Manaaki Whenua
Landcare Research

Land Use Information System – Land Use Classification Framework

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Deliverable 8: Land Use Information System – Land Use Classification Framework: Final Report

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Manaaki Whenua – Landcare Research

Contents

Summary

Project and client

Manaaki Whenua – Landcare Research (MWLR) was contracted by the Ministry for the Environment to develop a draft land-use classification framework for New Zealand. This was specified to include extractive and non-extractive uses, and te ao Māori perspectives. It will allow us to describe how we use and care for our land while aligning with international land-use classification standards.

Several distinct pieces of work were identified under this contract, and this final report presents only certain components. These are:

- an information synthesis and glossary
- a draft land-use classification framework
- a draft land-use classification system
- the results of workshops held with central government, regional councils, industry sector representatives, and researchers to inform the above.

A synthesis of iwi/Māori perspectives and a plan for engagement with iwi/Māori are available in separate reports.)

Objectives

To develop a hierarchical land-use classification system and associated draft land-use classification framework for New Zealand that includes extractive and non-extractive uses, and te ao Māori perspectives, by:

- undertaking a synthesis of information on land-use classification in New Zealand, including a specific synthesis of iwi/Māori perspectives and requirements
- developing a draft land-use classification system that can be a starting point for defining land uses in New Zealand, to be tested with stakeholders
- developing a draft land-use classification framework that provides a basis for the classifications
- establishing a plan for engaging with iwi/Māori for the development of the framework and land-use classifications
- presenting options and pathways for the next steps towards full implementation of the land-use classifications and framework.

Approach

The full project includes two parallel workstreams.

A Māori workstream provided a preliminary synthesis of te ao Māori perspectives and key references related to land (whenua) and land use and developed an engagement plan. This is reported fully in Harcourt et al. 2024a, b, and only a brief a summary is provided here.

A general workstream drew on previous land-use information to develop a framework for land-use classification and provide some example land-use classifications. This included:

- a review of previous research on land-use categorisation and classification systems, with a focus on those systems with which MWLR has been involved
- a virtual workshop, held with a wide range of stakeholders on 27 March 2024 to elicit broad-ranging views on and uses of land-use information
- developing a proposed land-use classification framework and a corresponding draft top-down land-use classification system, based on the Australian Land Use and Management (ALUM) classification system, and an initial exploration of one bottom-up land-use classification system beneath this framework
- virtual workshops held with the Regional Council Land Monitoring Forum (10 May 2024) and the broader stakeholder group (16 May 2024) to seek feedback on the proposed (top-down) land use-classification system, and to describe the proposed land-use classification framework in which it sits.

The outcomes of the synthesis, workshop discussions, draft land-use classification framework and classifications are presented in this report. Further information on the framework is available at https://github.com/manaakiwhenua/nzsluc, which also includes further links to the draft classification systems.

Results

There has been limited Māori participation in previous land-use frameworks and classifications, largely neglecting Māori cultural aspirations, knowledge, values, priorities, and interests.

Māori representation should be an integral part of any future governance overseeing the maintenance, sustainability, and durability of a national land-use classification and to guide any revisions or customisation.

Many land-use classification systems have been designed; some have seen application, few have been enduring. Several independent – though functionally similar – classifications are currently used in New Zealand. Rutledge et al. (2009) reviewed many land-use classification systems, and Mücher et al. (1993) suggested several reasons why classification systems are often left unimplemented, and also identified the features of a sound land-use classification system.

Following the suggestions of Mucher et al. (1993), we have made a conceptual division between a classification *framework* and a classification *system*.

A land-use classification *framework* describes the principles and best practices appropriate for any land-use classification system and associated outputs, based on the collective national and international experience of producing land-use information.

A land-use classification *system* is less abstract and includes a defined set of classes designed in a logical fashion, ideally including diagnostic criteria for classifications of land use.

We describe a complete proposal for a top-down land-use classification system with over 100 classes (at the tertiary level of the hierarchy), as follows.

- The classes in the system are systematically enumerated and provided with definitions.
- The class hierarchy is influenced by – but significantly different from – ALUM, but aspects of ALUM that we considered important are retained, in particular the controlled vocabulary for describing commodities and management practices.
- Aspects of the data schema and vocabulary where we consider extension beyond ALUM to be important have been identified. This includes initial proposals for how water and land tenure could be described.

A contrasting approach, whereby land-use classes are directly linked to available information in a bottom-up fashion, is briefly described.

Workshop materials and complete written summaries of responses are provided in the appendices.

Conclusions

The involvement of tangata whenua must be a crucial part of an enduring land-use classification framework and system, and we eagerly await the fruit of the iwi/Māori engagement plan.

One land-use classification system is unlikely to serve all uses for land-use information, so we have made a conceptual division between a classification *framework* and a classification *system*. This approach allows for the development of multiple systems using a variety of properties, potentially only applicable at specific spatial or temporal scales, to limited extents or for specific purposes (including the purposes of confidentiality and indigenous data sovereignty).

The proposed land-use classification framework and one proposed classification system have been developed iteratively and with reference to feedback from a wide range of practitioners. They are also informed by MWLR's experience producing land-use classifications for particular (and usually regional) application. The classification system is inspired by, but now substantially different from, ALUM.

The proposed land-use classification framework and dependent classification systems are also available authoritatively on GitHub at https://github.com/manaakiwhenua/nzsluc. This mode of delivery is intended to foster ongoing development of and collaboration on the framework by providing a public place to propose amendments to land-use classification systems. It may also be used as a home for tools developed to support this information, such as a web page that could be hosted using GitHub Pages. (The state of this repository at the date of delivery of this report is entirely contained within this report.)

Recommendations

- Convene an expert Māori advisory group to ensure the land-use classification framework is consistent with Māori priorities, as per the recommendations of Harcourt et al. (2024a).
- Establish a land-use governance group with responsibility for continuing the development of the classification framework principles and any land-use classification systems.
- Advocate for a land-use information system as a nationally significant information system, and establish a mandate for the continuation and adoption of the land-use classification framework.
- Establish evaluation criteria for the draft proposed (and potential future) classification systems against the principles of the framework.
- As per the recommendations of Harcourt et al. (2024a), in conjunction with the expert Māori advisory group ensure that the land-use classification framework's consideration of ideas such as *atua* domains (genealogical hierarchies) and *whakataukī* (proverbs, aphorisms) is consistent with Māori priorities.
- Develop and maintain metadata standards and templates that are suitable for land-use data.

1 Introduction

New Zealand currently lacks widespread adoption of a comprehensive land-use information system. Consequently, there has been no consistent definition of or approach to mapping land use at the national and regional levels. If we were to achieve consistency in how land use is defined and described 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. Further, a comprehensive, dynamic map of land use is required to assess the environmental pressures from land use and the effectiveness of policies that aim to reduce these pressures (Boffa Miskell 2023).

To address this limitation, the Ministry for the Environment (MfE) is leading an initiative that aims to investigate the development of a system that integrates diverse sources of information on land use. It also aims to enable land-use information to be gathered consistently and aggregated to provide information that is useful at both the national and regional scale. A nationally consistent measurement of land use over time has been identified as one of the highest priorities for investment in the 2022 Government Data Investment Plan, and this project fulfils the 2023/24 objective outlined in the Plan.[1]

The first phase of work was undertaken by Boffa Miskell (2023) to understand land-use requirements across a broad range of stakeholders. For the current project, MfE contracted Manaaki Whenua – Landcare Research (MWLR) to develop a draft land-use classification system and framework that build on the requirements identified by stakeholders (Boffa Miskell 2023).

2 Background

Land use is recognised as a critical driver of environmental change, and underpins regional council and national reporting on several facets. However, there are several recognised inconsistencies in land-use classification practices within and between councils (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 provide information in relation to:

- soil quality monitoring
- wetland condition
- land degradation
- land management
- greenhouse gas emissions
- carbon sequestration
- urban development

[1] https://www.data.govt.nz/leadership/data-investment-plan/

- 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.

'Land use', 'land cover', and 'land management' are often (erroneously) used interchangeably in discussions about land use. This erroneous use seems to stem from a lack of awareness of the distinct meaning of each of these terms. The following definitions may 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 manufacturing) and services (such as defence, recreation, biodiversity, and natural resources protection).

Land management 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 relating to 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), 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).

Not all conflations of land use, land cover, and other dimensions are erroneous, but may occur due to pragmatic reasons when there are specific justifications to produce land-use information. For example, because the purpose of a land-use classification was to satisfy the needs of the National Policy Statement for freshwater Management Science Programme at Environment Southland, Pearson and 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 in this case the distinction between land use and land cover was not crucial.

3 Objectives

To develop a hierarchical classification system and associated draft land-use classification framework for New Zealand that includes extractive and non-extractive uses, and te ao Māori perspectives, by:

- undertaking a synthesis of information on land-use classification in New Zealand, including a specific synthesis of iwi/Māori perspectives and requirements
- developing a draft 'land-use classification system that can be a starting point for defining land uses in New Zealand, to be tested with stakeholders
- developing a draft land-use classification framework that wraps around the classifications
- establishing a plan for engaging with iwi/Māori for the development of the framework and land-use classifications
- presenting options and pathways for the next steps towards full implementation of the land-use classifications and framework.

4 Approach

The full project included two parallel workstreams:

- a Māori workstream that provided a preliminary synthesis of te ao Māori perspectives and key references related to land (whenua) and land use, and developed an engagement plan
- a general workstream that drew on previous land-use information to develop a framework for land-use classification and which provides some examples of land-use classifications.

Further details on the approaches used are provided below.

4.1 Māori workstream

The Māori workstream produced a preliminary synthesis of te ao Māori perspectives and key references related to land and land use. This first phase of work was limited to four senior Māori researchers at MWLR with expertise in te ao Māori (the Māori world view), kaupapa Māori (Māori customary practice), and environmental research.

The second component of the Māori workstream involved planning an engagement strategy in collaboration with MfE to collate findings from a more diverse cross-section of iwi and hapū, Māori organisations, and key Māori representatives who could comment and provide advice on the provisional national land framework, structure, and classification given in this report. Specific Māori guidance and technical input are required to achieve a meaningful and enduring national land-use classification to better meet the current and future needs and aspirations of Māori.

A concise overview of the findings from the Māori workstream is provided in section 5, with full details available in the related reports (Harcourt et al. 2024a, b).

4.2 General workstream

The general workstream included the following components.

- Previous research on land-use categorisation (e.g. Rutledge et al. 2009) and classification systems (e.g. industry classifications such as farm classes used by Beef + Lamb, Land Information New Zealand ratings valuations) was reviewed to provide a synthesis.
- A glossary of the technical terms and definitions associated with the land-use classification framework was developed to enable a collective understanding of what they mean.
- An initial virtual workshop (see appendices) was held with a wide range of stakeholders on 27 March 2024 to elicit a range of perspectives on the classification and application of land-use information. There were 53 attendees from a variety of organisations, including MfE (six), Ministry for Primary Industries (eleven), NZ Transport Agency (three), Department of Conservation (two), AgResearch (two), Land Information New Zealand (two), Stats NZ (four), Horticulture New Zealand (one), Beef + Lamb NZ (two), DairyNZ (one), Landcorp/Pāmu (one), Foundation for Arable Research (two), Te Tumu Paeroa (one), Te Uru Kahika (two), and regional and unitary councils (13). There were 12 apologies, and 36 others who were invited to participate and who had the opportunity to send written responses. A Mural whiteboard was used to capture information on various aspects of land-use classification and the use of land-use information.
- Information from this workshop, along with the synthesis of land-use classification, was used to develop a draft land-use classification framework and land-use classification systems. The framework provides the principles that should be used to develop any land-use classification system. It also gives a series of best practices that we recommend for the development of practical and enduring land-use classification systems.
- One draft land-use classification system developed was based on an adaptation of the Australian Land Use and Management (ALUM) classification scheme, but also drew on previous classifications of land use in New Zealand and what we learnt at the workshop. We have called this NZLUM. The specification of this includes a data dictionary.
- Feedback on this draft national land-use classification system was sought through virtual workshops with the Land Monitoring Forum on 10 May 2024, and in a second workshop (with the same participants as the first, larger workshop) on 16 May 2024. Workshop material that presented an initial draft of NZLUM was circulated before the workshop, and then information was gathered through the workshop discussion, online chat, emailed responses to a dedicated shared email address, and an online collaborative Mural board.

The outcomes of the synthesis and workshop discussions, the draft land-use classification framework, and the classifications are presented in this report. Further information on the framework is available at https://github.com/manaakiwhenua/nzsluc, which also includes further links to the draft classification systems.

5 Māori workstream

Māori make up a diverse cross-section of New Zealand society. Many strongly identify with their iwi or hapū, and are involved with Māori organisations, business, sector- and industry-based organisations, and kaitiaki groups. As a result, many Māori have a strong interest in using land-use information for a variety of reasons, needs, uses, and applications.

There has been limited Māori participation in previous land-use frameworks and classifications, largely neglecting Māori cultural aspirations, knowledge, values, priorities, and interests. Māori groups and individuals consulted for earlier parts of this project have expressed a desire to see a long-term national land-use classification that reflects their values, knowledge systems, and interests in order to support decision-making, planning and policy, especially at the tribal, sector, and enterprise level.

An enduring and effective national land-use classification should reflect the uniqueness of New Zealand, its landscapes, its ecosystems, and its people. It needs to embrace and reflect te ao Māori to meet the needs of current and future generations across wider society, stakeholders and Māori. The values, needs, and aspirations of Māori should be considered across social, cultural, environmental, and economic dimensions, to align with and reflect the integrated and holistic nature of te ao Māori to maximise the usefulness, effectiveness, and implementation of the land-use classification.

Māori representation should be an integral part of any future governance overseeing the maintenance, sustainability, and durability of a national land-use classification, and to guide any revisions or customisation. Māori values and principles need to be embedded in the land-use framework to give effect to the Treaty of Waitangi and any use of mātauranga Māori, and to guide te ao Māori and data provision/sharing guidelines and protocols.

6 Glossary

A glossary is included as per the contracted requirements for this report. The list of terms is selected firstly to include technical terms, then based on whether they are often confused or (in our opinion) casually misapplied, and thirdly to enable us to draw a useful distinction in the context of this report (e.g. a classification system vs. a classification framework). The list is presented alphabetically.

Discrete Global Grid Systems (DGGS): multi-resolution grids defined on the surface of regular polyhedra (such as the icosahedron) and projected onto a sphere to create multi-resolution geospatial data structures that are global in extent without singularities (Sahr et al. 2003). A DGGS can be used as a hybrid raster-vector geospatial data model and has recently been employed in land-use classification (Law & Ardo 2023), but its application is not limited to land use.

Geographical unit: the geographical entity or entities to which a land-use classification (or relevant attributes) is associated. Many land-use classification systems attempt to classify parcels of land; the parcel is therefore the geographical unit. The appropriate unit may range from plot, field, farm or catchment to region; the concept is therefore one of geographical scale. The geographical unit may not be a specific type of geographical object a person may recognise; it may be a small, arbitrary raster or discrete global grid cell, or areas that appear sufficiently homogeneous from a remote-sensing perspective to be treated as a group, but which may have no legal association.

Land-use capability: primarily an evaluation of productive capacity depending on the physical qualities of the land, soil, and environment. Key factors assessed are susceptibility to erosion, steepness of slope, climate, susceptibility to flooding, liability to wetness or drought, salinity, and the depth, texture, structure, and nutrient supply of the soil (Lynn et al. 2009).

Land-use classification framework: 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 (ALUM) classification system
- the guidelines for how ALUM itself is structured (e.g. that it should be hierarchical, general-purpose, and may record ancillary uses as well as a primary use)
- the decision to align the classification with the Australian Spatial Data Infrastructure (ASDI) standard for land-use data sets, 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 geographical scale to end-users of the land-use data product.

Land-use classification system: narrower than a land-use classification framework and sits within one. It is the system of labels or terms used to describe land use, and structure (categorial, hierarchical), and often a system of numerical encoding.

Land-use information system: a collection of software and tools designed for the specific task of classifying land use. This often requires the integration of substantial amounts of geospatial data and the development of complex classification rules.[2]

Land-use intensity: the amount of a thing per unit area, which may refer to attributes such as stocking rates, fertiliser application, or population density.

[2] MWLR has developed several pieces of software that could contribute to land-use information systems, including LUMASS and PyLUC (which are open source; LGPL and GNU public license, respectively), and LUIS (which is not currently public). See https://github.com/manaakiwhenua/LUMASS and https://bitbucket.org/landcareresearch/pyluc

Land-use suitability: broadly speaking, the 'fitness' of a given piece of land for a defined land use. The process of land suitability classification involves 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 specific set of diagnostic criteria. In this regard land-use capability can be considered one version of a land-use suitability assessment. Other work in New Zealand has focused on land-use suitability with regard to impacts on catchment water quality.

Land tenure: ways of holding land (e.g. fee simple, customary title, leasehold, life estate). 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 value: the fiscal value of the land, which in New Zealand is formally defined in the Ratings Valuation Act 1998. The 'value of improvements' specifically relates to the added value that improvements give to land. Improvements in relation to land refers to all work done on, or material used on or for the benefit of, land by the expenditure of capital or labour.

7 Synthesis

Several attempts have been made to design and implement a land-use classification for New Zealand over at least two decades. None have been particularly enduring over multiple domains, so a key goal of this present discussion is to synthesise existing research and practice underpinning land-use classification in New Zealand. This has been done with the intention of identifying strengths and weaknesses, and any barriers to implementing the ideas.

7.1 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 system, increasing in complexity:

- categorial approaches, with discrete classes (no relationships between classes)
- hierarchical approaches, with nested sets of classes, where high-level classes (e.g. urban) become divided into more specific subclasses (e.g. residential, commercial)
- multi-dimensional approaches, which store information about attributes for unit areas, and these are recombined to generate different sets of land-use classes for particular applications
- semantic classifications, whereby land use is described using rich vocabularies and a formal grammar, which can be sued to derive classifications.

International practice is typically to construct hierarchical classifications, and many countries adopt official versions of such classifications. However, multi-dimensional

approaches have also been used, such as the American Planning Association's Land Cover Classification System (LCCS), Sistema de Información sobre Ocupación del Suelo de España (SIOSE) in Spain, and Land Environments of New Zealand (LENZ) in New Zealand (for physiography).

Rutledge et al. (2009) noted *four* distinct attempts to develop a land-use classification in New Zealand; none of these were officially adopted, but the process of land valuation in New Zealand does include a *de facto* land-use classification system that has possibly been the most successful 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 proposing yet *another* classification system. It is therefore clear that there are fundamental limitations to the development and application of land-use classifications that tend to 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 categorial land-use classification; rather, it recognises that no single hierarchical classification can ever be satisfactory to all users, but it is crucial to record information about land and geographical objects in landscapes in such a way that multiple interpretations of land use can be constructed.

Rutledge et al. (2009) reviewed three failed attempts to develop an official land-use classification in New Zealand and two that have been implemented. These five attempts are described briefly below.

1 ***The Survey and Classification of 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, multi-dimensional classification system where relevant attributes are organised into five broad groups. Each attribute has categorial or ordinal values that are represented by digits, which are then assembled into a distinct identifier. An implementation of this system at a wide geographical scale would be challenging due to the richness of the information required to completely fulfil 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 multi-dimensional land-use classification system, it is richly illustrative. Each dimension is clear and based on observable criteria.

2 **Draft New Zealand Land Use Classification (Standard Land Use Code Committee 1984).** A committee was formed within the New Zealand Department of Statistics 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 1,000 total categories. It was encoded as a four-digit code, with each level limited to 10 categories (0–9). The classification was never formally adopted or used.

3 **Australia and New Zealand Land Use Codes (ANZLUC) (AS/NZS 4584(int):1999) (Australia and New Zealand Land Information Council 1999).** Similar to the 1984 classification, ANZLUC was a four-level hierarchical classification consisting of 1,132 classes at Level 4. A set of 23 auxiliary codes organised into three categories (general, agricultural, 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, and the standard has been withdrawn.[3]

4 **Land Use New Zealand (LUNZ) (see CLUES Project, Woods et al. 2006).** This is a rural land-use data set for New Zealand, formed by combining data from AgriBase (Sanson 2005), the Land Cover Database (volume 2), LENZ, and Ministry of Agriculture and Fisheries (MAF) monitor farm types. The unit of observation is the sub-farm area: a homogeneous 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 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. These were determined by reference to the MAF monitor farm types. The LUNZ map was produced specifically for CLUES project and has not been reproduced since.

