion, fire), have lost vegetation cover. | 0 - Unknown |
| **75 - High producing grassland** | Includes:   * grassland with high-quality pasture species * linear shelterbelts that are <1 hectare in area or <30 metres in mean width (larger shelterbelts are mapped separately as grassland – with woody biomass) * areas of bare ground of any size that were previously grassland but, due to natural disturbances (e.g., erosion), have lost vegetation cover. | 0 - Unknown  501 - Winter forage  502 - Grazed - dairy  503 - Grazed - non-dairy  504 - Ungrazed |
| **76 - Low producing grassland** | Includes:   * low-fertility grassland and tussock grasslands (e.g., *Chionochloa* and *Festuca* spp.) * mostly hill country * montane herbfields either at an altitude higher than above-timberline vegetation or where the herbfields are not mixed up with woody vegetation * linear shelterbelts that are <1 hectare in area or <30 metres in mean width (larger shelterbelts are mapped separately as grassland – with woody biomass) * other areas of limited vegetation cover and significant bare soil, including erosion and coastal herbaceous sand-dune vegetation. | 0 - Unknown  501 - Winter forage  502 - Grazed - dairy  503 - Grazed - non-dairy  504 - Ungrazed |
| **77 - Perennial cropland** | Includes:   * all orchards and vineyards * linear shelterbelts associated with perennial cropland. | 0 - Unknown |
| **78 - Annual cropland** | Includes:   * all annual crops * all cultivated bare ground * linear shelterbelts associated with annual cropland. | 0 - Unknown |
| **79 - Open water** | Includes:   * lakes, rivers, dams and reservoirs * estuarine–tidal areas including mangroves. | 0 - Unknown  901 - Naturally occurring  902 - Human induced |
| **80 - Vegetated wetland** | Includes:   * herbaceous and/or non-forest woody vegetation that may be periodically flooded. Includes scattered patches of tall tree-like vegetation in the wetland environment where cover reaches <30 per cent * estuarine–tidal areas including mangroves. | 0 - Unknown |
| **81 - Settlements** | Includes:   * built-up areas and impervious surfaces * grassland within ‘settlements’ including recreational areas, urban parklands and open spaces that do not meet the forest definition * major roading infrastructure * airports and runways * dam infrastructure * urban subdivisions under construction. | 0 - Unknown |
| **82 - Other land** | Includes:   * montane rock and/or scree * river gravels, rocky outcrops, sand dunes and beaches, coastal cliffs, mines (including spoil), quarries * permanent ice and/or snow and glaciers * any other remaining land that does not fall into any of the other land use categories. | 0 - Unknown |

## Land Use Capability (LUC)

The land use capability system categorises land into eight classes according to the ability of the land to sustain one or more productive uses based on physical limitations (land, soil, climate, etc.) and site-specific management needs. This does not classify actual land use, but rather only potential use for productive use in terms of pastoral, horticultural or silvicultural systems.

Historically, attempts were made to develop an equivalent *urban* land use capability classification, which was intended for use by planners to help with land use decisions at the urban fringe (Jessen, 1987). This proposed five classes A-E reflecting the overall degree of physical constraint which determines the land’s capacity for urban development and sustained urban use. Jessen’s system did in fact propose recording present land use, using the draft New Zealand Land Use Classification (NZLUC, 1984) as a classification system. In recording land use but also many relevant physical limitations on urban land use, it would be classified as a multidimensional land use classification system.

# Standards

Data and information must be shared to be effective, which is where data standards come in. Standards are agreements that make it easier for people and organizations to publish, access, share, and use data. Documented agreements mean everyone using the data understands the language, concepts, rules, guidance, or results agreed on. Standards work best when it is essential to be consistent, make processes repeatable, allow easier comparisons, or when we want to reach a shared understanding. Standards make sharing data simpler, faster, and cheaper.

Standards are not legal documents. They may be based on legislation, but they are voluntary guidelines. There are many types of standards. Here, we distinguish between two broad, domain independent categories: normative and informative standards. Normative standards indicate requirements of conformity by using 'shall' in their verbiage. They can also describe when something is good practice, or encouraged as well as when the user has options available to them. Informative standards are closer to best practices; they offer guidance and recommendations, but this is not material a user is required to follow to comply with the standard. It is there to complete the picture and help make sense of the normative requirements. Normative content strives to provide clarity by spelling out what to do. Informative standards help understanding the bigger picture.