5 **Land Information New Zealand (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 1998, LINZ includes assessments of land use, which are recorded for every rating unit. This is a multi-dimensional classification framework that captures multiple attributes for a defined geographical unit (rateable land). Information is included about land use in terms of activity, but also permitted activities (council zone) and details about the principal building situated on the rating unit (e.g. age, condition, construction materials). Perhaps due to the power of the Valuer-General and the standard being promulgated by LINZ, this classification system is implemented by valuers.

However, obtaining the required information in the form of useful geospatial data can be expensive, with local governments typically contracting third parties (such as QV or Opteon) to manage their District Valuation Roll (DVR). Until recently LINZ had a role in auditing DVRs. Some companies (including CoreLogic and Headway Systems) standardised and sold a collective DVR for New Zealand.

As of March 2024 LINZ has a new role as aggregator of DVR information. Valuation is performed every 3 years, but because 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 have an indeterminate date.

Also, 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

[3] https://www.standards.govt.nz/shop/asnzs-4584int1999/

‘Multi-use within rural industry’. This represents a loss of information compared to simply recording multiple uses individually. However, it still provides incredibly valuable information, particularly because there is some assurance that a human has assessed land use at some point.

7.2 Summary of selected land-use classification systems

There have been many attempts at designing land-use classification systems, both in New Zealand and abroad. Table 1 presents a summary of a selection of these. Following this, special attention is paid to particular classification systems that have relevance to New Zealand, or with which MWLR has had direct involvement.

Table 1. Summary of selected land classification systems

Classification System [Organisation]	Year	Type	Context	Summary
Australian Land Use and Management classification (ALUM) [ABARES]	1999–	Land use	Australia	A 3-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 multi-approach to land-cover classification that seeks to avoid the situation where land cover cannot be classified as one of a set of predetermined 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 multi-dimensional approach to land-use classification with the following 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 [SIOSE]	2005–	Land use / land cover	Spain	A multi-dimensional classification system whereby 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 paid to temporal consistency to enable analysis of change over time, relative to a 1989 baseline. Justified by NZ being a signatory to the United Nations Framework Convention on Climate Change and commitments to the Kyoto Protocol and the Paris Agreement.

Classification System [Organisation]	Year	Type	Context	Summary
Land Use in Rural New Zealand (LURNZ) [MOTU]	2012?–	Land use / land cover	NZ	An econometric model with an associated non-hierarchical land classification system, with 11 classes focused on the major rural industry types (forestry, dairy, sheep & beef, horticulture, etc.)
New Zealand Forestry and Agricultural Regional Model (NZFARM) (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. revenue and profit). Consequently, it inherits classifications such as those used by Beef + Lamb NZ for sheep & beef farms.
Farm classes [Beef + Lamb NZ]		Production systems	NZ (sheep & beef farms)	Classification of NZ sheep & beef farms into 8 classes. Used for publishing aggregate statistics, and then by farmers to compare their operations to those of their peers.
Farm Production Systems [DairyNZ]		Production systems	NZ (dairy farms)	Classification of dairy farm production systems by allocation of imported feed balance into 5 classes, primarily to balance feed supply and demand.
Environment Southland (customised)	2016	Land use / land cover	NZ (Southland)	A property-scale 2-tier hierarchical land-use classification for Southland. Intended for use setting catchment-scale freshwater policy. The data also include 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 to make it easier to use for its intended application.
Land Environments of New Zealand (LENZ) [MWLR]	2003–	Physiography / land-use capability	NZ	A multi-dimensional classification with 15 dimensions (or attributes) related to climate, landform, and soil. Ultimately forms a hierarchical classification of 4 levels and 500 distinct classes (land environments), even though the underlying design was non-hierarchical. Distinct groups were determined computationally by using a multivariate clustering process.
Waikato Integrated Scenario Explorer (WISE) (Rutledge et al. 2016) [Waikato Regional Council]	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-use change, which requires a land-use classification system and a map of present-day land use. Land-use change is modelled using cellular automata, on a 25 m^2 grid, with 25 classes of land use (32 would have been the technical limit). Land-use classes are organised into 3 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.

Classification System [Organisation]	Year	Type	Context	Summary
Horizons Regional Council Land Use Map (HORLUC) (Herzig et al. 2020) [Horizons Regional Council]	2020	Land use / land cover	NZ (Manawatū-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 for and constraints on intensive land-use expansion within the region. Auxiliary land-resource information was provided at the parcel scale: NZ Land Resource Inventory (Land Use Capability and Fundamental Soil Layers), Māori land, ownership information, and water management zones.
Customised contaminant loss risk (Monaghan et al. 2021) (customised)	2021	Land use	NZ dairy and sheep & beef farms	A typology of dairy and sheep & beef farms derived from records held by DairyNZ and Beef + Lamb NZ. A hierarchical analysis of 4 primary attributes that influence contaminant losses to water was used to classify farms into a discrete typology that represents contrasting levels of contaminant loss risk. The attributes were temperature (cool/warm), wetness (irrigated/wet/ moist/dry), soil drainage (light/well-drained/poorly drained), and slope (flat-undulating/rolling/steep), for a total of 72 possible classes, though analysis was confined to the 12 most common.

7.2.1 DairyNZ

For the purposes of benchmarking dairy farms, DairyNZ has a system of classification for commercial dairy farms that places each farm into one of five classes, based primarily on the relative importance of the use of supplementary feed (Table 2).

Table 2. DairyNZ farm system classification

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.

Source: https://www.dairynz.co.nz/feed/fundamentals/fundamentals-overview/

7.2.2 Beef + Lamb NZ

For benchmarking and statistical reporting Beef + Lamb NZ has a system of classifying commercial sheep & beef farms according to fuzzy but multi-dimensional criteria, the broadest of which is geographical region (Table 3).

Table 3. Beef + Lamb farm classes

Farm class	Description	Estimated no. of farms (2019/20)
1. South Island high country	Extensive runs located at high altitude. These farms run a diverse mix of operations, which include breeding sheep (often fine-wool), and breeding cows and deer. Stocking rate is typically up to 3 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 2 and 7 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 crops. Located mainly in Southland, and in south and west Otago.	1,040
8. South Island mixed cropping and finishing farms	Located mainly on the Canterbury Plains. A high proportion of revenue is derived from grain and small seed production as well as stock finishing.	465

Source: https://beeflambnz.com/industry-data/farm-data-and-industry-production/farm-classes

7.3 Manaaki Whenua – Landcare Research's previous projects and research

7.3.1 Land Use Database (LUDB) project

After the assessment conducted by Rutledge et al. (2009), the New Zealand Land Use Database (LUDB) project was funded as a 2-year Envirolink Tools project, running from January 2010 to December 2011. This involved identifying gaps and areas for prioritisation in developing the LUDB, which included a survey of information used by councils to determine land use (Morgan et al. 2010). It was found that 27 different sources of land-use information were used, with the top five being (in order of frequency):

- Land Cover Database (LCDB)
- AgriBase
- remote sensing (aerial or satellite photos)
- New Zealand Land Resource Inventory (NZLRI – Land Use Capability)
- Statistics NZ (the Census).

A land-use classification agreed with councils was undertaken as part of this project, which drew on six existing land-use classifications:

- Land Use New Zealand (LUNZ)
- Creating Futures Land Use
- AgriBase
- Environment Canterbury land use for water quality
- LINZ land use for rating valuation
- Land Use and Carbon Analysis System (LUCAS).

The agreed LUDB land-use classification is reproduced in Appendix 2 (from Cavanagh & Whitehead 2022).

However, beyond the descriptions provided in that table it is unclear how and what information was specifically used to delineate the different land-use classes. The aim of the project was not so much to develop a national classification as to analyse the process of land-use classification and enable flexible land-use classification (see Figure 1). The project focused on the use of publicly available and nationally consistent data sets for input data, including the LCDB, NZLRI (Land Use Capability), LENZ, and Census data. A working model was developed, with documentation for users. However, it seems that the technological requirements of the database, potentially alongside the challenges of integrating the input data to develop robust classifications, resulted in the database not continuing to be used.

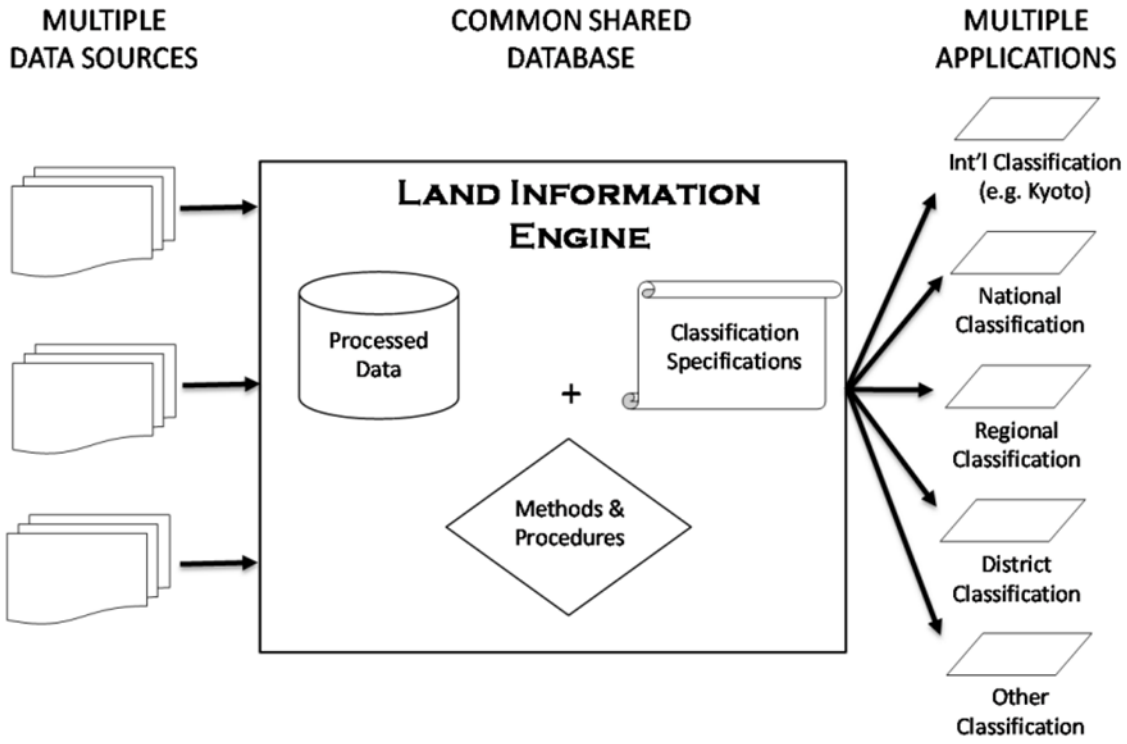

Figure 1. Conceptual model of the national Land Use Database. (Source: Price et al. 2010)

7.3.2 Innovative Data Analysis (IDA) programme

Following the LUDB work, the Innovative Data Analysis (IDA) programme was funded by the Ministry of Business, Innovation and Employment over 2014–2018. This programme aimed to 'research and develop processes to integrate and harmonise high priority heterogeneous land resource and biodiversity datasets to support a step change in the quality of environmental reporting' (Medyckyj-Scott 2018).

The programme included the development of the NZ Land Use Classifier (Manderson et al. 2018). This tool was based on a software framework using Python scripts (pyLUC) that contained all the classification rules, as well as links (URLs) to original data sources (thus providing information on the provenance of the classification). It was shown to successfully reconstruct three different existing national land-use classifications. The pyLUC required input data sources to be stored on the Land Resource Information Systems (LRIS) portal and was suggested to be most useful in the final stages of land-use classification development as a tool for automation and reproduction (Manderson et al. 2018).

Further projects after IDA included an improvement of the grassland information in the LUCAS project (Newsome et al. 2018). This project used national-scale pasture yield simulation modelling with a fuzzy-logic-based framework to classify high- and low-producing grassland into a general farm class (dairy, other livestock, and grassland not otherwise used for agriculture). Further work scoped approaches for developing a national land-use intensity indicator (Manderson et al. 2019).

7.3.3 Land Cover Database (LCDB)

The New Zealand LCDB data set is a multi-temporal database with a classification of New Zealand's land cover. The mainland version consists of 33 different classes (35 if the offshore Chatham Islands are included). Currently the LCDB is up to its fifth version (v5.0). Although land-cover classes have been revised between versions 1, 2 and 3 (backwards compatibility is ensured), the classification has been stable ever since. The classes in the 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 seven first-order classes at the top level, increasing to 33 classes at the lower level. The classes outlined in the LCDB classification system are designed to be harmonised wherever possible with the other international land-cover initiatives (e.g.. the Food and Agriculture Organization of the United Nations (FAO) Land Cover Classification System; Thompson et al. 2003). The first-order classification is based on physical features of the land cover (grassland, cropland, water bodies, etc.), while the second-order classes are based on other characteristics (geomorphological: lake or pond; phenology: evergreen/deciduous; or use: transport infrastructure).

The classes of the LCDB comprise:

i artificial surfaces: anthropogenic land cover, mainly consisting of use classes – Built-up Area, Uban Parkland / Open Space, Surface Mines and Dumps, and Transport Infrastructure

ii 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

iii water bodies: open water bodies – Lake or Pond, River, and Estuarine Open Water

iv cropland: land that is occupied by crop production – Short-rotation Cropland, and Orchard Vineyard & Other Perennial Crops

v 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

vi 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

vii forest: land where cover is predominantly forest cover – Exotic Forest, Forest – Harvested, Deciduous Hardwoods, Indigenous Forest, and Mangrove.

7.3.4 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, which 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 on 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 association 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 LUM has 12 major classes and was developed to provide input on carbon accounting to underpin New Zealand's international reporting obligations. To meet this requirement, the LUM's baseline is 1989. The LUM has had five additional time-steps added: 2007, 2012, 2016, 2020, and 2024.

A general description of the land-use classes mapped and/or recorded for LUM is given in Table 4. The woody land-use classes (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 (Penman et al. 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 planted in the ground. Another example is where infrastructure, transport, and utilities (such as roads and tracks less than 30 m 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 of carbon monitoring and accounting, as well as to enable reporting on United Nations commitments to the Kyoto Protocol and, now, the Paris Agreement. However, this limits the use of the system, and it is not intended for use as a general New Zealand land-use map. Nevertheless, in the absence of a general land-use map, information on the area of land under the different agricultural production uses determined through LUCAS LUM is commonly used (see Appendix 2).

Table 4. LUCAS LUM 2020 land-use class definitions and subclasses

Land-use class	Definition	Subclasses
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% 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 metres 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

Land-use class	Definition	Subclasses
73: Post-1989 forest	Includes post-1989 planted forest, which consists of: • exotic forest (with the potential to reach ≥5 metres 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% 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% 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

Land-use class	Definition	Subclasses
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

Land-use class	Definition	Subclasses
80: Vegetated wetland	Includes: • herbaceous and/or non-forest woody vegetation that may be periodically flooded. • scattered patches of tall tree-like vegetation in the wetland environment where cover reaches <30% • 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

7.3.5 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 (Lynn et al. 2009). This does not classify land use, but rather potential 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 to 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 (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 multi-dimensional land-use classification system.

7.3.6 Northland Regional Council land-use classification

MWLR recently used the ALUM classification system to develop a regional land-use map of Northland (Law & Ardo 2023). ALUM 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 data sets 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 interested in both the processes (e.g. land management practices) and the outputs (e.g. commodities).

Hierarchical structure: it 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 several concurrent land uses. Land-use class allocations are based on the primary land management objective of the nominated land manager, but ancillary or secondary uses can also be recorded.

The classification has six primary classes of land use, which are distinguished in order of 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 mainly used for primary production, based on limited change to the native vegetation.

3 **Production from dryland agriculture and plantations:** land is mainly used for primary production, based on dryland farming systems.

4 **Production from irrigated agriculture and plantations:** land is mainly used 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.

ALUM 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 for 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) customised classification system. This was to avoid protracted discussions on what an appropriate classification system should be within the finite budget of the project, and considering that ALUM has been applied in a similar physical geography (i.e. Tasmania). 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 to applying ALUM in New Zealand were noted, the benefits of having a stable classification system were immense. These included 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). In particular, 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)[4], has been developed iteratively and the current version 8 includes the ability to describe agricultural and mineral commodities and management practices. Its scope extends beyond the hierarchical class system to defining the minimum spatial unit, data schema, and governance arrangements (parts of what we would term a 'classification framework'). Its wide and consistent adoption and revision

[4] The science and economics research division of the Department of Agriculture, Fisheries and Forestry

contrasts with New Zealand's lack of adoption of an equivalent framework or system of land-use classification.

7.3.7 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 state of the environment (SOE) soil quality monitoring underpins national reporting on land use (e.g. *Our Land 2021*, MfE 2021). However, there are several recognised inconsistencies in land-use classification used for SOE 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 a review and evaluation of the land-use categories used, and collaborated with regional councils through the Land Monitoring Forum to define land-use categories more clearly, and to 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 categorisation of land use based on information captured.

Cavanagh and Whitehead (2023) also provide a preliminary mapping of the refined SOE soil quality land-use categories using categories from some other New Zealand land-use / land-cover classification schemes. An overview of the agreed land-use categories, and their relationship to the land-use types specified in the National Environmental Monitoring Standard for Soil Quality and Trace Elements (NEMS-SQ), is provided in Table 5.

Table 5. Summary of land-use category definitions for state of the environment soil quality monitoring, and attributes used to confirm land use

Category	NEMS class	Potential subgroups	Definition
Conservation and natural environments	Indigenous vegetation	Forest Scrub and shrubs Native grassland	Native forest, tussock, shrubland, and scrub dominated by indigenous species. Undisturbed or unfertilised in recent decades. May include cut-over forest.
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 Vine crops Berry fruit	Permanent tree, vine, or berry crops[b]
Short-rotation cropping	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 crops 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. 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 from 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.

Category	NEMS class	Potential subgroups	Definition
Rural residential[e]		*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, which 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, and wheat. It can also include feed that is cut and carried to the milking platform.

[e] The 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[5] for rural residential may also be useful; specifically, 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.

Note: Italics indicate land uses that were discussed but are currently not incorporated into the model.

Source: adapted from Cavanagh & Whitehead 2023.

[5] https://www.agriculture.gov.au/abares/aclump/land-use/alum-classification

7.4 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 organisations to publish, access, share, and use data. Documented agreements mean everyone using the data understands the language, concepts, rules, guidance, and results. Standards work best when it is essential to be consistent, make processes repeatable, and 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 wording. 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 a user is not required to follow or comply with an informative 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 of the bigger picture.

Formal standards, like those developed by ISO, the OGC, and W3C, typically contain both normative and informative components. The normative components are necessary to comply with the standard, while the informative components are there for further context and, while useful, do not affect compliance. Informative components can often implemented in multiple ways and while they are often considered best practice it is up to the developer or engineer to decide how to best orchestrate those components with the overarching architecture or system.

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

7.4.1 International Organization for Standardization (ISO)

ISO 19144-1:2009 Geographic information – Classification systems, Part 1: Classification system structure: '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 Geographic information – Classification systems, Part 2: Land Cover Meta Language: '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 several 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.' Withdrawn and revised by ISO 19144-2:2023, which 'specifies a Land Cover Meta Language (LCML) expressed [diagrammatically] as a UML metamodel that allows different Land Cover classification systems to be described based on physiognomic aspects.'

ISO 19144-3 Geographic information – Classification systems – Part 3: Land Use Meta Language (LUML). 'This part of ISO 19144 specifies a Land Use Meta Language (LUML) expressed as a UML metamodel that allows different land use classification systems to be described. This part of ISO 19144 recognizes that there exist a number of land use classification systems. It provides a common reference structure for the comparison and integration of data for any generic land use classification system but does not intend to replace those classification systems. This part of ISO 19144 complements part 2, the Land Cover Meta Language (LCML) and may be used independently to describe Land Use or together with LCML to describe a combined Land Cover Land Use. Reference is made to an external register of elements that may be used to extend LUML. The detailed structure of the register is defined in a separate part of 19144.'

7.4.2 Standards New Zealand

There was one interim (now withdrawn) standard for a systematic land-use classification designed for application in New Zealand (and Australia): **AS/NZD 4584(Int): 1999** Geographic information – Australian and New Zealand land-use codes. This was not formally adopted, nor was it used. It provides a hierarchical code for describing land use in terms of both the *purpose* for and the *manner* in which land is used. The primary code has four levels of detail in the hierarchical structure (Table 6), and there is allowance for an auxiliary code for other purposes (Table 7). Considerations of cover, physical features or tenure were specifically excluded, although they were recognised as being helpful with land-use interpretation. At the quaternary level, the classification system has 1,132 classes; 23 auxiliary codes in three categories (general, agricultural, mining/extractive) allowed for the description of the manner of use.

The standard recommended assigning multiple codes for areas with multiple uses spatially (multi-level buildings) and temporally (crop rotations), or both, using auxiliary codes to add detail to describe the nature of the multiple use.

Table 6. General structure of AS/NZD 4584(Int): 1999, specifying Level 1 land-use classes

Level 1 land-use classes		Number of subclasses		
Code	**Title**	**Level 2**	**Level 3**	**Level 4**
1000	Accommodation	4	15	60
2000	Manufacturing	9	53	184
3000	Commerce	9	47	146
4000	Services	7	38	216
5000	Agriculture, Forestry, and Aquaculture	7	39	213
6000	Mining or Extractive Industries	7	13	157
7000	Protected and Recreational Area	4	11	22
8000	Transport, Storage, Utilities & Communication	5	22	117
9000	Land not elsewhere classified	4	6	17

As indicated by the number of subclasses at the fourth level in the hierarchy, this is an extremely comprehensive classification system. As one example, it permits a distinction between '2852 Electric Cable and Wire Manufacturing' and '2854 Electric Light and Sign Manufacturing'. The full code is actually six numerical characters: four characters for the primary code and two for an optional auxiliary code. The primary code may be repeated for an area of land with different auxiliary codes; for example:

- 5000 Agriculture, Forestry and Aquaculture
- 5300 Horticulture – Trees
- 5320 Citrus Fruit
- 5322 Lemons.

The auxiliary codes are used to describe the manner in which land is used, or to allow the identification of high-risk activities for emergency services; for example:.

- 532221 Lemons (grown using dry land agricultural practices).

If the auxiliary code is unused it is coded 00.

The ANZLUC allowed for 'local requirements' to be incorporated into the auxiliary codes between the range 40–99 for (presumably incompatible) customisation and extension. Not all codes in the range 01–39 were assigned, allowing for limited future expansion.

Auxiliary codes could be used to record multiple land uses, temporally or spatially. Spatially, the example given is of a land area that is used for both the retail sale of petroleum and for mechanical repairs, which could be coded as both 3861 (Automotive Fuel Retailing) and 3816 (Automotive Repairing). Temporally, the example given is of an area of land used to grow wheat in winter and sorghum in summer, and relies on auxiliary codes (for the manner of use):

- 521127 (Wheat – Winter Agriculture)

- 521626 (Sorghum – Summer Agriculture).

This example could also be represented with one more general primary code and auxiliary code:

- 521025 (Cereal Crops – Temporal Agriculture).

Table 7. AS/NZD 4584(Int): 1999 auxiliary codes

Category	Code	Label
General	00	Not an Auxiliary Code
	01	Owner Occupied
	02	Non-owner Occupied
	03	Hazardous Chemicals
	04	Hazardous Waste
	05	Contaminated Land
Agriculture	20	Natural Environment Agriculture
	21	Dryland Agriculture
	22	Irrigated Agriculture
	23	Extensive Agriculture
	24	Intensive Animal Production
	25	Temporal Agriculture
	26	Summer Agriculture
	27	Winter Agriculture
Mining or Extractive Industries	30	Dredging
	31	Open Cut
	32	Hand
	33	Underground
	34	Bore Hole
	35	Quarrying
	36	Alluvial
	37	Undermined Area
	38	Subsidence Area

AS/NZS 4584(Int): 1999 is clear about its definition of land use and 'land use area', and its relationship to other standards, but less so how it was intended to be adopted. The land-use area is the object of classification (the geographical unit) and is considered to be an enclosed geometrical area (a polygon), which includes (but is not limited to) administrative parcels or lots, or enclosed areas of land that have land uses independent of the parcels. However, the unit was not actually prescribed (the classification system is scale-independent) and is left to the designers of information systems that implement the standard. To our knowledge it has not been implemented as geospatial land-use data.

The implementation of the ANZLUC was in turn intended to be left to 'individual jurisdictions, organizations and users' who 'would progressively implement the ANZLUC, or ensure that the codes or classifications they currently use can be easily translated to this code.' Therefore, despite the comprehensive nature of the primary classification codes, there is significant latitude in how the ANZLUC can be applied in practice, particularly in terms of the use of auxiliary codes and the definition of geographical unit.

7.5 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, which Rutledge et al. 2009 propose as reasons for the failure of classification systems to be adopted. It is important to be aware of these when designing another classification system. These drawbacks are:

- the lack of a sound definition of the basic unit of analysis: this may range from field to farm to parcel (i.e. they are appropriate for the class and geographical scale), but are too often confused with the mapping unit (the smallest mappable object or homogeneous area)
- 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, and are often far from comprehensive at lower hierarchical levels
- the subjective assignment of land use to a specific class due to the nearly ubiquitous absence of quantitative class boundaries (e.g. critical or threshold values of included criteria)
- combining land use with other features, such as climate characteristics, which may influence land use but are not inherent features of land use
- the objectives of land-use classification, which are often closely tied to a regional or disciplinary focus.

7.6 What are the features of a sound land-use classification system?

Mücher et al. (1993, cited in Rutledge et al. 2009) identified several features of land-use classification systems that may make them more suitable for adoption.

- Land-use systems should be *comprehensive*.
- Criteria must be based on the inherent characteristics of *land use alone*; i.e. it should be independent of other systems of classification for soil, vegetation, and farm systems. In this way the systems will be complementary.
- Diagnostic criteria for the classification of land should be *stable*, meaning they characterise the land over a prolonged period.
- The basic unit of analysis, or the unit of observation, must be based on *the unit of biophysical management* appropriate to each class. Parcels and plots are not useful units for many types of land use (although they are for some).

- The land-use classification should be *scale-independent*, meaning the labels can be applied at any chosen scale or level of detail.
- The approach for land-use classification should be as pragmatic as possible for its intended end-users, who are typically policy-makers in international and national organisations, land-use planners, and scientists working from a global to a regional scale. The hierarchy should be *convenient* for the intended user.
- Land-use classification should be 'usugenetic': related to the evolution of land use. Just as biological taxonomies are phylogenetic and soil classifications are based on the principles of soil genesis (i.e. are pedogenetic). In other words, there should be a logical and scientifically sound foundation to the classification, *based on observable, discrete characteristics.*
- The diagnostic criteria should be based on characteristics at the 'field' level (higher than the 'plot'.) This is because some *relevant characteristics* of the land are not necessarily discernible at the plot level but are at the field level (e.g. irrigation infrastructure).
- The number of diagnostic criteria should increase with the level of the hierarchy: there should be only a few diagnostic criteria at the highest level of the hierarchy to match the limited number of classes, but the *number of criteria should increase* together with the number of classes. In addition, diagnostic criteria should not be re-used at a lower level of the hierarchy.

8 Draft land-use classification framework

We propose a land-use classification *framework* that includes principles and best practices appropriate for any land-use classification system (and associated output; i.e. geospatial information and maps). This must allow for multiple land-use classifications systems, each with its own intended use cases, potentially across multiple value systems. This may (or may not) include hierarchies for generalisation, as well as other types of relational information, such as lineage, parts, and/or terminological variation. Multiple hierarchies are important because they will facilitate one to one, one to many, many to one, and many to many relationships, as appropriate, even if all that can be captured is that there *is a* relation between two classes, despite not fully understanding how the classes are related.

The wider project of which this report is a part has also involved the development of a set of recommendations for engagement with Māori, which have not yet been undertaken. In this context we must emphasise that this proposal is a draft, based on our synthesis of preceding work, and participation at the land-use workshops conducted as part of the general workstream.

We also propose that land-use classification *systems* be developed within the proposed framework. It is at the classification system level that a more concrete set of classes can be designed. It is unlikely that one classification system will be appropriate for integrating all data or for application in all use cases. The separation of concerns between the framework and the system allows for the development of multiple systems using a variety of properties, potentially only applicable at specific spatial or temporal scales, limited extents,

or specific purposes (including for the purposes of confidentiality and indigenous data sovereignty).

8.1 The New Zealand Standard Land Use Classification framework (NZSLUC)

The NZSLUC framework presents principles and best practices for designing land-use classification systems. Principles are intended to guide practitioners in how they use, reuse or design classification systems.

> *Kua raranga tahi tatou he whāriki, mātauranga mō āpōpō.*
>
> *Together we weave the mat / In terms of mātauranga / For future generations.*

This whakataukī envisions a mat-weaving analogy, which in this context recalls the reliance on multiple independent sources of input data, information, and knowledge from different people and organisations, with the ultimate aim of creating a shared understanding of land use as spatial information. A land-use map can be used by and for future generations to answer the enduring questions they have about land.

Principles

1 Prioritise atomic data (i.e. the decomposition of multi-dimensional attributes to observable, discrete characteristics; e.g. tenure).

- Classification systems should break down information being collected into individual (atomic, primitive, indivisible, discrete) attributes (diagnostic criteria) to expose important data-differentiating categories.
- Classification systems should be based on collections of primary data (rather than secondary categorial data), where feasible.

2 Be specific about purpose and scope.

- Classification systems shall be designed for an explicit spatiotemporal geographical unit (e.g. property parcels with land use recorded over a seasonal time scale).
- Classification systems should consider the additional use of abstract fixed geographical units, such as DGGS zones, so that data can be reorganised to different geographical units.
- Classification systems do not have to be comprehensive and will almost certainly consider some land-use types 'out of scope', according to the purpose.

3 Ensure extensibility.

- Classification systems shall ensure flexibility for land-use classification systems that support indigenous data sovereignty protocols (see Te Mana Raraunga – Māori Data Sovereignty Network).

4 Use hierarchies where they are appropriate, required, and logically consistent.

- Classification systems should consider the possibility for both generalisation hierarchies (aggregation/disaggregation) and genealogical hierarchies (lineage).

5 Improve over time.

- The classification framework itself shall be reviewed based on the comments and requests of stakeholders.
- The publication of the ISO 19144-3 standard (*Geographic information – Classification Systems – Part 3 Land Use Meta Language (LUML)*) shall prompt an examination of these principles and best practices.

6 Prioritise reproducible and transparent methodologies.

- Classification systems should allow for their methodology to be independently verified.

7 Accommodate multiple land uses.

- Classification systems should differentiate between secondary/co-located land uses (same place, same time) with intra-period land-use variation (same place, different time); e.g. rotational grazing, summer housing.

Best practices

This collection of best practices is intended for producers of land-use information to benefit the consumers of land-use information.

1. Purpose

Land-use information is collected at multiple scales and for a variety of purposes, which, directly and indirectly, affect relevant decisions based on how that information is organised and/or applied. It is best practice to explicitly state the purpose for which land-use classification systems are designed, and this purpose will inform other decisions. When deciding on the purpose, consider what questions are likely to be answered if land-use information is systematically organised according to the classification system. An inter-agency central government report provides a useful framing for these questions as 'enduring'; i.e. questions that do not really change over time, but the way we answer them (under a type of system or architecture) does (Stats NZ et al. 2013).

Choice of geographical unit (e.g. property parcels) may make extension and reorganisation of land-use information difficult in some circumstances. Obviously there are pragmatic reasons for choices of this nature. Be mindful of knock-on effects stemming from what are effectively modelling decisions. Potential issues include alignment with existing tools or published data, computational (in)feasibility, the expected absence of finer-scale input data, restrictions on the use of required input data, and privacy. Where possible, a specification to use grids without pre-defined boundaries (such as DGGS zones[6] or raster grids) should be preferred.

2. Scope

Land-use classification systems should describe their intended scope (e.g. spatiotemporal characteristics) and domain of discourse. Land-use classification systems need not be

[6] https://docs.ogc.org/as/20-040r3/20-040r3.html

comprehensive: they may consider only a few land-use types and deem others as 'out of scope'. For example, a classification of protected land may choose to classify all other land as non-protected without attempting more precise classification, according to the purpose of that classification system.

3. Extensibility

Ensure flexibility for land-use classification systems to interact with other land-use data and classification systems. This must include, for example, Māori attribute layers that maintain indigenous data sovereignty.

It should always be possible to extend or widen a classification system with more properties/attributes that can be determined by other users, such that information can be reorganised, re-presented, and corrected according to local priorities, and owned by individuals, hapū, and iwi without an expectation that this will be visible 'upstream'.

Allowing both a class hierarchy and the annotation of multiple attributes is intended to enable the representation of whakapapa (genealogy) and whanaungatanga (origins, interdependencies, and interconnections) within a land-use classification system; and to represent the multiplicity of uses any area of land can simultaneously be associated with, which may go beyond the original intended purpose of a land-use classification system.

4. Description of data quality

The quality of published land-use data should be described using a standard (e.g. ISO 19157-1:2023).

5. Semantic versioning

Any changes made to already-published land-use classification systems (including changes to the geographical unit or geographical scale) should be communicated to users using semantic versioning indicating major, minor and patch versions, e.g. v0.2.4. Once a version has been released, the contents of that version must not be modified; modifications should be released as an updated version.

The following are guidelines for semantic versioning:

- Major version for backwards incompatible functionality.
  - Major version 0 is reserved for initial development and the tolerance for breaking change is higher than for other major versions.
- Minor version for new or modified functionality in a backwardly compatible manner.
- Patch version for backwardly compatible fixes and minor adjustments.

6. Metadata

One or more established metadata standards should be used when publishing land-use data (whether public or private). Appropriate examples include:

- ISO 19115 (geospatial metadata standard)

- Dublin Core (DCMI)
- DCAT-2 (Data Catalog Vocabulary, version 2)
- Schema.org.

7. Compatibility and reuse

Compatibility with existing New Zealand or international classification systems should be preferred in the design of classification systems. This should take the form of published concordances where such associations are possible. Examples of reuse and compatibility include Protected Areas Network of New Zealand (PAN-NZ) for conservation land, Australia and New Zealand Land Information Council (ANZLIC)for industrial categories, and DairyNZ classes.

This concept extends beyond land use narrowly considered and extends to land-use management practices and lists of commodities (i.e. established vocabularies). As an example, consider the New Zealand Farm Data Standards glossaries (https://www.datalinker.org/).

8. Definition of land

Classification systems should individually determine the definition of 'land' with reference to their stated purpose (e.g. whether it includes marine and terrestrial water bodies). It is also relevant for land-use classification systems to declare their extent of application (e.g. whether it should be applied to New Zealand's offshore islands, marine areas out to the Exclusive Economic Zone, the entire continental shelf, etc). There is no consensus as to whether a definition of 'land' can exclude uses such as aquaculture, marine conservation areas, fishing areas, mining permits, shipping lanes, etc., particularly in the notable absence of sea-use maps. This also allows for classification systems that are developed for particular application to the rohe pōtae (tribal territory) of iwi, but it may be inappropriate to apply elsewhere.

9. Primary land use

A justification should be given for the choice of primary land uses (e.g. land area, economic value, duration). Some classification systems are intended to capture only the primary land use for geographical entities, typically defined in economic terms. Some classification systems allow for the encoding of multiple uses, but in such a way that information about the primary land use is lost. For example, the ratings valuation rules (LINZS30300) allow for 'multiple use' classes without the ability to encode the component uses.

In contrast, data schemas for land-use classification systems produced under this framework should be designed in such a way that multiple uses *can* be recorded without loss of information (as with indeterminate 'mixed' classes, where the components are unspecified). This may be as a primary/secondary distinction, an enumeration, or some other form of attribution, but it must be possible in some fashion.

10. Provenance

Source information (i.e. geographical scale, time/date, operator, and confidence) should be recorded. The value of land-use data is enhanced when information on provenance is available. This relates to the epistemological foundation of land-use data: how it is that we know the land use? Within the data schema of a classification system it must be possible to record provenance information, including, if applicable:

- the geographical scale of any input data
- the publication or (preferably) feature-level creation date of any input data features
- the operator (who is performing the classification or who has decided on the appropriateness of a particular class label for a feature)
- a quantitative measurement (e.g. probabilistic) or qualitative statement (e.g. operator confidence) of confidence in the applied class.

8.2 NZSLUC GitHub repository

The draft land-use classification framework is delivered as a git repository, available on GitHub at https://github.com/manaakiwhenua/nzsluc. The intention behind this means of delivery is that we recommend that the classification be considered an ongoing, open, collaborative effort between interested individuals and organisations. Although its genesis is as a deliverable for this project, we want it to be a living framework. Ideas for changes can be proposed, debated, and incorporated or rejected as a community sees fit. Yet those with radically diverging ideas can 'fork' and develop those ideas independently. By forking, a user can copy the repository, allowing the user to experiment with changes without affecting the original project (but in a way that eases "merging" these changes back into the original source. Having an online repository provides the opportunity for canonical references to the classification system to be shared and used in publications. Tools, such as vocabulary services or cartographic symbology rules, could be developed within the repository to support the use of any classification systems that function under the framework.

The framework repository contains a primary 'README' document, which contains links to two land-use classification systems (described below), which are also contained within the same repository.

9 Draft land-use classification systems

9.1 New Zealand Land Use Management (NZLUM) classification system

NZLUM is adapted from the Australian Land Use and Management (ALUM) classification (version 8) for application in New Zealand, taking into account common land-use classification usage in New Zealand for several different purposes, including SOE soil quality monitoring (see Cavanagh & Whitehead 2022, 2023), the Waikato Integrated Scenario Explorer (Rutledge et al. 2016), Greater Wellington Regional Council whaitua (catchment) classifications (Cavanagh 2022), Land Use Database version 4 (LUDB4) (Price et al. 2010), the New Zealand Planning Standards (MfE 2019), and LINZ rating valuations rules (LINZ 2010).

The rationale for the adaptation of ALUM is that ALUM provides a useful data structure and platform for standardisation, which, simply put, avoids some reinvention of the wheel in this regard. ALUM is licensed under a Creative Commons Attribution 3.0 Australia Licence, which explicitly permits adaptation of ALUM. Where direct overlap of an ALUM class is considered appropriate, it has been retained. However, both particular classes and the arrangement of the class hierarchy are significantly different, and additional classes have been added to reflect what we consider to be relevant considerations for land-use information in New Zealand.

The two biggest changes from ALUM are the removal of consideration of irrigation as a demarcation between two primary classes of agriculture, and the removal of water as a primary class. We considered ALUM's division and duplication of classes according to irrigation status to be redundant, given that irrigation (status and type) can be recorded as a management practice, and that retaining it would impede usability. We also modified the primary intensive-use class to separate intensive agricultural production from other intensive land uses and included these within the primary agricultural production class.

The other major difference is the absence in NZLUM of a water primary class. We have done this not because we consider water unimportant or out of scope, but rather because we consider water to be a land cover, not a land use. We propose an attribute to capture the presence of water using a controlled vocabulary of terms for water features (such as 'river'). In this way, end-users can control the inclusion or exclusion of water features.

Certain land uses can only occur on water (e.g. aquaculture and fisheries); some can occur on either land or water (e.g. oil and gas infrastructure), or at the interface of land and water (ports and wharves); and obviously many land uses can only occur on land (e.g. pastoral farming), but, even then, pieces of such land may include water (e.g. dams, ponds, and lakes), or affect water (irrigation water take consents, tailings, and pollution). ALUM classifies water as a primary class but admits that this presents some difficulty. One proposal for NZLUM is that water be recorded as a distinct attribute that can be applied to a geographical unit.

Currently there is inconsistency in our proposal with respect to how water features should be captured; see, for instance the water features under class 2 (Production agriculture and plantations and class 3 (Built environment). This inconsistency should be resolved before

applying this draft classification system, because a final decision about the treatment of water will affect future organisational changes to the classification system. Water also has a special status for Māori, and engagement with iwi/Māori in the further development of this classification system is required. Here we do make the case that including water as a land cover attribute, rather than a class, does have merit.

Following the pattern of ALUM attributes (for commodities and management practices), we propose that a water attribute should have an associated, controlled set of terms that could be applied to a geographical unit. An incomplete short list (using English language terminology) is:

- `lake`
- `reservoir`
- `dam`
- `evaporation basin`
- `river`
- `channel`
- `aqueduct`
- `wetland`
- `estuary`
- `intertidal`
- `marine`

Subtypes could be used to disambiguate where information allows. For example, just as the list of commodities allows for either `cattle` (i.e. unspecified) and `cattle dairy`, `cattle beef`, `cattle meat` to accommodate some additional information, one could imagine the use of `marine inshore`, `wetland stormwater`, and `wetland bog`. The parallel or exclusive use of te reo Māori terms could be helpful to create subtypes along dimensions that are important to Māori, and adds the potential for localism and flexibility on top of the classification system as it pertains to water. (Treating water as a primary class would not allow this to the same extent.)