The following standards have been highlighted here as they are related to land use classification and/or data, broadly considered.

**International Organization for Standardization (ISO)**

**ISO 19144-1:2009** “establishes the structure of a geographic information classification system, together with the mechanism for defining and registering the classifiers for such a system. It specifies the use of discrete coverages to represent the result of applying the classification system to a particular area and defines the technical structure of a register of classifiers in accordance with ISO 19135.”

**ISO 19144-2:2012** “specifies a Land Cover Meta Language (LCML) expressed as a UML metamodel that allows different land cover classification systems to be described based on the physiognomic aspects. ISO 19144-2:2012 also specifies the detailed structure of a register for the extension of LCML but does not specify the maintenance of the register. ISO 19144-2:2012 recognizes that there exist a number of land cover classification systems. It provides a common reference structure for the comparison and integration of data for any generic land cover classification system but does not intend to replace those classification systems.”

# References

ABARES. 2016. “The Australian Land Use and Management Classification (Version 8).” Canberra, Australia: Australian Bureau of Agricultural and Resource Economics and Sciences. <https://www.agriculture.gov.au/sites/default/files/abares/aclump/documents/ALUMCv8_Handbook4ednPart2_UpdateOctober2016.pdf>.

Australia and New Zealand Land Information Council. 1999. “Interim Australian/New Zealand Standard: Geographic Information – Australian and New Zealand Land Use Code.” Wellington: Standards Australia, Homebush, and Standards New Zealand.

Cavanagh, JE, and Brandon Whitehead. 2022. “Land-Use Classification for State of the Environment Soil Quality Monitoring and Reporting.” Contract Report LC4146. Manaaki Whenua-Landcare Research, New Zealand, Ltd. <https://www.envirolink.govt.nz/assets/2222-GSDC170-Land-use-classification-for-state-of-the-environment-soil-quality-monitoring-and-reporting.pdf>.

Cavanagh, Jo, and Brandon Whitehead. 2023. “Enabling Flexibility and Connectivity in Land-Use Classification for State of the Environment Soil Quality Monitoring.” Contract Report LC4309 for Land Monitoring Forum under Envirolink Tools Grant C09X2205. Manaaki Whenua-Landcare Research, New Zealand, Ltd.

Cavanagh, Jo-Anne, K Munir, S McNeill, and Bryan A Stevenson. 2017. “Review of Soil Quality and Trace Element State of the Environment Monitoring Programmes.” Manaaki Whenua – Landcare Research contract report LC for Envirolink Advice Grant for Hawkes Bay Regional Council: 1757-HBRC226. [https://envirolink.govt.nz/assets/Envirolink/Reports/1757-HBRC226-Review-of-soil quality-and-trace-element-State-of-the-Environment-monitoring-programmes.pdf](https://envirolink.govt.nz/assets/Envirolink/Reports/1757-HBRC226-Review-of-soil%20quality-and-trace-element-State-of-the-Environment-monitoring-programmes.pdf).

Cavanagh, Jo-Anne, Brandon Whitehead, Shirley Vickers, and Bryan A Stevenson. 2020. “2020 SOE Soil Quality Data Collation.” Whenua – Landcare Research contract report LC3803 for Envirolink Advice Grant 2050-HBRC254 prepared for Hawkes Bay Regional Council. [https://www.envirolink.govt.nz/assets/2050-HBRC254-Collating-soil quality-and-trace-element-State-of-Environment-monitoring-data-v2.pdf](https://www.envirolink.govt.nz/assets/2050-HBRC254-Collating-soil%20quality-and-trace-element-State-of-Environment-monitoring-data-v2.pdf).

Cumberland, Kenneth B. 1944. “The Survey and Classification of Land in New Zealand: A Basis for Planning.” *Transactions and Proceedings of the Royal Society of New Zealand* 74 (1944–45): 185.

Daigneault, Adam, Suzie Greenhalgh, and Oshadhi Samarasinghe. 2018. “Economic Impacts of Multiple Agro-Environmental Policies on New Zealand Land Use.” *Environmental and Resource Economics* 69 (4): 763–85. <https://doi.org/10.1007/s10640-016-0103-6>.