Overall, this draft classification system is proposed as a 'general purpose' land-use classification in the context of grouping the nature of interaction of land-use activities with the use of soil and water resources relevant for land-use change modelling or environmental management. The development of the system will allow for some end-user reclassification of land use (e.g. on the basis of irrigated vs non-irrigated land to meet alternative purposes), although in other cases (e.g. for LUCAS LUM) and the specification of pre-1990 forest, or to better reflect te ao Māori values, additional classification systems would still more than likely be required.

The present classification system retains ALUM's practice of attempting to record additional information (e.g. land management practices) using defined terminology. The additional information – termed 'attributes' – is related to, but independent of, the land-use classes themselves.

The collection of specific additional attributes is intended to allow for the reclassification of land use based on these attributes, which may be able to be determined at the time of mapping, or recorded after the fact. The number and type of attributes captured within this system needs to be agreed in order to recognise the value of the information, and the context of use within this classification, versus the use of an alternative classification. These attributes are optional, but they should be included where information permits.

Potential attributes could include the following.

- **Commodity** (as in ALUM): captures information about crops and livestock that allows for further distinction within a land-use class and may be useful in the context of biosecurity, economic modelling, nutrient modelling, greenhouse gas estimation, site-selection, etc.
- **Management practices** (as in ALUM): captures additional information not otherwise captured in the class hierarchy, such as irrigation, crop pasture rotations, free range stock, or wintering off of dairy stock. ALUM maintains a list of 44 management practices with agreed names (a controlled vocabulary, or enumeration – a set of named constants). This set of names was compiled from existing sources, such as the Australian Bureau of Statistics, Meat and Livestock Australia, Horticulture Innovation Australia, Grains Research and Development Corporation, and state and territory lists. We propose adopting this list but making minimal extensions where necessary (dairying wintering off practice is an obvious extension that we recommend). Management practices are expected to apply only to particular land-use codes, so they must be used in conjunction with these codes. Going beyond the ALUM practice, in the built environment this attribute could be used to include information such as building materials or floor levels.
- **Tenure**: relates to the potential for changes to land use and land-use management practices (because tenure may constrain possible land-use changes). Information relating to land tenure could be captured in two attributes: "`land_estate`" and "`land_status`". How land is owned, and by whom, is an important consideration for how land may be used or managed. Recognising that tenure is an extension of the considerations of ALUM (on which this classification system is based), it is important to note that Boffa Miskell Limited (2023) identified the need for land tenure status as a requirement for a land information system to address the needs of councils to monitor and implement freshwater regulations, and to map urban growth.
- **Zoning:** such as that described in the 2019 New Zealand Planning Standards (e.g. rural zone, Māori purpose zone) will help to identify future land-use changes and can be matched with additional information such as land-cover information to confirm current use. Once again, the need for zoning information as a dimension of land information was identified in Boffa Miskell 2023; it is especially relevant for councils considering patterns of urban expansion and intensification.
- **Land cover**: this is particularly relevant in the context of identifying crop rotations within various primary production classes. These would probably be framed as land cover at the time of mapping. There would need to be further decisions regarding the appropriate land-cover terminology, so this idea has not progressed beyond an initial proposal.

- **Permeability:** whether land is considered 'sealed' or 'unsealed'. This allows further delineation within classes, particularly in the built environment, which probably contains mixtures of sealed and unsealed land (e.g. in residential areas and road corridors).
- **Water:** as discussed above.

It is worth noting that all these attributes are categorial and not continuous variables. There may be a need to include additional continuous variables (such as farm stocking rates in stock units per hectare). However, these should be appropriately discretised or otherwise captured as ancillary information so that the total number of combinations of all attributes can be enumerated.

Land is classified according to its primary use, based on the primary land management objective of the landowner or manager, and additional ancillary land uses can be captured separately. Some uses may only ever be ancillary, so the proposed classification system necessarily includes some such uses.

An overview of the class hierarchy is provided in Figure 2, with further details of the different classes following.

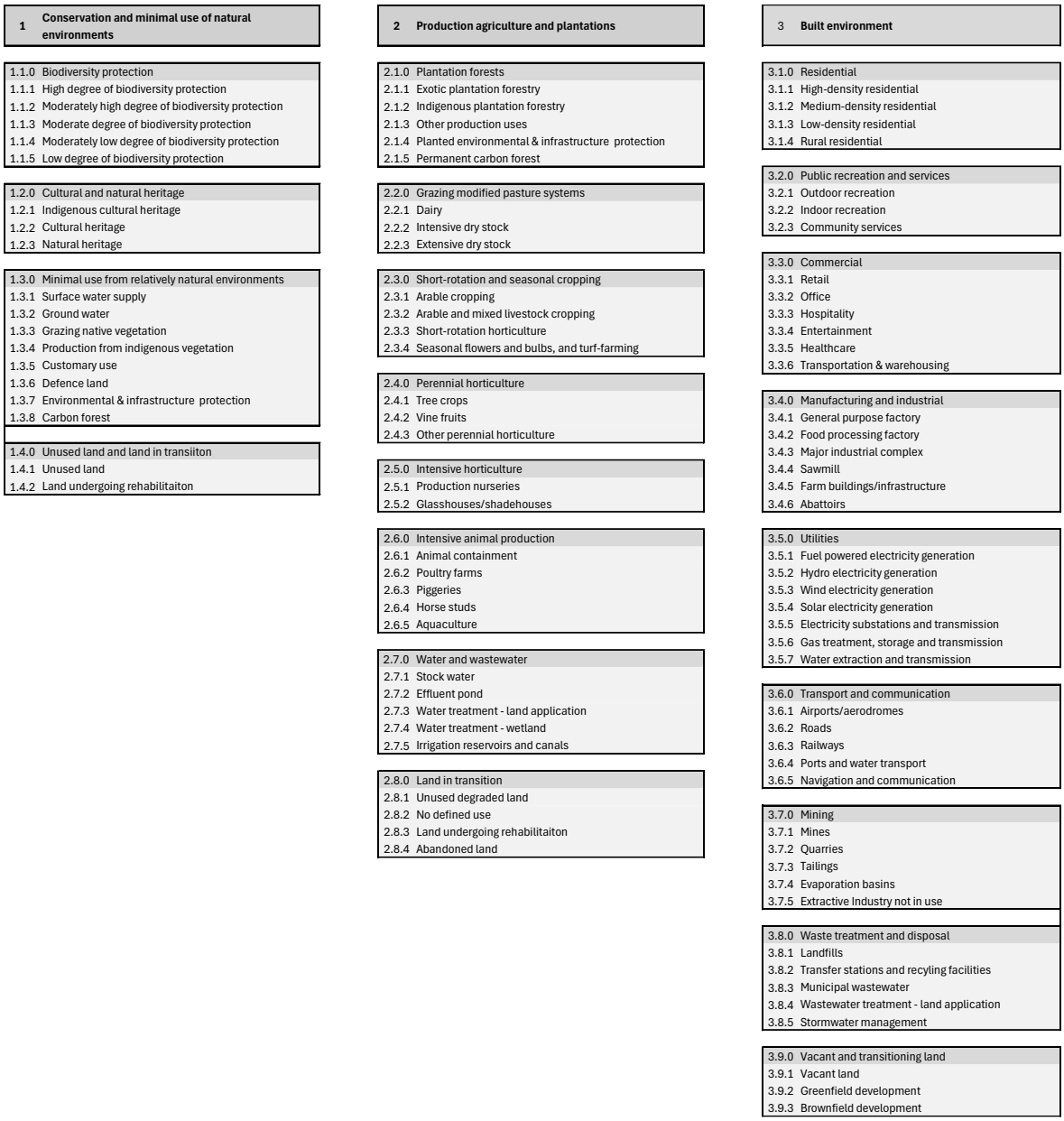

Figure 2. Overview of the New Zealand Land Use Management classification system.

1 Conservation and minimal use of natural environments

This class includes land that has a relatively low level of human intervention. The land may be formally reserved by government for conservation purposes, or conserved through other legal or administrative arrangements. Areas may have multiple uses but nature conservation is a central consideration. (Some land may be unused because of a deliberate decision of the government or landowner, or due to circumstances).

Where a classification is based on information about legal protection, the relevant information (e.g. the Act) should be mentioned in the `comment` field.

1.1.0 Biodiversity protection

Nature conservation classes are based on the suggested classification scheme for the Protected Areas Network of New Zealand (PAN-NZ) in relation to biodiversity protection, following Bellingham 2016 and Planzer et al. 2024. Specifically, Tertiary classes 1.1.1–1.1.3 are based on the classification for areas legally protected for biodiversity (see Appendix A for more details).

1.1.1 ***High degree of biodiversity protection (Bellingham Rank 5)*** – protection is the main purpose or is ranked equally with a limited number of other compatible purposes (e.g. national parks, nature reserves).

1.1.2 ***Moderately high degree of biodiversity protection (Bellingham Rank 4)*** – protection is a main purpose (e.g. conservation park, QEII open space covenant), but is shared with other less compatible purposes (e.g. recreation).

1.1.3 ***Moderate degree of biodiversity protection (Bellingham Rank 3) –*** protection is a desired purpose, but subject to capability with a different main purpose (e.g. stewardship land, wildlife management reserve), or may be less comprehensive (i.e. only some aspects of biodiversity protection are targeted).

Areas with lower levels of biodiversity protection are anticipated to have other primary uses, but biodiversity protection ranking could be captured as an ancillary use with the following classes:

1.1.4 ***Moderately low degree of biodiversity protection (Bellingham Rank 2)*** – some biodiversity protection is achieved, but it is of secondary importance.

1.1.5 ***Low degree of biodiversity protection (Bellingham Rank 1)*** – protection results indirectly and fortuitously as a result of other activities (e.g. road reserve, riverbed).

1.2.0 Cultural and natural heritage

Conservation classes are for purposes other than biodiversity protection.

1.2.1 ***Indigenous cultural heritage*** (e.g. historical pā sites, New Zealand land wars sites, DOC Māori sites)

1.2.2 ***Cultural heritage*** (e.g. historical mining sites, selected DOC 'iconic sites' and Toru Whenua landmarks)

1.2.3 ***Natural heritage*** – protected areas for the conservation of specific natural features, and landscapes (e.g. Waitaki Whitestone Geopark, Banks Peninsula Geopark).

1.3.0 Minimal use from relatively natural environments

This class includes land that is subject to relatively low levels of intervention or that is largely unused in the context of prime use or use for resource protection. This land may be

covered with indigenous or exotic plant species. It includes land where the structure of the native vegetation generally remains intact despite deliberate use, although the floristics of the vegetation may have changed markedly (e.g. grazing on native tussock land).

Where native grasses have been deliberately and extensively replaced with other species, the land use should not be classified under class 1.

1.3.1 ***Surface water supply*** – an area managed as a catchment for water supply.

1.3.2 ***Ground water*** – an area managed as an aquifer recharge zone.

1.3.3 ***Grazing native vegetation*** – land uses based on grazing by domestic stock on native vegetation where there has been limited or no deliberate attempt at pasture modification. 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. This is probably limited to South Island high-country farms. Verification (e.g. assessment of vegetation on grazed land) to assess the extent of modification is required. ALUM specifies this class when there is greater than 50% dominant native species, although this criterion needs to be confirmed as being appropriate in a New Zealand context.

1.3.4 ***Production from indigenous vegetation*** – commercial production from retained native forests and related activities on public and private land. This class includes wood production forestry on native timber without clearfelling, and other native forest production (non-sawlog or non-pulpwood production, including oil, wildflowers, firewood, fenceposts, and mānuka/kānuka honey).

1.3.5 ***Customary use*** – natural environments associated with traditional and sustainable indigenous food-gathering practices (mahinga kai). This is often an anciliary use; this class should only be assigned if the collection of food or other customary use is indeed the prime use of land. (This may include land zoned for Māori purposes, and should only describe contemporary, not historical, use.)

1.3.6 ***Defence land*** – natural areas allocated to field training, weapons testing, and other field defence uses, predominantly in rural areas (e.g. Kaipara Air Weapons Range and the Waiouru Military Camp). Areas associated with buildings or more built environments on defence land are captured under an urban class.

1.3.7 ***Environmental & infrastructure protection*** – land, usually under vegetative cover, used for non-production or environmental purposes (e.g. prevention of land degradation, windbreaks, shade, and shelter). This is not limited to indigenous vegetation. This class includes land with a primary purpose of flood management (e.g. stop banks, spillways). Land that has been *planted* for the purposes of environmental and infrastructure protection should be captured under 2.1.4. Planted environmental & infrastructure protection.

1.3.8 ***Carbon forest*** – retained (non-planted) indigenous vegetation set aside for carbon credits.

1.4.0 Unused land and land in transition

Corridors and roadside areas may fit under this class, along with unused land (in the sense of productive, conservation or urban use), such as cliffs, rock faces, boulders, and tors, where there are relatively low levels of disturbance. It does not include land undergoing natural succession in the context of changing plant species.

1.4.1 ***Unused land*** – includes land that is unusable for productive agriculture or urban uses, such as cliffs, rock faces, boulders, and tors, where there are relatively low levels of disturbance.

1.4.2 ***Land undergoing rehabilitation*** – degraded land (e.g. due to erosion or flood damage) that is being actively rehabilitated through planting with indigenous or exotic species to return land to a natural state. This includes riparian plantings.

Delineation between indigenous and exotic vegetation for the minimal use and unused land and land in transition classes can be made by reference to land-cover information.

2 Production agriculture and plantations

This class includes land used principally for primary production, where native vegetation has largely been replaced by introduced species through clearing, the sowing of new species, the application of fertilisers or the dominance of volunteer species. The range of activities in this category includes plantation forests, pasture production for stock, cropping and fodder production, and a wide range of horticultural production. If there is evidence of irrigation infrastructure or water-take consents, land should have irrigation listed as a management practice, even if it appears that irrigation water has not been recently applied.

Fallow or ploughed land should be assigned to the most likely land use based on the dominant activity conducted in comparable nearby areas or other available evidence. Fallow or ploughed land should be allocated to the relevant pasture, cropping or horticultural class (rather than using land in transition). The fallow or ploughed status should be recorded in the management field.

2.1.0 Plantation forests

This is land on which plantations of trees or shrubs (native or exotic species) have been established (i.e. *planted*) for production, or environmental and resource protection purposes. This includes farm forestry and may consist of monocultures or mixed species. Specific additional attributes that could be captured are plantation age, rotation number, and species.

2.1.1 ***Exotic plantation forestry*** – an area managed for pulpwood or saw-log production (exotic species).

2.1.2 ***Indigenous plantation forestry*** – an area managed for pulpwood or saw-log production (native species).

2.1.3 ***Other production uses*** – an area managed for non-pulpwood production, including oil, wildflowers, honey (e.g. kānuka/mānuka plantations).

2.1.4 ***Planted environmental & infrastructure protection*** – an area managed for environmental and indirect production uses (e.g. prevention of land degradation, windbreaks, shade, and shelter).

2.1.5 ***Permanent carbon forest*** – an area planted with indigenous or exotic trees for the purpose of gaining carbon credits (carbon farming).

2.2.0 Grazing modified pasture systems

This class includes grazing pasture and/or forage, both annual and perennial, based on significant active modification or replacement of the natural vegetation. Land under pasture at the time of mapping may be in a rotation system, so that at another time the same area may be, for example, under cropping.

The ability to distinguish between dairy and dry-stock production is provided by including the relevant commodity information, such as 'cattle dairy', 'cattle beef', 'sheep wool', 'sheep meat', etc. Multiple commodities should be recorded if appropriate. Crops used in rotation should also be recorded as commodities, if known.

Dairy support is land that is used to support non-lactating dairy stock (dry cows, heifers and 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, and wheat. It can also include feed that is cut and carried to the milking platform. Dairy support land that is not actively used for grazing should be classified as an arable use.

2.2.1 ***Dairy*** – the land on which milking cows (or other stock, such as goats or sheep) are grazed during the milking season. Dairy production systems can include rotations of grazed forage crops and maize for silage, and dry-stock grazing, but this class should only be used where dairy is the primary purpose of the land. Where the land is permanently used for dry-stock grazing, it should be classified under dry-stock land use.

2.2.2 ***Intensive dry stock*** – includes non-milking platform pasture where there is a high level of inputs from fertiliser, water requirements (i.e. may be irrigated), and high stocking rates. This is most likely to occur on flat/rolling terrain. Land used for high-intensity dry-stock grazing may include rotations for arable or winter forage crops, as well as grazing of non-lactating (dry) dairy cattle, beef cattle, sheep, and cattle breeding. Grazing of other stock, including deer, goats, and horses, should be captured under class '2.2.3 Extensive dry stock'.

2.2.3 ***Extensive*** **dry stock** – as for class 2.2.2, but for grazing on modified pastures with relatively fewer inputs, lower likelihood of irrigation, and lower stocking rates. This is more likely to take place on hill, hard-hill, or high-country terrain. Grazing livestock other than dairy, sheep or beef should usually be captured in this class (though it does not exclude sheep or beef), and the commodity type

appropriately recorded. Where there is a high proportion of indigenous vegetation for grazing land, land use should be classified as grazing native vegetation. Arable or winter forage crops are unlikely to be common rotations in this land-use category.

2.3.0 Short-rotation and seasonal cropping

This class includes agricultural practices characterised by the cultivation of crops with rapid turnover cycles and seasonal planting patterns, typically optimised for efficient land use and high-yield production. This class encompasses agricultural activities such as the cultivation of fast-growing crops such as maize, barley, and certain vegetables, often rotated on short-term cycles to maintain soil health and maximise productivity. Arable, and mixed livestock cropping, integrating both crop cultivation and animal husbandry, is also included in this class.

If the type of crop is known, record this in the commodity field. For mixed arable and livestock operations, both commodities should be captured as the primary commodity (neither is ancillary).

2.3.1 ***Arable cropping*** – predominantly grain, seed, or fodder crops; over time it may include vegetable rotations. Includes maize, barley, wheat, peas, other grain and seed crops, and fodder crops. May be used for dairy support (which should be recorded as a management practice if this is known). If the crop type(s) is (are) known, record it (them) in the commodity field using the commodity list.

2.3.2 ***Arable and mixed livestock cropping*** – predominantly grain, seed, or fodder crops; over time it may include short-term (c. 1–3 years) pasture and livestock rotations, and/or vegetable rotations. Pasture and livestock rotations may occur less than 50% of the time. Includes maize, barley, wheat, peas, other grain and seed crops, and fodder crops. May be used for dairy support (which should be recorded as a management practice, if this is known). If the crop type(s) is (are) known, record it (them) in the commodity field using the commodity list.

2.3.3 ***Short-rotation horticulture*** – crop plants living for *less than 2 years* that are intensively cultivated, usually involving a relatively high degree of nutrient, weed, and moisture control. Predominantly rotations of vegetable crops or seasonal fruits grown for human consumption; may include livestock rotations, but this is considered less likely.

2.3.4 ***Seasonal flowers and bulbs, and turf farming*** – agricultural practices focused on the cultivation of seasonal ornamental flowers, bulbs, and turf grass for commercial purposes. This class encompasses activities such as the cultivation of flowers and bulbs for seasonal markets, landscaping, and turf-farming for sports fields, lawns, and recreational areas.

2.4.0 Perennial horticulture

This class includes crop plants living for *more than 2 years* that are intensively cultivated, usually involving a relatively high degree of nutrient, weed, and moisture control.

Management practices such as irrigation or netting to protect crops from hail or birds can be recorded as management practices. Crop type can be recorded as the commodity and used to identify key crops (e.g. kiwifruit, avocados, and grapes).

2.4.1 ***Tree crops*** – includes long-term cultivated plants, typically trees or woody shrubs, grown for their fruits, nuts, or other edible parts. These crops require intensive management practices aimed at ensuring optimal growth, productivity, and quality over multiple years. Examples include orchard fruits such as olives, apples, oranges, and apricots, as well as tree nuts such as hazelnuts, macadamias, and chestnuts, which should be recorded in the commodity attribute, if known. Management practices may include pruning, pest and disease control, irrigation, and harvesting techniques specific to tree crops.

2.4.2 ***Vine fruits*** – includes fruit-bearing plants that grow on vines or trailing stems, often requiring support structures such as trellises or arbours. These plants produce fruits that typically hang from vines and may include grapes, kiwifruit, and passionfruit. Vine fruit cultivation involves specific management practices such as pruning, training, trellising, and pest and disease control specific to vine plants.

2.4.3 ***Other perennial horticulture*** – encompasses perennial plants beyond tree crops and vine fruits, such as berries (e.g. strawberries, blueberries), perennial herbs (e.g. lavender, rosemary), and ornamental perennials (e.g. roses, lilies).

2.5.0 Intensive horticulture

This class includes intensive forms of plant production, often with special-purpose improvements used for horticultural production. If crop type is known, record this in the commodity field. Similarly, management practices such as hydroponic systems should be captured when known.

2.5.1 ***Production nurseries*** – specialised intensive horticultural facilities dedicated to propagating and growing plants for commercial purposes. These nurseries focus on cultivating a wide range of plant species, including ornamentals, fruit trees, and shrubs, typically for landscaping, reforestation, or ornamental purposes. Nurseries may be outdoor (exposed) or under cover. Production nurseries may employ advanced techniques such as grafting, tissue culture, and controlled environment systems to optimise plant growth and quality.

2.5.2 ***Glasshouses/shadehouses*** – controlled-environment structures utilised within intensive horticulture for protected cultivation of plants, including both vegetable and floriculture production. Glasshouses provide a transparent enclosure, typically made of glass or plastic, allowing natural sunlight to penetrate while shielding plants from adverse weather conditions. Shadehouses utilise shade cloth or netting to regulate light exposure and temperature levels. These structures enable year-round production of a wide variety of crops, including vegetables, herbs, flowers, and ornamental plants.

2.6.0 Intensive animal production

This class covers intensive forms of non-pastoral animal production, livestock production facilities or animal-holding yards. The animal type can be recorded as a commodity. The management field can be used to record practices such as free range or organic. Further development of this category is likely to be required to ensure it is fit for purpose.

2.6.1 ***Intensive animal containment*** – facilities or systems designed to confine and manage animals, often including feed lots, pens, dairy sheds and yards, and herd homes where animals are raised intensively for meat production or other purposes.

2.6.2 ***Poultry farms*** – specialised facilities dedicated to the intensive production of domestic fowl, including chickens, turkeys, ducks, and geese, typically for meat or egg production.

2.6.3 ***Piggeries*** – facilities designed for the intensive rearing of pigs, where large numbers of pigs are housed and managed for meat production.

2.6.4 ***Horse studs*** – establishments focused on the breeding and raising of horses, typically specialising in selective breeding for desirable traits.

2.6.5 ***Aquaculture*** – the controlled cultivation of aquatic organisms, such as fish, molluscs, or algae in natural or artificial environments, typically for food production, but also for stock feeds, pharmaceutical uses, biofuels, etc.

2.7.0 Water and wastewater

This class captures built water features associated with agricultural use.

2.7.1 ***Stock water*** – reservoirs or farm dams on agricultural land for the purpose of supplying drinking-water for stock.

2.7.2 ***Effluent pond*** – effluent ponds typically associated with dairying.

2.7.3 ***Water treatment – land application*** – land used for effluent disposal, probably an ancillary use where some form of grazing is the primary use.

2.7.4 **Water treatment – wetland** – constructed or natural wetlands used to improve water quality prior to discharge.

2.7.5 ***Irrigation reservoirs and canals*** – land used for water storage, management or distribution intended for agricultural purposes; artificial or natural areas allocated for irrigation for agricultural purposes.

2.8.0 Land in transition

As a subclass of 'Production agriculture and plantations', land categorised under this class must recently have been used for agriculture or plantations. In the case of greenfield development, where it is known that the land use is in transition to a built-environment

category (e.g. due to a zoning change), classify the land under 3.9.0 'Vacant and transitioning land', or a further subclass thereof.

2.8.1 ***Unused degraded land*** – unused land that is degraded through erosion or flood events that is not being rehabilitated. Can include contaminated land.

2.8.2 **No defined use** – land cleared of vegetation and where the current proposed land use is unknown.

2.8.3 ***Land undergoing rehabilitation –*** land in the process of rehabilitation for agricultural production (e.g. after significant flooding), and which is actively being recovered.

2.8.4 ***Abandoned land*** – land where a previous pattern of agriculture may be observed but that is not currently under production, but not due to physical land degradation.

3 Built environment

This class captures land uses that involve high levels of interference with natural processes, generally in association with the built environment of closer settlement and supporting infrastructure. The level of intervention may be high enough to completely remodel the natural landscape – the vegetation, surface and groundwater systems, and land surface.

However, land used for active recreational purposes and/or tourism (e.g. mountain bike parks) outside of urban areas and that are not captured in other land-use categories may be captured under the 'Outdoor recreation' category, which is a subclass of the built environment, though may still retain much natural character.

3.1.0 Residential

This captures land uses primarily designated for private, long-term human habitation, encompassing a variety of housing types and densities.

The following subclasses are proposed. Some alignment with the National Planning Standards (Zone Framework Standard) (MfE 2019) has been considered in the development of these classes. This information (as at time of classification) should be captured in the zone attribute to allow for some reclassification and specification.

The class includes holidays homes, retirement villages, student hostels and other forms of low-turnover or longer-term accommodation, even if these are run commercially. Shorter-term forms of accommodation (motels, hotels, holiday parks, etc.) are captured under '3.3.0 Commercial' or '3.3.3 Hospitality'.

3.1.1 ***High-density residential*** – areas characterised by a high concentration of housing units per unit of land area, typically in multi-storey buildings or high-rise developments, often found in urban centres supporting high population density.

3.1.2 ***Medium-density residential*** – areas featuring a moderate concentration of housing units per unit of land area, typically in the form of townhouses, semi-

detached, terraced, or low-rise apartment buildings, often situated in suburban or semi-urban settings in large cities, or central areas of provincial towns. Alignment to the Medium Density Residential Standards (MfE 2022) should be considered.

3.1.3 Low-density residential – residential properties within urban boundaries that fall within large-lot or low-density residential zones and are often single-family, one- to two-storey houses with yards and landscaping and lower population density.

3.1.4 Rural residential – residential properties with low-intensity (non-commercial) land management practices (e.g. hobby farms) on land in rural or peri-urban areas. Typically featuring larger parcel sizes amidst agricultural or natural surroundings. Concordant with the 'Rural lifestyle zone' from the Zone Framework Standard.

3.2.0 Public recreation and services

This land-use type includes land designated for recreational facilities and community amenities, serving the recreational needs and essential functions of the local population.

3.2.1 Outdoor recreation – land areas dedicated to leisure activities conducted in natural or semi-natural settings, such as parks, trails, beaches, sportsgrounds, camping grounds, zoos, botanic gardens, recreational reserves, sports grounds, tourist parks, mountain bike parks, etc. with a primary purpose of recreation and culture and typically with considerable unsealed vegetated areas.
These often cater to activities such as tramping, cycling, picnicking, and wildlife observation. Parks or reserves with a high level of native bush or that are protected areas should be classified under class 1.
The specific identification of this land is intended to enable more ready identification of urban green space. However, this category may also be used to identify recreational areas that fall outside urban boundaries, such as mountain-bike parks.

3.2.2 Indoor recreation – facilities designed for recreational activities conducted within enclosed or semi-enclosed structures, including sports centres, gyms, fitness clubs, swimming pools, and indoor sports arenas.

3.2.3 Community services – land used for providing essential services and facilities to support the local community, including educational institutions, public healthcare facilities, libraries, museums, courts, prisons, civic buildings, emergency services, marae, religious buildings, cemeteries, and other public amenities for community functioning and well-being.

3.3.0 Commercial

This land-use type includes land in a built environment context that is used for private-sector economic activities, encompassing various sectors such as retail, office, hospitality, entertainment, healthcare, transportation, and warehousing. Central government offices when these are privately rented should be captured in this category, even if they are public-facing.

3.3.1 Retail – areas used for the sale of goods and services directly to consumers, including shops, supermarkets, shopping malls, convenience stores, suburban dairies, and other retail outlets.

3.3.2 Office – land and buildings primarily used for administrative, professional, or managerial activities, including corporate offices, professional services, financial services (banks), government buildings, business parks, and coworking spaces.

3.3.3 Hospitality – land and buildings providing accommodation, food, and beverage services to the public, including hotels, motels, resorts, bed and breakfast establishments, restaurants, bars, and nightclubs.

3.3.4 Entertainment – land areas and facilities offering leisure and recreational activities for public enjoyment, such as cinemas, theatres, amusement parks, casinos, and concert venues.

3.3.5 Healthcare – land dedicated to providing private medical services, including hospitals, speciality medical clinics, physiotherapists, medical offices, laboratories, and other healthcare facilities aimed at diagnosis, treatment, and prevention of illness or injury.

3.3.6 Transportation & warehousing – privately owned land associated with the movement and storage of goods, including distribution centres, warehouses, logistics facilities, car dealerships, and commercial parking lots. Excludes airports, ports, roads, and train stations which should be classified under class 3.6.0.

3.4.0 Manufacturing and industrial

This land-use type includes land uses dedicated to production, processing, and industrial activities, contributing to the production of goods and materials for commercial purposes.

3.4.1 General purpose factory – an area used for manufacturing, assembly or repairs of various products. Includes some specialised or purpose-built machinery and equipment for mass production across multiple industries.

3.4.2 Food processing factory – an area where the principal use is food processing, packaging, and preservation. The building is most likely to be purpose built and may have extensive plant and equipment included (e.g. cannery, milk production plant).

3.4.3 Major industrial complex – an area with large-scale industrial use and significant infrastructure (e.g. car plant, paper mill).

3.4.4 Sawmill – an area with special improvements for the processing (milling and curing) of raw timber, wood products, and by-products.

3.4.5 Farm buildings/infrastructure – an area with buildings, sheds and other infrastructure associated with farm enterprises, including barns, silos, storage sheds, and irrigation systems supporting agricultural operations.

If it is possible to discriminate a domestic area from a farm, the house and any adjoining non-productive (e.g. domestically landscaped) land should be classified as 3.1.4 Rural residential.

3.4.6 Abattoirs – areas with specialised improvements for the slaughter of stock and the preparation of meat for the wholesale market.

3.5.0 Utilities

This land-use type includes land allocated to providing electricity, gas, or water.

3.5.1 Fuel powered electricity generation – includes facilities that produce electricity by burning fossil fuels such as coal, oil, and natural gas.

3.5.2 Hydroelectricity generation – facilities that use the energy of flowing or falling water, typically through hydroelectric dams, converting hydraulic energy into electrical power. Includes dams and canals.

3.5.3 Wind electricity generation – power generation from wind, including wind farms.

3.5.4 Solar electricity generation – facilities that harness sunlight using photovoltaic cells or solar thermal systems to convert solar radiation into electrical power.

3.5.5 Electricity substations and transmission – facilities and infrastructure associated with the distribution and transmission of electrical power from generation sources to end-users, including substations, transformers, and large, high-voltage transmission towers (pylons).

3.5.6 Gas treatment, storage, and transmission – facilities and infrastructure involved in the processing, storage, and transportation of natural gas, including gas treatment plants, storage facilities, and pipelines for transmission to consumers.

3.5.7 Water extraction and transmission – facilities and infrastructure for extracting, purifying, treating, and transporting water from natural sources such as rivers, lakes, or reservoirs to meet various human needs, including drinking-water supply, irrigation, and industrial use. Includes drinking-water reservoirs themselves.

3.6.0 Transport and communication

This land-use type includes land allocated to infrastructure used for the transportation of goods or people, or navigation and communication equipment. Zoning of land for roading or rail purposes that has not yet been constructed should be captured as attributes.

3.6.1 Airports/aerodromes – locations from which aircraft flight operations take place, including areas used for the accommodation of aircraft and coordination of air cargo or passengers. Includes heliports.

3.6.2 Roads – includes the full roading corridor (i.e. sealed road areas and unsealed roadside strips and roading corridors), with the permeability attribute recorded as appropriate (sealed/unsealed).

3.6.3 Railways – permanent rail transport tracks and associated infrastructure, including stations and terminals. The full rail corridor (track and land alongside tracks required for safety clearance) should be classified under this class.

3.6.4 Ports and water transport – harbour locations where ships dock to transfer people or cargo to or from land, such as ports, docks, and wharves. Includes both the terrestrial parts of ports and the *marine* areas (harbours, navigational channels) that are specifically designated and controlled for activities associated with the port. The water attribute can be used to differentiate the terrestrial and marine parts of the same facility.

3.6.5 Navigation and communication – includes radar stations, beacons, lighthouses, TV, and radio transmission towers, etc.

3.7.0 Mining

This land-use type includes mining and extractive industries (including salt extraction from evaporation basins). Record the type of mining, if known, in the commodity field.

3.7.1 Mines – land from which minerals, precious stones or coal is being extracted. Includes open-cut and deep-shaft mines.

3.7.2 Quarries – land from which stone, gravel, clay, slate, sand, soil, rock, or other construction materials are being extracted, for use in construction, infrastructure, and other industrial applications.

3.7.3 Tailings – tailings dumps and dams for the storage or treatment of waste material left over after the extraction of desired minerals or metals from ore, often stored in containment facilities or tailings ponds. Also includes quarrying output.

3.7.4 Evaporation basins – basins and associated facilities used for the evaporation of water from irrigation drainage or (predominantly) salt extraction.

3.7.5 Extractive industry not in use – land undergoing rehabilitation after mining activities, and unmined land within a mining permit.

3.8.0 Waste treatment and disposal

This land-use type includes land uses dedicated to managing and processing various types of waste materials, primarily associated with industrial and urban activities, including solid waste, wastewater, and stormwater, to mitigate environmental impacts and protect public health.

3.8.1 Landfills – designated areas for the disposal of solid waste, typically where waste materials are deposited, compacted, and covered with soil or other materials

to reduce environmental contamination and control emissions.
Landfill gas recovery systems (which generate electricity through the burning of methane in landfill gas) should still be classified as part of a landfill land use.
Includes all class 1 to 5 landfills (e.g. landfills designed to receive inert construction materials are also included in this category).

3.8.2 Transfer stations and recycling facilities – facilities where solid waste is collected, sorted, processed, and prepared for recycling or transfer to landfills or other disposal sites, aiming to minimise waste generation and promote resource recovery.

3.8.3 Municipal wastewater – wastewater generated from residential, commercial, and industrial activities within urban areas, requiring treatment to remove contaminants before discharge into water bodies or reuse for irrigation or other purposes. Includes municipal wastewater ponds and sewerage pipelines.

3.8.4 Wastewater treatment – land application – areas where treated municipal wastewater is applied onto land surfaces for beneficial reuse, such as irrigation of agricultural crops, recharging groundwater aquifers, or enhancing soil fertility, following appropriate treatment processes to ensure environmental safety. This is often likely to be an ancillary use.

3.8.5 Stormwater management – infrastructure aimed at controlling and mitigating the impacts of stormwater runoff, including detention basins, drainage systems, retention ponds, and green infrastructure (rain gardens, wetlands), to prevent flooding, erosion, and pollution of water bodies.

3.9.0 Vacant and transitioning land

This land-use type includes areas that are currently unused or undergoing a transition from one land use to another, but in this case with a clear transition towards or within other concepts under the built environment.

3.9.1 Vacant land – includes derelict land and developed land that is idle.

3.9.2 Greenfield development – previously undeveloped or agricultural land zones for or undergoing new construction projects or urban expansion, typically involving the conversion of rural or natural areas into residential, commercial, industrial, or infrastructural uses.

3.9.3 Brownfield development – areas of active redevelopment of previously developed (often industrial) land that may be abandoned, contaminated, or economically under-utilised, with the aim of rehabilitating and repurposing these sites for new urban activities. May include residential areas undergoing infill development that increase housing density.

9.1.1 Data structure

This section specifies the proposed data structure for the attribution of land-use information. Each set of attributes applies to one geographical unit and can contain information about the primary and ancillary land uses, as well as attributes for disambiguation and end-user reclassification, recording provenance and any operator comments.

A standard data structure is essentially a simple application programming interface (API). Third parties can create visualisations, models, and dashboards on top of land-use data that conform to this standard to enhance their value and adoption over time.

Table 8. Proposed data structure for the capture of land-use information (other attributes may be added as desired, to support flexibility)

Attribute	Type	Example	Notes
lu_code_primary	integer	1	Primary-level land-use code
lu_code_secondary	integer	2	Secondary-level land-use code
luc_code_tertiary	integer	3	Tertiary-level land-use code
lu_code	string	1.2.3	Land-use code (primary use)
lu_description	string	Natural Heritage	Land-use class label (primary use)
lu_code_ancillary	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	string	cattle dairy	Commodity type; multiple commodities are to be specified with comma separation with optional whitespace characters
commod_ancillary	string	pulpwood	Commodity type(s) relating to the ancillary land-use code(s)
manage	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
land_status	string	*(To be determined.)*	Land status type (public–private continuum; terminology to be determined).
water	string	lake	Water type (null for non-water)
zone	string	Large format retail zone	District plan zone; terminology to be taken from the Zone Framework Standard (National Planning Standards, 2019)
permeability	string	sealed	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	26/05/2024	Date of (primary) land use code

Attribute	Type	Example	Notes
source_data	string	Northland Regional Council	Primary source data (e.g. field mapping, local knowledge, ancillary data set, air photo, imagery). Often, multiple sources of information are combined to come to a conclusion; only one should be specified.
source_data_doi	uri	doi:10.26060/W5B4-WK93	Optional (i.e. when available) DOI or HTTP URI for the source data
source_date	date	1/12/2023	Date of spatial feature (e.g. image date, ancillary photo date) in primary source data
source_scale	integer	25000	Geographical scale of primary source data, expressed as an implied ratio of 1:n, (e.g. 1:25,000). For raster data, the value should be the larger of cell height or width.

9.1.2 Potential next steps for further development

This is a *draft* land-use classification system, which was built on an Australian system, partly for the sake of expediency and pragmatism (using existing components). It has been helpful to test a pre-existing comprehensive land-use classification system in the New Zealand context so that we can more easily identify requirements that are unique to New Zealand.

The draft has been through one round of feedback from a range of stakeholders in two workshops, but we do not recommend that it be adopted as is, without further consideration. We note that Harcourt et al. (2024a) have developed a set of recommendations for engagement with Māori, and the engagement *has not yet been undertaken* (although there has been involvement of Māori researchers in the development of this system, who have engaged with land-use classification ideas for many years). It is therefore important to note that before this engagement occurs this classification system is not a predetermined outcome.

Further work is also required to assess the robustness and applicability of the proposed land-use classes under different use cases. This testing also needs to assess the feasibility of applying the land-use classes using available data and to identify what data are required and missing to conduct a classification. Testing of the classes also requires further clarity around the potential mode of delivery and ease of use by stakeholders, because there is a tension between the principle of atomisation of information and whether end-users would prefer to use classes directly, or should be expected to examine commodity, management practice, and other attributes.

For example, with dairying, a compromise position has been met, as dairy is both a class and a commodity. This decision was made for user convenience, because dairying is a critical land-use class for the intended purpose of this land-use classification system. We also expect to incorporate additional land management practices that specifically relate to dairying (and thus it is helpful to have a class to which they must correspond).

For dry-stock sheep & beef systems, there is still debate regarding the use of 'intensive' and 'extensive', specifically in the context of how these might be distinguished, and whether sheep & beef farm systems should be directly identified as specific classes separate from other dry stock (i.e. deer, goats), in the same way that we have proposed for dairy farms. Once again, there is a trade-off between a principled approach grounded in the idea of the atomisation of information and a simplified, hard-coded, aggregate, which may be convenient for some users. However, it is important to appreciate how the proposed system of commodities and management practices works in practice (as in, how a data analyst may use the data to answer questions) before criticising the proposed hierarchical classification structure for not being specific enough in particular domains. Data and information can be organised in different ways, and the assigned primary land-use class is not to be used in isolation from the other information.

Other key areas that require further attention include the 'Cultural and natural heritage' classes, and the 'Built environment; classes. For the former, further consideration should be given to the extent to which it may be useful to link these classes directly to the IUCN (International Union for Conservation of Nature) protected area classes. These discussions would ideally be linked with further development of the Protected Areas of New Zealand (Planzer et al. 2024), noting that discussions on the Protected Area Network have focused heavily on biodiversity protection rather than capturing the full extent of purposes for which land may be protected.

Limited feedback has been received on the 'Built environment' classes and the extent to which a higher or lower level of delineation of land use may be relevant. On the one hand, in terms of the interaction between land use and the use of soil and water resources, there are minor differences between the commercial land-use classes, high-density residential and many industrial uses, but for some purposes it might be highly relevant to identify these differences. It is relevant to identify the area of open green space within an urban area, and also to identify industrial uses (e.g. a dairy factory) in rural areas. Finally, as noted earlier, there is some inconsistency in how water features are handled in the proposed structure, with some identified as specific classes (e.g. effluent pond, stormwater management), while others (e.g. rivers, lakes) are identified simply via attribute description.

More broadly, there is a need to fully confirm which attributes and which vocabularies are useful and feasible to include in this classification system. This includes the outstanding question of the terminology that should be used to describe tenure (such as 'public', 'freehold', etc.). This is outside our area of expertise, although we recognise the demand for land tenure information to be inter-operable with land-use information in some way.