Herzig, Alexander, Andrew Manderson, Ben Jolly, Michelle Barnes, and L Baish. 2020. “Opportunities and Constraints on Intensive Land-Use Expansion in the Horizons Region – Land-Use Mapping.” Contract Report LC3838. Palmerston North, New Zealand: Manaaki Whenua-Landcare Research, New Zealand, Ltd. <https://digitallibrary-landcareresearch-co-nz.landcareresearch.idm.oclc.org/digital/collection/p20022coll23/id/8928/rec/3>.

ISO 19144-2:2012. 2012. “Geographic Information - Classification Systems — Part 2: Land Cover Meta Language (LCML).” 19144-2:2012. International Organisation for Standardization. <https://www.iso.org/standard/44342.html>.

Law, Richard, and James Ardo. 2023. “Northland Regional Council Land-Use Classification: Methodological Report.” Contract Report, Prepared for Northland Regional Council LC4345.

Mücher, C. A., T. J. Stomph, and L. O. Fresco. 1993. “Proposal for a Global Land Use Classification.” Rome, Italy: Food and Agriculture Organization of the United Nations. <https://core.ac.uk/download/pdf/48027663.pdf>.

Pearson, Lisa, and Matt Couldrey. 2016. “Methodology for GIS-Based Land Use Maps for Southland.” Environment Southland Technical Report 2016–10. <https://www.es.govt.nz/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/environment/water/southland-science-programme/land-use-inputs/documents/Report%20-%20Methodology%20for%20GIS-based%20Land%20Use%20Maps%20for%20Southland.pdf>.

Rutledge, Daniel, M Cameron, Craig Briggs, S Elliott, T Fenton, J Hurkens, G McDonald, et al. 2016. “WISE Waikato Integrated Scenario Explorer.” Technical Report #3506882. Waikato Regional Council.

Rutledge, Daniel, Robbie Price, Craig Briggs, and Sarah Cowell. 2009. “Geospatial Land-Use Classification for New Zealand: Review and Recommendations.” 5. Official Statistics Research Series. Wellington, Aotearoa New Zealand: Statistics New Zealand. <https://docs.niwa.co.nz/library/public/9780478315981.pdf>.

Sanson, R. L. 2005. “The AgriBaseTM Farm Location Database.” In *Proceedings of the New Zealand Society of Animal Production*, 65:93–96. Christchurch: New Zealand Society of Animal Production. <http://www.nzsap.org/proceedings/2005/agribase%C3%B6-farm-location-database>.

Standard Land Use Code Committee. 1984. “Report of the Standard Land Use Code Committee Incorporating a Draft New Zealand Standard Land Use Classification.” Wellington: New Zealand Department of Statistics.

Stevenson, Bryan A, Jo-Anne Cavanagh, Robbie Price, Alistair Ritchie, Shirley Vickers, and Brandon Whitehead. 2020. “Soil Quality and Trace Element Data for Land 2021.” Contract Report LC3857. Manaaki Whenua -- Landcare Research. <https://environment.govt.nz/assets/Publications/soil-quality-data-for-land-2021.pdf>.

Sullivan, Neill. 2010. “Rating Valuations Rules 2008.” LINZS30300. LINZ. <https://www.linz.govt.nz/resources/regulatory/rating-valuations-rules-2008-version-date-1-october-2010-linzs30300>.

Thompson, S, Ingrid Grüner, and Nelson Gapare. 2003. “New Zealand Land Cover Database Version 2. Illustrated Guide to Target Classes. Version 4.0.” Report for the Ministry for the Environment, Wellington.

United Nations. 1997. “Glossary of Environment Statistics.” Studies in Methods, Series F, No. 67. New York, USA: United Nations.

<https://www.stats.govt.nz/indicators/agricultural-and-horticultural-land-use>

1. https://github.com/manaakiwhenua/LUMASS [↑](#footnote-ref-2)
2. https://bitbucket.org/landcareresearch/pyluc [↑](#footnote-ref-3)
3. <https://www.agriculture.gov.au/abares/aclump/land-use/alum-classification> [↑](#footnote-ref-4)