This draft land-use classification system has been designed 'top down' and does not consider whether suitable, reliable, timely, high-resolution information exists to produce a national land-use map according to the proposed system. For this reason, we have also proposed a draft land-use classification system that is 'bottom up' in design, and begins with the explicit knowledge of what information exists to identify which land-use classes can be discriminated (section 9.2).

9.1.3 Collaboration on future work

Because the proposed NZLUM classification system is nested within the proposed land-use classification framework, it has also been included within the GitHub repository. Again, this is intended to foster collaborative changes to the proposal in the future. For the latest version of the NZLUM classification system, refer to: https://github.com/manaakiwhenua/nzsluc/ tree/main/classification-systems/nzlum.

9.2 Epistemological classification systems

Classification schemes are incredibly important for describing how we understand our natural world. While always purposeful, they are often not systematic. Land use is inherently not any single *thing*. It is a combination of qualities at a particular scale (or resolution), which can be assembled to provide meaningful information. At present, our classification schemes are based on a small set of available datasets, most of which are not directly fit for purpose, along with a massive amount of expert knowledge in the form of interpretation, inference, rules, assumptions, and probabilities. This form of expert knowledge is largely implicit (unrecorded, or informally recorded), which negatively affects the inter-operability of the classification schemes.

As an example, consider Figure 33, which represents the concept of *horticulture* as it is described (at a high level) in several previous land classifications discussed in section 7. Each classification scheme is uniquely coloured, showing links to concept definition or a description as it relates to defining the class, along with broader or narrower concepts where applicable.

The first thing to notice is the similarities. One could argue these should not be separate entities at all; merging these categories would allow for a richer description and property association of the overall concept (as a class). However, most, if not all, of the descriptions and/or definitions are not rich enough to determine the differences, or similarities, between them. As such, important questions arise. Which crops does 'orchard' include or exclude? Do land management practices need to be considered; and if so, when? What are the intended spatial units (or range)? Which data were used in determining, and identifying, the concept of horticulture as applied in practice? In the absence of transparent methodologies (including the possibility of numerical boundaries to distinguish certain concepts) in existing classifications, there may be no other option but to loosely infer the answers to these questions.

Perhaps the classes are similar because they are based on the same data. Does the available data drive our questions? What we do not have easy access to is a clear understanding of which supporting data were used, how they were used or generated (subset, processed, etc.) and which other data may have been incorporated. For example, LUNZ used LCDB *with* AgriBase to determine horticulture classes (Leathwick et al. 2003). How many other categories rely on this information, directly or indirectly?

Any classification scheme, or system of categories, adhering to the principles outlined in the land-use classification framework should be able to be traced back to its supporting data. This epistemological model (i.e. one in which we can be clear *how* we know what we

know) allows for transparency and reproducibility by providing rigour to the classification and supporting methodology. For any given category, the aspects that define use, and *how that has been determined*, are of paramount importance.

Another way of expressing this idea is to make the point that the preceding NZLUM classification system is a 'top down' classification system that begins from a consideration of what classification structure would be useful for most intended use cases. It does not entail that sufficient data and/or information actually exist to fill, or represent, the categories in the classification structure in practice. Therefore, another (complementary) approach is to consider a 'bottom up' classification system that first establishes what information exists, including its quality, availability, and access rights, and only then systematically determines what land-use classes might be achievable in practice.

Ultimately, the ideas of top-down and bottom-up classification systems are complementary, since, once it is established what information is available for use within a land-use information system, one still needs to determine what concepts to aim at expressing as knowledge. Doing both establishes the existence of data gaps that must be addressed before complete realisation of a useful land-use classification system.

The shortcoming of a top-down classification system is that it is an open-ended problem. Although it is possible to satisfy the needs of end-users with respect to a land-use classification system when designed top down, from a bottom-up perspective there is always the potential for new data that need to be integrated into the broader body of knowledge (i.e. a knowledge graph). As a result, we have not produced a completed example of this idea for this report. An example of this approach, clearly specifying the attributes to be captured for the classification of land use for soil quality monitoring, and based on the on-site visitation of sampling sites, is described in Cavanagh & Whitehead 2022 and further developed in Cavanagh & Whitehead 2023.

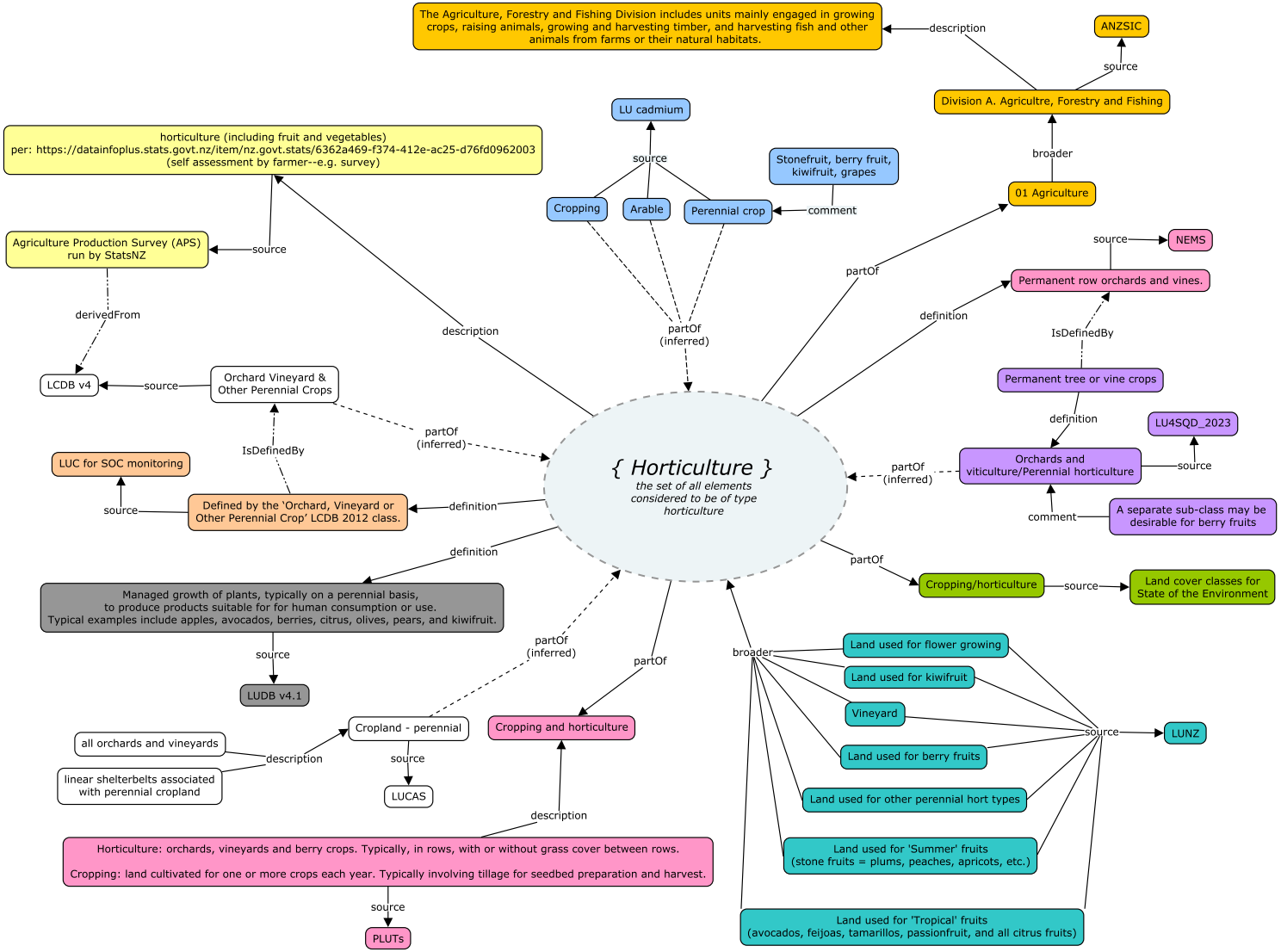

Figure 3. The concept of 'horticulture' as represented in previous land-use classifications.

10 Conclusions

Many land-use classification systems have been designed; some have seen application, few have been enduring, and several are currently in use. Rutledge et al. (2009) reviewed the fundamental basis for many of these systems. Mücher et al. (1993) suggested several reasons why classification systems are often left unimplemented and identified features of a sound land-use classification system.

A key reason why land-use classification systems have failed to be enduring is that they do not clearly distinguish between lasting principles of land-use classification, on the one hand (a classification framework), and the immediate need for a particular, systematic land-use class structure, on the other (a classification system). Our proposed land-use classification framework presents overarching principles and best practices to which land-use classifications (intentionally plural) should adhere. Specifically, one land-use classification system is unlikely to serve all uses for land-use information, and this approach allows for the principled development of multiple systems using a variety of properties, potentially only applicable at specific spatial or temporal scales, limited extents, or specific purposes (including for the purposes of confidentiality and indigenous data sovereignty), while providing consistency and transparency in the development of a system.

The proposed land-use classification framework and one proposed classification system have been developed iteratively and with reference to feedback from a wide range of practitioners, informed by MWLR's experience producing land-use classifications for particular (usually regional) application. The classification system is inspired by, but now substantially different from, ALUM, and addresses some stakeholder calls for a common land-use classification system.

An initial attempt has been made to gather Māori perspectives because there has been limited participation in previous land-use frameworks and classifications, largely neglecting Māori cultural aspirations, knowledge, values, priorities, and interests. Arising out of the work undertaken by Harcourt et al. (2024a) is a clear call for a long-term national land-use classification that reflects Māori values, knowledge systems, and interests, to support decision-making, planning and policy, especially at the tribal, sector, and enterprise levels. This is most effectively achieved through Māori representation as part of any future governance of a national land-use classification, and an engagement plan has been developed to better enable Māori values and principles to be embedded Harcourt et al. (2024b).

To foster ongoing development and collaboration on the framework, the proposed land-use classification framework and associated classification systems are also available canonically on GitHub at https://github.com/manaakiwhenua/nzsluc. This mode of delivery provides a public place to propose additional land-use classification systems. It may also be used as a home for tools developed to support this information, such as a web page that could be hosted using GitHub Pages.

This report presents a synthesis of land-use classifications with which Manaaki Whenua – Landcare Research has been involved in some way over the past decade. Two workshops

were run over the lifetime of this project to engage with people for whom land-use information is of professional importance. The first workshop was broad in scope, but the second was designed to elicit feedback on a specific recommendation for a new, draft land-use classification system. This classification system (NZLUM) is presented as part of this report, including changes made following the second workshop. It is intentionally embedded within what we have termed a land-use classification framework. The fundamental idea is that we have identified that one reason why land-use classification systems have failed to be enduring is that they do not clearly distinguish between lasting principles of land-use classification, on the one hand (a classification framework), and the immediate need for a particular, systematic land-use class structure, on the other (a classification system).

Our proposed land-use classification framework presents overarching principles and best practices to which land-use classifications (intentionally plural) should adhere. To that end, the report presents two land-use classification systems (although only one was discussed at the second workshop). A key recommendation is that consideration be given to designing core components as building blocks to facilitate extensible classification systems designed for specific needs, rather than focusing solely on a *single* general-purpose land-use classification system *to the exclusion of* the idea of multiple, compatible (or at least coherent) systems. The alternative is not, in fact, a central general-purpose classification system, but rather will tend towards the *ad hoc* development of competing and incoherent classification systems without overarching governance (the status quo).

11 Recommendations

11.1 General

Convene an expert Māori advisory group to ensure the land-use classification framework is consistent with Māori priorities, as per the recommendations of Harcourt et al. (2024).

Establish a land-use governance group with responsibility for continuing the development of the classification framework principles and any land-use classification systems. This governance group should:

- ensure the classification framework and systems are adequate to meet the demands of national policy statements and resource management legislation on regional and local governments
- genuinely deliver on the outcomes from Māori engagement
- establish and direct technical working groups to continue the development of appropriate classification systems that align with the framework
- manage the evolution of the classification schemas to ensure stability over time.

Advocate for a land-use information system as a nationally significant information system, and establish a mandate for the continuation and adoption of the land-use classification framework. Specifically, this should involve:

- advocating for the standardised collection, publication, and application of land-use information by those organisations that hold useful, public, land-use information, which will be necessary to realise the proposed classification systems
- advocating for the continued refinement of public land-use information and ensuring its fitness for purpose over time (e.g. anticipating increasing demands for improved spatial and temporal resolution over time).

11.2 Land-use classification framework

- Establish evaluation criteria for the draft proposed (and potential future) classification systems against the principles of the framework.
- As per the recommendations of Harcourt et al. 2024a, in conjunction with the expert Māori advisory group ensure the land-use classification framework's consideration of ideas such as atua domains (genealogical hierarchies) and whakataukī (proverbs, aphorisms) is consistent with Māori priorities.
- Develop and maintain metadata standards and templates that are suitable for land-use data.

11.3 Land-use classification systems

11.3.1 NZLUM

1 Ask the Māori expert advisory group to identify a broad representation of land-use attributes suitable to meet the needs of Māori decision-makers (hapu/iwi to identify these attributes for themselves) (Harcourt et al. 2024a).

2 Continue work on the specific definitions and refinement of the boundaries of proposed land-use classes, through considering specific use cases that particularly apply to each of the three primary classes (conservation, agricultural production, built environment).

   a Ensure fitness of use for the implementation of specific policies (e.g. any relevant national policy statements).

   b Use pilot implementations of NZLUM to consider the performance of NZLUM against the framework's evaluation criteria.

   c Refine NZLUM as a result of these test cases.

3 Establish tools for the technical evaluation and examination of the logical consistency of NZLUM. This should include technical specifications (e.g. a machine-readable data schema, vocabulary services, metadata profiles).

4 Consider the feasibility of implementation for all classes at the tertiary level, with explicit reference to existing data. Identify any data gaps that must first be addressed before full implementation of the revised NZLUM.

11.3.2 Epistemological foundation of land-use information

5 Consider curating an inventory of available data sets that may be useful as inputs for a land-use information system. Some existing reports on land-use classification systems are well documented, but some data are only available at regional or local scales, and these have not always been included in inventories focused on nationally consistent information.

6 Formalise knowledge about these available data in a structured way: ascertain which target classes in the proposed NZLUM are supported by existing data, and which are not (which may vary geographically). These latter are to be noted as suffering from outstanding data gaps. These data gaps will preclude the full implementation of NZLUM (or any alternative land-use classification system), but a partial implementation may still be useful, and adoption of it may provide impetus for filling the identified data gaps.

11.3.3 Standardisation of building blocks and reusable components

7 Create, promote, and support a set of discrete observations and measurements that which can be consistently identified and recorded to satisfy the questions we will seek to ask of our land.

8 Consider a consistent, shared styling scheme for all visualisations adhering to the proposed framework. This could be as simple as consistent colouring rules for top-level categories.

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Appendix A – Biodiversity protection classes

One recommendation from Planzer et al. (2024) is that all data in PAN-NZ should be classified using the ranking system of Bellingham et al. 2016 and mapped to the IUCN classification system. The levels of biodiversity protection as proposed by Bellingham (2016, Tables 15-6, 15-7) are:

1 **High degree of biodiversity protection** (Bellingham Rank 5); protection is the main purpose or is ranked equally with a limited number of other compatible purposes. Examples:

- National Parks Act 1980
  - National Park
- Reserves Act 1977
  - Nature Reserve
  - Scientific Reserve
- Conservation Act 1987
  - Sanctuary Area
  - Wilderness Area
  - Wildlife Management Area
- Resource Management Act 1991
  - Water Conservation Order
- Wildlife Act 1953
  - Wildlife Sanctuary

1 **Moderately high degree of biodiversity protection** (Bellingham Rank 4); protection is a main purpose but is shared with other, less compatible purposes (i.e., recreation). Examples:

- Conservation Act 1987
  - Amenity Areas
  - § 23 Watercourse Area
- Reserves Act 1977
  - Conservation Covenant
  - Protected Private Land
  - Scenic Reserve
- Conservation Act 1987
  - Conservation Park
  - Ecological Area

Te Ture Whenua Māori Act 1993

  - Māori Reservation (Wetland or Scenic Reserve)
- Queen Elizabeth II National Trust Act 1977
  - QEII Open Space Covenant
- Wildlife Act 1953
  - Wildlife Refuge

1 **Moderate degree of biodiversity protection** (Bellingham Rank 3); protection is a desired purpose but subject to capability with a different main purpose or may be less comprehensive (i.e., only some aspects of biodiversity protection are targeted). Examples:

- Conservation Act 1987
  - Ecological Area
  - Stewardship Area
- Reserves Act 1977
  - Government Purpose Reserve (Ecological or Wildlife)
  - Ngā Whenua Rāhui Kawenata
  - Local Purpose Reserve (Ecological)

Te Ture Whenua Māori Act 1993

  - Māori Reservation (Conservation or Conservation of Native Bush)
- Wildlife Act 1953
  - Wildlife Management Reserve

2 **Moderately low degree of biodiversity protection** (Bellingham Rank 2); some biodiversity protection is achieved but it is of secondary importance. Examples:

- Resource Management Act 1991
  - Esplanade Reserve or Strip
  - Consent Notice (i.e., subdivisions granted subject to conditions to be complied with on a continuing basis by the subdividing landowner and subsequent owners)
- Reserves Act 1977
  - Historic Reserve
  - Local Purpose Reserve (Other – various)
  - Recreation Reserve

Te Ture Whenua Māori Act 1993

  - Māori Reservation (various purposes related to Recreation, Camping, Water Supply, Meeting Places, Historic Significance, etc.)
- Conservation Act 1987
  - Marginal Strip
- Local Government Act 2002
  - Regional Parks

3 **Low degree of biodiversity protection** (Bellingham Rank 1); protection results indirectly and fortuitously as a result of other activities. Examples:

Te Ture Whenua Māori Act 1993

  - Māori Reservation (various purposes related to Marae, Pā Sites, Papakāinga, Urupā, Wāhi Tapu, etc.)
- River Boards Act 1908
  - River Bed
- Reserves Act 1977
  - Road Reserve

Appendix B – Stakeholder engagement – first workshop

One of the deliverables of this project was to hold workshops/hui with Māori, central government, regional councils, industry, and researchers, with the purpose of testing our proposed framework and classifications for feedback. It was agreed that development of a land use classification framework with Māori first requires the preparation of an engagement plan (which is a parallel deliverable to the workshops), so that engagement or co-development with Māori can only be executed *after* the conclusion of this initial work. Therefore, our workshops were limited to engagement with government and industry practitioners, those who use or who would benefit from land use information.

An online-only workshop was organised and held on 27 March 2024, for 1.5 hours. There were 48 attendees from a variety of organisations, including Ministry for the Environment, Ministry for Primary Industries, Te Uru Rakau, NZ Transport Agency, Department of conservation, Ag Research, Land Information NZ, HortNZ, Beef + Lamb NZ and DairyNZ. This workshop was not intended to canvas Māori perspectives on land-use classification or information, as it does not build on the iwi/Māori engagement plan. Despite this, this workshop was designed to ensure that the team build a broad view of definitions of land use in New Zealand. We wanted to get the perspective of experts on how information on land use is currently used. We considered attendees could provide some promising ideas on the role and future benefits of a national land use classification.

Prior to the workshop, attendees were asked to think about the classified land use information that attendees currently use; what they use it for, and how it is classified. We asked attendees to think about what is good and bad about the classification systems they currently use. We did not ask for written responses to these questions.

During the workshop, Manaaki Whenua gave a 10-minute introduction to the topic of land use classification, focussing particularly on some of the work that Manaaki Whenua has done in the previous 15 years. For the remainder of the session, participants were asked to contribute to a collaborative Mural board (an online "sticky note" board), answering our key guiding questions:

1 What is land use?

2 Why do you need land use information?

3 What land use classifications do you currently use?

4 What land use classifications are you aware of? What are the benefits or pitfalls of these?

5 What land use data do you currently use? What is good or bad about these?

We also included space for "random thoughts" that may have occurred to attendees throughout the session but may not fit under one of these guiding questions.

What is land use?

By far most participants identified land use as being in the domain of human use of resources. They spoke of land use information as identifying the purpose or purposes of

activities that happen on the land. Some drew a distinction between actual vs intended (or planned) uses of land, and some spoke of future use or constraints on land. Participants were clear that land use is distinct from land cover. Some mentioned management practices, but in divergent ways—one stating that how land (e.g. fodder cropping) is managed should be distinct from the human intention for that land (e.g. livestock production); others that this "how" is inseparable from the "why." In cases where examples were given, they were almost exclusively related to rural industry (grassland, dairy, sheep, horticulture, fodder crops).

One example dealt with "secondary functions" of apparently dedicated land use, giving the example of transport corridors that may retain natural properties and therefore a function for biodiversity.

Two responses identified a less human-oriented understanding of land use, describing land use as "what currently occupies ... space regardless of whether it is a deliberately human activity;" or as "the fauna and flora that are currently living in a defined area."

One response dealt specifically with a Māori worldview, noting the interconnectedness and inter-dependency between people and the environment, and how this dynamic across space and time.

Why do you need land use information?

The three most-often mentioned requirements for land use information were the inter-related domains of modelling, planning, and policy. This may reflect the audience's own preoccupations.

With respect to modelling, examples include:

> *To better understand causality and pathways for flow on impacts on the environment land, freshwater, marine, air, climate).*
>
> *To relate indicators of environmental state (to pressures, drivers, outcomes, responses).*
>
> *Nutrient loss modelling.*
>
> *Catchment modelling.*
>
> *Targeting necessary changes, e.g. CC [climate change] adaptation.*
>
> *Land use modelling, scenario analysis.*
>
> *Modelling water quality scenarios.*
>
> *To examine possible scenarios, and their environ[mental], social, economic, and cultural impacts.*
>
> *Land use map as the underlying foundation for any spatial modelling.*
>
> *Regional future scenario modelling.*

With respect to planning:

> *To estimate the intensity of human impact on the environment for policy development.*
>
> *Allocating resources for a growing population.*
>
> *Planning for current and future land uses.*
>
> *Farm's land and environmental planning and management.*
>
> *Making the opportunities and impact at place clear.*

Policy requirements (including reporting):

> *Supports application of mandatory National Planning Standards in district and regional plans.*
>
> *Broadly, different activities that are either permitted under the RMA framework, and other activities that require authorisation.*
>
> *To stratify monitoring design to determine the effectiveness of regional policies.*
>
> *Finding properties that are required to have FWFP [freshwater farm plans] or Regulatory*
>
> *When we design policies that affect land, we need to know how they will affect the relationship between people and their land.*
>
> *NPS-HPL [National Policy Statement – Highly Productive Land]*
>
> *NPS freshwater requires regional councils to create wetland inventory – very difficult to map tho*
>
> *SOE reporting*
>
> *Spatial plan development and targetting of rules to specific areas.*
>
> *Identifying uses on highly erodible land so they can be managed through policy.*
>
> *National Environmental Reporting. Including producing statistics on water quality by land use type, etc.*

These and other participants were interested in land use *change* information, to both understand past land use, but to project future land use (and the impacts thereof). One specific example was highly productive soils in Auckland peri-urban areas; another was to see changes in residential intensity over time.

Many of these needs for land use information reflect the idea of "enduring questions" regarding official data and statistics, including land information (Statistics New Zealand, Ministry for the Environment, Department of Conservation, 2013). An enduring question of land use information is likely to be a requirement that many of our participants have repeated.

Other examples include: a need for detailed land cover and forestry information for gauging wildfire risk and other natural hazards; information for supply and value chains.

A minority of the feedback under this banner was challenging to categorise, but included uses generally related to "high level story-[telling]", visualisation and public comms; farm system design, biodiversity, and value; resilience to natural disasters; biosecurity; and a concern that because transport land uses are public and "skinny", that they are often ignored, subsumed into surrounding land use. On this latter point, one participant noted that for transportation planning, current land use is required to properly negotiate prices or to understand existing rights and responsibilities to land earmarked for future transportation use.

What land use information do you currently use?

Grouped responses to this question include classified data or classification schema controlled by various organisations:

- Stats NZ
  - Meshblocks (presumably data published to this "unit," or else groupings made with census data)
  - Agricultural Production Survey
  - ANZSLIC industrial classification—within the Stats NZ Data Lab
- LINZ
  - Topo 1:50
  - LINZ S30300 ratings valuations rules
- Local and regional government
  - Identified highly productive land (which relies on NZLRI LUC)
  - Zoning information ("general rural," and "rural production" zones under the National Planning Standards — "Rural Production," "Rural Coastal" and "Mixed Rural" under the Auckland Unitary Plan).
  - Waikato Regional Council, Waikato Integrated Scenario Explorer (WISE) land use classification for scenario modelling.
  - Information on contaminated land from the Hazardous Activities and Industries List (HAIL).
- AsureQuality
  - AgriBase
- Manaaki Whenua
  - LCDB
  - NZLRI LUC
- Ministry for the Environment
  - LUCAS LUM
  - National Environmental Monitoring Standards (NEMS) soil quality land use classes

- AgResearch
  - Our Land and Water National Science Challenge (OLW NSC) typologies, including farm typology for freshwater monitoring modelling (power analysis).
- IUCN
  - Protected land typology
- Department of Conservation
  - Concession records
- Beef + Lamb NZ
  - Farm classes
- Milk suppliers

Detailed spatial data (that cannot usually be shared)

Three responses mentioned the use of satellite imagery, aerial imagery, and hyperspectral images (for farm-scale mapping) as land use information. In post-workshop discussion with one attendee who mentioned hyperspectral imagery, he concurred that although remotely-sensed information is a promising, multi-temporal and rich source of land cover information, it is not always sufficient for identifying land use specifically. Examples where this is the case could be whether land is subject to conservation covenant, or how it is managed (e.g. stocking rates). Most attendees who responded referred to existing classified data—many were eager to mention the limitations of their source of information.

What land use classifications are you aware of? What are the benefits or pitfalls of these?

Responses to this question were generally confused with responses to the questions about land use classification and land use data; it is difficult to separate concerns about a land use classification from data in which a classification is realised. However, participants did add details about the limitations of existing land use information.

Clarity — Confusion between land use capability, suitability, land cover, and land use. An inability to record the *purpose* of conservation, e.g. indigenous biodiversity protection, rather than just the fact of conservation.

Flexibility — Accommodation or flexibility for additional/new/future land use types.

Zoning — Distinction between planned/zoned uses and current/built uses, e.g. for road parcels and urban fringes.

Tenure vs management — Land ownership does not entail land management, e.g. land owned by DOC but managed by councils. One participant also noted a desire to discriminate conservation and farming on pastoral leases.

Land use intensity — A need for disaggregated farm types, e.g. according to intensity demonstrated by stocking rate.

Detail — Farm-scale mapping; a lack of detail within urban areas; inability to include pipelines and other linear features; plantation forestry age; the presence or absence of weeds, wilding pines.

Managment practices — Lack of information regarding soil conservation practices; practices that imply environmental risks (e.g. accelerated erosion, nutrient, and other contaminants), including fertiliser application, irrigation, and pesticides); lack of discrimination between dairy, dairy support, and dry stock; whether a plantation forest is permanent; conservation activities; shelter belts.

Commodities — Honey production by type (e.g. mānuka); crops (e.g. hops, berries, lavender, apples, etc.) on annual basis; forestry (species, end use (sawlog vs pulp), carbon farming), livestock types

What land use data do you currently use? What is good or bad about these?

Only one example of an existing land use classification was provided, and that was for Bay of Plenty Regional Council.[7] BOPRC uses a parcel-scale[8] land use classification system, with data from a variety of sources (LCDB, Terralink, AgriBase, consents, ratings, satellite and aerial imagery, individual regional council staff, the Rotorua Nitrogen Agreement, Ministry for the Environment, etc.). This has been a multi-year project. It is described verbatim:

> *This map shows the land use types in the Bay of Plenty region (dairy, kiwifruit, orchard, forest, etc).*
>
> *The land use layer began from a combination of landcare groundtruthed data, lcdb4 and agribase data. This was then used as a base dataset to begin the next phase which was digitising the land use from imagery. 2011, 2014, 2016 imagery, Google Earth and Google Street View was used where available (at times the imagery used was recorded in the data). The digitized landuse was then verified by BOPRC Land Management Staff.*
>
> *A series of ground truthing exercises were conducted to help validate some areas and also classify areas that were unknown. Not all of the data has been verified as correct or has been ground truthed. Land use may have changed since the dates of the aerial photos used to digitize the layer and may have been incorrectly categorised. However, this is the only complete and best information available. It is a work in progress.*

This classification has the following classes:

- Not defined
- Arable
- Dairy
- Deer

[7] https://maps.boprc.govt.nz/apps/defe8819f0274d008c15b733563356f1

[8] Parcels are the basic unit of classification, but land cover features may disrespect these boundaries, e.g. forests and waterways.

- Forest exotic
- Forest native
- High intensity beef or dairy grazing
- Hydro [water, e.g. rivers]
- Kiwifruit
- Lifestyle block or mixed land use
- Not confirmed
- Orchard or permanent horticulture
- Other
- Parks and reserves
- Scrub
- Sheep and beef
- Urban/road/rail
- Vegetables
- Wetland

Apart from the class and a free-text source field to record some provenance, there is no other ancillary information published about the described land use.

One participant noted that consents data identifies some critical land uses (e.g. dairy effluent discharge locations indicate dairy farms) but does not define, or cannot easily be related to, the spatial extent of farms, which significantly limits its utility for spatial analysis.

'Random thoughts'

Classification — the ability to capture multiple co-located uses; the ability to capture dynamism within a land use (e.g. crop rotation); the need to include marine/coastal information out to the extent of the NZ EEZ; "interactive" classes that can be adapted based on a user type or requirement.

Data — update frequency needs to be higher than LCDB, LUM, etc. as land use is more dynamic than land cover; linking to supporting information; a need for a confidence indicator; potential for a "security layer" to include more sensitive information such as consents; being able to dynamically build a classification from available dimensions of land use information, rather than a static end product; data sharing that doesn't currently occur, needs to occur.

Scale — The appropriate scale depends on the application; one attendee indicated a potential need for data at 1 m^2 resolution; others have indicated repeatedly that using geographic units (e.g. parcels) eliminates the potential to describe linear features that aren't roads or rivers; several mentioned that the scale for current national and regional land use/cover products does not meet requirements, and that better class discrimination and accuracy would still not address this issue.

Standardisation — ISO 19144-3 Geographic information — Classification Systems — Part 3: Land Use Meta Language (LUML); letting one group collect high value information properly instead of many groups doing it piece-meal and part-time; different councils zone differently, which will make zoning information difficult to integrate.

Methodology — A recognition that good input data is the most significant limiting factor; potential for farm plants to provide land use information; the application for artificial intelligence to realise more dynamic land use classifications; a recognition that flexibility comes at a cost—too many standards and tools proliferating will cause problems for analysis and reporting; a requirement for a robust, and published methodology to make data reliable, including for potential hearings in the environment court; data must include metadata at a feature-level, including dates, sources and any parameters.

Benefits — There are potentially significant benefits to councils for reporting and analysis with consistency of data and a centralised source of truth.

Drawbacks — The idea of "one dataset (or classification) to rule them all" will not work, due to disparate requirements for this information; the publication of land use data will probably raise privacy concerns.

Licensing/publishing — Data should be licensed (creative commons) and provided through a standard portal.

Appendix C – Land-use classification in New Zealand (workshop 2)

Following the conclusion of the first workshop, we used the information to help guide a draft of one land use classification system. The same people invited to the first workshop were invited to attend the second, and we requested either direct feedback during the workshop, notes on a virtual workspace, or written responses via email to a group email address (classifying_land_use@landcareresearch.co.nz).

During the workshop, we briefly introduced the current distinction between a land use classification framework, and a land use classification system. We explained that the goal of this workshop was to get direct feedback on one particular classification system, with the understanding that it is a draft, and that we are not proposing it as the only appropriate or possible land use classification system under the framework. We emphasised that the classification system for discussion in this session does not necessarily reflect a te ao Māori conceptualisation of land use.

When drafting this land use classification system, several questions occurred to us, and we posed these to attendees as we stepped through each primary then secondary class. For comments left on the online Mural board, we do not know the authors. Some of the questions and responses (indented) were:

- Should conservation classes more clearly link to IUCN protected areas categories (which more clearly identify the reason for conservation, which may be other than for biodiversity) and is what is used in ALUM?
    - NZ's protected areas may not align smoothly with the IUCN categories, so it may result in some ambiguity about the proper classification of conservation areas.
    - This may be a concern for a group focussed on PAN-NZ, and simply become a component of this land use classification to inherit.
- Is management of areas for surface water supply or aquifer recharge ever the primary use? (If not, these classes [minimal use from relatively natural environments] and their position in the classification hierarchy may still be sensible to retain for use as secondary/ancillary classes.)
    - This question gets at a fundamental issue of hierarchical land use classification systems when multiple uses can be accommodated: some uses are likely to only ever be secondary, not primary uses. Do we (and how do we) create space for such classes?
    - Other examples may be recreational activities in natural areas, such as hunting or fishing; or even entire landscapes with value in terms of their ecosystem services, scenic appeal, or spiritual significance.
- How important is it to identify production from indigenous vegetation?
    - Multiple attendees indicated that they would find this valuable.
- Is it useful to have a high-level delineation between softwood and hardwood species? Or simply to know they are exotic species? Do we allow for potential plantations of indigenous species for pulpwood or saw log production?

    - An attendee from Waikato Regional Council said that a differentiation between softwood and hardwood (which is made in ALUM) is not particularly relevant in NZ.
    - However, another argued that an argument in favour of the distinction would be as an indicator of likely time to harvest, which is relevant from a soil conservation perspective.
- How useful is it to know that vegetation for environmental protection has been planted, e.g. to track pro-active management activities? Is it useful to delineate between planting of indigenous or exotic species?
    - Two attendees agreed that knowing the planting status is important, particularly to track future assessment of restoration. (However, this might require further supplementary information that is difficult to obtain, such as the date of planting and the nature any ongoing management that is applied to it.)
- How important is it to delineate between land used for grazing dairy and dry stock (or non-dairy) systems within the classification scheme itself?
    - There is a tension here between the principle of atomisation of information, and user convenience. The principled position could be to clearly separate the land use as animal grazing from the commodity produced from that activity (dairy cattle, or milk). However, as this is such an important land use activity that very many users of land use information would want to identify, directly identifying it within the classification structure would be convenient to users.
- Is it useful to provide high-level delineation between distinct types of land used for dry stock grazing (as an indicator or relative intensity of land use) e.g. flat-rolling, hill country?
    - The attention placed on topography is not entirely consistent with a focus on land use. Although (according to one attendee) there is a general relationship between the percentage of sheep and beef that are finished prime and the slope and region, there are still many exceptions.
    - Multiple users agreed that explicitly identifying the slope in the class was problematic, and that it could be later overlaid by users as required. This is true; however, we again see the trade-off between convenience for intended use, abstraction, and separation of concerns. It may also be that it is easier to group sheep and beef farms based on physical landform characteristics than it is to get information about alternative indicators of intensity such as the rate of finishing stock, fertiliser inputs, or stocking rates.
- Is there value in having a separate high-level intensive agricultural production class, versus this being a subclass of agricultural production and plantations?
- Would it be useful to capture farm buildings as an additional class?
- Is there value in mixed residential/commercial and mixed commercial/industrial as classes or should these be captured with the use of a primary/secondary class. Does an explicit "mixed" class violate the general structure of this classification, or make it harder or easier to use?
- Should "industrial" be divided into light, medium, and heavy industrial? (These could also be captured using alternative means, such as "management practices," rather than through the class structure.)

    - One comment was made against this idea; and proposing the use of some kind of attribute instead.
- Is it useful to identify greenfield development (i.e. urban expansion, usually at the urban fringe)? Is greenfield a (vacant) subtype of agricultural production, or of the built environment, even if building has not begun?
    - There is a need to distinguish rural residential land from other turban land for the purposes of considering land fragmentation.
- Is it useful to identify "water" features as an attribute under other uses or would it be more useful to group under a specific "water" class?
    - This is one area of radical departure from ALUM; we decided that capturing water as an attribute rather than a class would allow for better association between water bodies and the adjacent, surrounding, or overlaying land uses. For instance, water ways on farms can be identified as belonging to a form of agricultural production, but still made distinct from land if necessary. Ultimately, water, broadly considered, is a land cover type and not a land use.
    - It will be necessary to address the issue of the distinction between land and water, even in difficult cases such as tidal estuaries, if using categorical attribute labels to describe types of water.
    - There is interest in identifying areas of aquaculture.
    - The land application of waste water: is this a management practice, rather than a use?
    - In urban areas, for considering climate adaptation, being able to identify the "green and blue networks" is critical (Wagner, 2022). The Parliamentary Commissioner for the Environment recently published a report on how urban development patterns have changed over time and how recent subdivisions generally have less public and private greenspace than earlier periods, and that infill development is reducing private greenspace in urban areas (Parliamentary Commissioner for the Environment, 2023).
    - Under the National Policy Statement for Indigenous Biodiversity (NPS-IB), regional councils are required to report on the extent of areas under indigenous vegetation cover in urban areas. Greenspaces may help to identify these.
    - Effluent ponds and wastewater are not primary land uses in themselves; one attendee described them as externalities linked to a particular land use.
- Is it useful to have clearly identified water features e.g. lakes, rivers, wetlands as specific land-use classes? What if this makes it difficult to distinguish between, say, a lake within a conservation area from a lake on a farm? Alternatively, would it be better to not include water as a primary class, but rather to have a typology of water types and list these as attributes, in the same way that commodities and management practices can be attributed to land uses as further details?

Other comments unassociated with any question that was posed:

1 Nutrient studies need to distinguish dairy winter grazing from dairy platforms.

2 In solar farms, co-incident grazing may occur. Which is primary (solar electricity generation or livestock production) will not always be clear.

3 Dairy is simultaneously a commodity (under ALUM, as the commodity "cattle dairy") and a class, which is confusing.

   a One difficulty here is distinguishing dairy milking platform from dry stock areas, which needs attention. Both land uses could have a commodity of "cattle dairy."

   b If dairy is distinguished as a specific class, so should sheep and beef due to the large land area used for it.

4 One comment was made regarding the identification of emergency service facilities (fire stations, police, civil defence), public transport, telecommunications, pumping stations, etc., for emergency planning.

5 A question was raised how information about contaminated land (such as old landfills) might be included, if it is relevant. More generally, the description of historic information: past use can constrain future use so may be pertinent if a land use map is to be used for forecasting.

When asked if anyone would be interested in forming a governance organisation to refine the proposed classification system, very few people expressed interest. No contact information was left in the relevant space in the online Mural board, and only non-committal responses were made verbally. Therefore, establishing a governance structure on a voluntary basis may prove difficult. However, attendance was still high, suggesting that focussed work groups on a smaller set of problems relating to the organisation of a land use class hierarchy and definitions may still be effective.

Material

The following material was provided as a discussion document ahead of the land use classification workshop.

> Workshop: Land use classification in New Zealand
>
> Thursday 16th May 1:30 – 3:30 pm
>
> Location: Teams meeting

This workshop will provide an update on progress in the Land Use Information System – Land Use Classification Framework project and seeks your feedback on a proposed land use classification framework and system that have been developed drawing on drawing on existing literature, experience and information provided at the last workshop (thank-you for your input!). Specifically, we have identified that on reason previous attempts at designing land use classification for adoption in New Zealand have failed to be enduring is that they do not clearly distinguish between lasting principles of land use classification on the one hand (what we have termed a "land use classification **framework**") and immediate needs for a particular, systematic land use classification system or class structure on the other hand (a "land use classification **system**").

The proposed framework outlines the over-arching principles and best practices that should be adhered to in developing any land use classification system. The land use classification system outlines a potential classification that may be used for several

purposes focussed on environmental management, particularly of soil and water – and we emphasise that different land use classification systems may be more relevant for different specific purposes. We are seeking your feedback particularly on the land use classification system with regards to the utility of the systems in the context of your work.

This document provides further detail on the framework and system ahead of the workshop to allow you some time to digest ahead of the workshop. We have asked some specific questions to assist with further development of the NZLUM and welcome your feedback on these and more general comment. If you are unable to attend the workshop, or wish to provide written feedback please email that to:
classifying_land_use@landcareresearch.co.nz

Agenda:

1:30 pm Welcome and introduction

1:35 pm Brief overview of project

1:40 pm Presentation and discussion on the proposed land use classification framework

2:00 pm Presentation and discussion on a proposed land use classification system

3:00 pm Close

New Zealand Standard Land Use Classification Framework

The NZSLUC Framework presents principles and best practices for designing land use classification systems. The principles are intended to guide practitioners in how they use, re-use or design classification systems.

(Draft) Principles

Prioritise atomic data (i.e. decomposition of multidimensional attributes, e.g. tenure)

- Break down information being collected into individual (atomic) attributes.
- Collect primary data in place of secondary categorical data, where feasible.

Be specific about purpose

- Each classification is designed for an explicit spatiotemporal geographic unit.

Hierarchies are encouraged where appropriate

- This will allow for both generalisation hierarchies (aggregation/disaggregation) and genealogical hierarchies (lineage).

This classification framework is intended to be improved over time

- The classification framework shall be reviewed based on comments and requests of stakeholders.

- In particular, the publication of the ISO 19144-3 standard (*Geographic information – Classification Systems – Part 3 Land Use Meta Language (LUML)*) shall cause a revision of these principles and best practices.

Prioritise reproducible and transparent methodologies

- User confidence increases when methodologies can be verified independently.

Classification systems shall accommodate multiple (e.g. co-located, secondary) land-uses

- Differentiate between secondary land use (same place, same time) with intra-period land use variation (same place, different time). For example: rotational grazing, summer housing, etc.

(Draft) Best practices

This collection of best practices is intended for producers of land use information, to benefit consumers of land use information.

1 **Purpose** Land use classification systems shall describe their intended use-cases.

2 **Description of data quality** The quality of published land use data shall be described using a standard, e.g. ISO 19157-1:2023.

3 **Semantic versioning** Changes made to land use classification systems (including geographic unit or scale) shall be communicated to users using semantic versioning of the form major.minor.patch, e.g. v0.2.4. Once a version has been released, the contents of that version must not be modified; modifications must be released as an updated version.

4 **Metadata** land use datasets and classification schema should be published using established metadata standards.

5 **Compatibility and re-use** Compatibility with existing New Zealand classification systems shall be preferred. Compatibility with international classification systems may also be relevant.

6 **Definition of land** Classification systems shall individually determine the definition of "land" with reference to their stated purpose, e.g. whether it is inclusive of marine features.

7 **Primary land use** A justification should be given for the choice of primary land uses (e.g. land area, economic value, duration).

8 **Provenance** Source information (i.e. geographic scale, time/date, operator, and confidence) shall be recorded.

New Zealand Land Use and Management (NZLUM) Classification System

NZLUM is adapted from the Australian Land Use and Management (ALUM) Classification (version 8) for application in New Zealand, taking into account common land use classification usage in New Zealand for several different purposes including State of the Environment soil quality monitoring (see Cavanagh and Whitehead 2022, 2023), the Waikato Integrated Scenario Explorer (Rutledge et al., 2016), Greater Wellington Regional Council whaitua classifications (Cavanagh, 2022), LUDB4 (Price, Rutledge & Morgan, 2010), the New Zealand Planning Standards (MfE, 2019), and LINZ ratings valuations rules (LINZ, 2010).

The rationale for the adaptation of ALUM provides a useful data structure and platform for standardisation, which, simply put, avoids some reinvention of the wheel in this regard. ALUM is licensed under a Creative Commons Attribution 3.0 Australia Licence, which explicitly permits adaptation of ALUM. Where direct overlap of an ALUM classes is considered appropriate, it has been retained. Yet, both particular classes and the arrangement of the class hierarchy are significantly different, and additional classes have been added, to reflect what we consider to be relevant considerations for land use information in New Zealand.

This is proposed as a potential "general purpose" land use classification in the context of 'grouping' the nature of interaction of land use activities with the use of soil and water resources relevant for land use change modelling or environmental management. The development of the system will allow for some 're-classification' of land use e.g. based on irrigated vs non-irrigated land to meet alternate purposes, although in other cases e.g. for LUCAS LUM and specification of pre-1990 forest, different classification systems are required.

The classification retains ALUM's practice of attempting to record additional information e.g. land management practices, using defined terminology. The additional information—termed **"attributes"**—is related to but independent of the land use classes themselves.

The collection of specific additional attributes is intended allow for the "simple" reclassification of land use based on these attributes which may be able to be determined at the time of mapping, or recorded post factum. The number and type of attributes captured within this system needs to be agreed to recognise the value of that information, and the context of use WITHIN this classification, versus use of an alternative classification. Potential attributes could include:

- **Commodity** (as in ALUM) – captures information about crops and livestock that allows for further distinction within a land use class and may be useful in the context of biosecurity, economic modelling, nutrient modelling, greenhouse gas estimation, site-selection, etc.
- **Tenure** – relates to the potential for changes to land use and land use management practices (i.e. tenure may constrain possible land use changes). Information relating to land tenure could be captured in two attributes: `land_estate` and `land_status`. How land is owned, and by whom, is an important consideration for how land may be used or managed.

- **Zoning** – such as those described in the 2019 New Zealand Planning Standards (e.g. rural zone, Māori purpose zone) will help to identify future land use changes and can be matched with additional information such as land cover information to confirm current use.
- **Land cover** – this is particularly relevant in the context of identifying crop rotations within various primary production classes. This would likely be framed as land cover at the time of mapping.
- **Permeability** – i.e. whether land is considered "sealed" or "unsealed."

Land is classified regarding its primary use based on the primary land management objective of the landowner or manager, and additional ancillary land uses can be captured separately. As some uses may only ever be ancillary, the proposed classification system necessarily includes some uses that may only ever be ancillary uses.

An overview of the scheme is provided in Figure 1 with further details of the different classes below. **We have identified specific questions we are seeking your feedback on to assist with further development of the NZLUM**.

1	Conservation and minimal use of natural environments
1.1.0	Nature Conservation
1.1.1	High degree of biodiversity protection
1.1.2	Moderately high degree of biodiversity protection
1.1.3	Moderate degree of biodiversity protection
1.1.4	Moderately low degree of biodiversity protection
1.1.5	Low degree of biodiversity protection
1.2.0	Cultural and natural heritage
1.2.1	Indigenous cultural heritage
1.2.2	Cultural heritage
1.2.3	Natural heritage
1.3.0	Minimal use from relatively natural environments
1.3.1	Surface water supply
1.3.2	Ground water
1.3.3	Grazing native vegetation
1.3.4	Production from indigenous vegetation
1.3.5	Customary food gathering
1.3.6	Defence land
1.3.7	Environmental & infrastructure protection
1.3.8	Carbon forest
1.4.0	Unused land and land in transiiton
1.4.1	Unused land
1.4.2	Land undergoing rehabilitaiton

2	Production agriculture and plantations
2.1.0	Plantation forests
2.1.1	Softwood plantation forestry
2.1.2	Hardwood plantation forestry
2.1.3	Other production uses
2.1.4	Environmental & infrastructure protection
2.1.5	Permanent carbon forest
2.2.0	Grazing modified pastures systems
2.2.1	Dairy production
2.2.2	Dry stock (flat/rolling)
2.2.3	Dry stock (hill country)
2.3.0	Short-rotation arable and mixed livestock croppir
2.3.1	Cereals
2.3.2	Beverage and spice crops
2.3.3	Hay and silage
2.3.4	Oilseeds
2.3.5	Pulses
2.4.0	Short-rotation horticulture
2.4.1	Seasonal vegetables and herbs
2.4.2	Seasonal fruits
2.4.3	Seasonal flowers and bulbs
2.4.4	Turf farming

Alternative short-rotation cropping classification

2.3.0	Short-rotation Cropping
2.3.1	Arable and mixed livestock cropping
2.3.2	Short-rotation horticulture

2.5.0	Perennial horticulture
2.5.1	Tree fruits
2.5.2	Tree nuts
2.5.3	Vine fruits
2.5.4	Shrub berries and fruits
2.5.5	Perennial flowers and bulbs
2.5.6	Perennial vegetables and herbs

Alternative perennial horticulture classification

2.4.0	Perennial horticulture
2.4.1	Tree crops
2.4.2	Vine fruits
2.4.3	Other perennial horticulture

2.6.0	Land in transition
2.6.1	Unused degraded land
2.6.2	Land undergoing rehabilitaiton
2.6.3	Abandoned land
2.6.4	Greenfield development

3	Intensive production agriculture
3.1.0	Intensive horticulture
3.1.1	Production nurseries
3.1.2	Glasshouses/shadehouses
3.2.0	Intensive animal production
3.2.1	Dairy sheds and yards, herd homes, feedlots
3.2.3	Poultry farms
3.2.4	Piggeries
3.2.5	Aquaculture
3.2.6	Horse studs
3.2.7	Saleyards/stockyards
3.3.0	Water and wastewater
3.3.1	Stock water
3.3.2	Effluent pond
3.3.3	Water treatment - land application
3.3.4	Water treatment - wetland
3.3.5	Irrigation reservoirs and canals

4	Built environment
4.1.0	Residential, urban, commercial and industrial
4.1.1	Rural residential
4.1.2	Low-density residential
4.1.3	Medium-density residential
4.1.4	High-density residential
4.1.5	Mixed residential and commercial
4.1.6	Commericial
4.1.7	Mixed industrial and commercial
4.1.8	Industrial
4.1.9	Outdoor recreation and culture
4.1.10	Indoor recreation and culture
4.2.0	Utilities
4.2.1	Fuel powered electricity generation
4.2.2	Hydro electricity generation
4.2.3	Wind electricity generation
4.2.4	Solar electricity generation
4.2.5	Electricity substations and transmission
4.2.6	Gas treatment, storage and transmission
4.2.7	Water extraction and transmission
4.3.0	Transport and communication
4.3.1	Airports/aerodromes
4.3.2	Roads
4.3.3	Railways
4.3.4	Ports and water transport
4.3.5	Navigation and communication
4.4.0	Mining
4.4.1	Mines
4.4.2	Quarries
4.4.3	Tailings
4.4.4	Evaporation basins
4.4.5	Extractive Industry not in use
4.5.0	Waste treatment and disposal
4.5.1	Landfills
4.5.2	Transfer stations and recyling facilities
4.5.3	Sewage/sewerage
4.5.4	Wastewater treatment
4.5.5	Stormwater management
4.6.0	Vacant and transitioning land
4.6.1	Vacant land
4.6.2	Brownfield development

1 Conservation and minimal use of natural environments

This class includes land that has a relatively low level of human intervention. The land may be formally reserved by government for conservation purposes or conserved through other legal or administrative arrangements. Areas may have multiple uses, but nature conservation is a central consideration. (Some land may be unused because of a deliberate decision of government or landowner, or due to circumstance).

Where a classification is made based on information about legal protection, the relevant information (e.g. the Act) should be mentioned in the `comment` field.

1.1 Nature conservation

Nature conservation classes are based on the suggested classification scheme for the New Zealand Protected Areas Network (PAN-NZ) in relation to biodiversity protection following (Bellingham 2016). Specifically, Tertiary classes 1.1.1–1.1.3 are based on the classification for areas legally protected for biodiversity, (see appendix for more details)

- **High degree of biodiversity protection** (Bellingham Rank 5); protection is the main purpose or is ranked equally with a limited number of other compatible purposes e.g. National Parks, nature reserves.
- **Moderately high degree of biodiversity protectio*n*** (Bellingham Rank 4); protection is a main purpose but is shared with other, less compatible purposes (i.e. recreation) e.g. conservation park, QEII open space covenant
- **Moderate degree of biodiversity protection** (Bellingham Rank 3); protection is a desired purpose but subject to capability with a different main purpose or may be less comprehensive (i.e. only some aspects of biodiversity protection are targeted) e.g. Stewardship land, wildlife management reserve

Areas with lower levels of biodiversity protection are anticipated to have other primary uses, but biodiversity protection ranking could be captured as an ancillary use with the following classes:

- **Moderately low degree of biodiversity protection** (Bellingham Rank 2); some biodiversity protection is achieved but it of secondary importance. E.g.

Low degree of biodiversity protection (Bellingham Rank 1); protection results indirectly and fortuitously as a result of other activities e.g. road reserve, river bed.

1.2 Cultural and natural heritage

Conservation classes for purposes other than biodiversity protection

- **Indigenous cultural heritage** – e.g. historical pā sites, NZ land wars sites, DoC Māori sites
- **Cultural heritage** e.g. historical mining sites, selected DoC "icon sites" and Toru Whenua.

- **Natural heritage** - protected areas for conservation of specific natural features, and landscapes e.g. Waitaki Whitestone Geopark, Banks Peninsula Geopark.

Question: Should conservation classes more clearly link to IUCN protected areas categories (which more clearly identify the purpose for conservation, which may be other than for biodiversity), and is what is used in ALUM.

1.3 Minimal use from relatively natural environments

This class includes land that is subject to relatively low levels of intervention or that are largely unused in the context of prime use or used for resource protection. This land may be covered with indigenous or exotic plant species. This includes land where the structure of the native vegetation generally remains intact despite deliberate use, although the floristics of the vegetation may have changed markedly e.g. grazing on native tussock land.

Where native grasses have been deliberately and extensively replaced with other species, the use should not be treated under class 1.

- **Surface water supply** – Area managed as a catchment for water supply
- **Ground water** – Area managed as an aquifer recharge zone

Question: is management of areas for surface water supply or aquifer recharge ever the primary use? (If not, these classes and their position in the classification hierarchy may still be sensible to retain for use as secondary/ancillary classes).

Grazing native vegetation – 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. This is probably only limited to South Island high country farms.

Production from indigenous vegetation – Commercial production from retained native forests and related activities on public and private land. This class includes wood production forestry on native timber without clearfelling, and other native forest production (non-sawlog or non-pulpwood production, including oil, wildflowers, firewood, fence posts, and mānuka/kānuka honey).

Question: how important is it to identify production from indigenous vegetation?

Customary food gathering – Natural environments associated with traditional and sustainable indigenous food gathering practices (mahinga kai). This is often an ancillary use; this class should only be assigned if the collection of food is indeed the prime use of land. (May include land zoned for Māori purpose; and should only describe contemporary use.)

Defence land – Natural areas allocated to field training, weapons testing, and other field defence uses, predominantly in rural areas e.g. Kaipara Air Weapons Range and the Waiouru Military Camp. Areas associated with buildings or more built environments on defence land are captured under an urban class.

- **Environmental & infrastructure protection** – Land usually under vegetative cover, used for non-production or environmental purposes (e.g. prevention of land degradation, windbreaks, shade, and shelter). This is not limited to indigenous vegetation. This class includes land with a primary purpose of flood management (e.g. stop banks, spillways).

Carbon forest – retained (non-planted) indigenous vegetation set aside for carbon credits

1.4 Unused land and land in transition

Corridors and roadside areas may fit under this class, along with unused land (in the sense of productive, conservation or urban use) such as cliffs, rock faces, boulders, and tors, where there are relatively low levels of disturbance. Does not include land undergoing natural succession in the context of changing plant species.

Unused land – includes land that is unusable for productive agriculture or urban uses, such as cliffs, rock faces, boulders, and tors, where there are relatively low levels of disturbance.

- **Land undergoing rehabilitation** – Degraded land (e.g. due to erosion or flood damage) that is being actively rehabilitated through planting with indigenous or exotic species to return land to a natural state. Includes riparian plantings.

Delineation between indigenous and exotic vegetation for the minimal use and unusable land and land in transition classes can be made with reference to land cover information.

2 Production agriculture and plantations

This class includes land that is used principally for primary production. Native vegetation has largely been replaced by introduced species through clearing, the sowing of new species, the application of fertilisers or the dominance of volunteer species. The range of activities in this category includes plantation forests, pasture production for stock, cropping and fodder production, and a wide range of horticultural production. If there is evidence of irrigation infrastructure, land should have irrigation listed as a management practice even if irrigation water has not been recently applied.

Fallow or ploughed land should be assigned to the most likely land use based on the dominant activity conducted in comparable nearby areas, or other available evidence. Fallow or ploughed land should be allocated to the relevant pasture, cropping or horticulture class (rather than using land in transition). The fallow or ploughed status should be recorded in the management field.

2.1 Plantation forests

Land on which plantations of trees or shrubs (native or exotic species) have been established i.e. **planted**, for production, or environmental and resource protection purposes. This includes farm forestry and may consist of monocultures or mixed species.

Specific additional attributes that could be captured are plantation age, rotation number and species.

- **Softwood plantation forestry** – area managed for pulpwood or saw log production
- **Hardwood plantation forestry** – area managed for pulpwood or saw log production

Question: is it useful to have a high-level delineation between softwood and hardwood species? Or simply to know they are exotic species? Do we allow for potential plantations of indigenous species for pulpwood or saw log production?

Other production uses – Area managed for non-pulpwood production, including oil, wildflowers, honey (e.g. kānuka/mānuka plantations)

Question: how useful is it to know that vegetation for environmental protection has been *planted*, e.g. to track pro-active management activities? Is it useful to delineate between planting of indigenous or exotic species?

- **Environmental & infrastructure protection** – Area managed for environmental and indirect production uses (e.g. prevention of land degradation, windbreaks, shade, and shelter)
- **Permanent carbon forest** – Area planted with indigenous or exotic trees for the purpose of gaining carbon credits (carbon farming).

2.2 Grazing modified pasture systems

Grazing pasture and/or forage, both annual and perennial, based on significant active modification or replacement of the natural vegetation. Land under pasture at the time of mapping may be in a rotation system, so that at another time the same area may be, for example, under cropping.

The ability to delineate between dairy and dry-stock production is to be provided by including the relevant commodity information such as "cattle dairy," "cattle beef," "sheep wool," "sheep meat," etc., noting that multiple such commodities should be recorded if appropriate. Crops used in rotation should also be recorded as commodities, if known.

Question: How important is it to delineate between land used for grazing dairy and dry stock (or non-dairy) systems within the classification scheme itself?

Potential tertiary classification

- **Dairy production** – Dairy is the land on which milking cows (or other stock, such as goats or sheep) are grazed during the milking season. Dairy production systems can include rotations of grazed forage crops and maize for silage, and dry-stock grazing, but this class should only be used where dairy is the primary purpose of the land. Where the land is permanently used for dry stock grazing it should be classified under dry stock land use.

- **Dry stock (flat/rolling)** – All other (non-milking platform) pasture on flat/rolling terrain, including dry stock farms for sheep, beef, deer, goats, horses, dairy support, and cut and carry. May include rotations for arable or vegetable crops.
- **Dry stock (hill country)** – All other (non-milking platform) pasture on hill country terrain, including dry stock farms for sheep, beef, deer, goats, horses, dairy support, and cut and carry. Unlikely to include rotations for arable or vegetable crops. High country farms should be classified as minimal use from relatively natural environments.

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. Dairy support land that is not actively used for grazing should be classified as an arable use.

Question: Is it useful to provide high-level delineation between distinct types of land used for dry stock grazing (as an indicator or relative intensity of land use) e.g. flat-rolling, hill country?

2.3 Short rotation arable and mixed livestock 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.

If the crop type(s) is (are) known, record it (them) in the commodity field using the commodity list.

Potential tertiary classification based on ALUM, noting this does not capture the reality of crop rotations between these various classes. This level of detail may be more relevant to capture as a land-cover at the time of mapping.

- **Cereals**
- **Beverage and spice crops**
- **Hay and *silage***
- **Oilseeds**
- **Pulses**

2.4 Short-rotation horticulture

Crop plants living for *less than two years* that are intensively cultivated, usually involving a relatively high degree of nutrient, weed and moisture control. Predominantly rotations of vegetable crops grown for human consumption; may include livestock rotations but this is considered less likely.

- **Seasonal vegetables and herbs**

- **Seasonal fruits**
- **Seasonal flowers and bulbs**
- **Turf farming**

An alternative classification for short-rotation cropping:

- **Arable and mixed livestock**
- **Short-rotation horticulture**

Question: which option provides the most relevant classification for your purposes, noting that more detailed information on crop types and management practices can be captured through the ancillary information rather than reflected directly in the classes?

2.5 Perennial horticulture

Crop plants living for *more than two years* that are intensively cultivated, usually involving a relatively high degree of nutrient, weed and moisture control. Management practices such as irrigation or netting to protect crops from hail or birds can be recorded as management practices. Crop type can be recorded as the commodity and used to identify key crops e.g. kiwifruit, grapes.

Potential tertiary classification based on ALUM:

- **Tree fruits**
- **Tree nuts**
- **Vine fruits**
- **Shrub berries and fruits**
- **Perennial flowers and bulbs**
- **Perennial vegetables and herbs**

Alternative tertiary classification:

- **Tree crops**
- **Vine fruits**
- **Other perennial horticulture**

Question: does the more detailed or simplified classification provide the most relevant classification for your potential use – noting that detailed information on crop type can be captured in the additional information e.g. commodity type?

2.6 Land in transition

As a subclass of "Production Agriculture and Plantations," land must previously have been used for agriculture or plantations. This class can include areas where the land use is

undergoing active transition e.g. agricultural land undergoing subdivision for residential or commercial industrial purposes.

- **Unused *degraded land*** – unused land that is degraded through erosion, or flood events that is not being rehabilitated. Can include contaminated land.

Land undergoing rehabilitation – Land in the process of rehabilitation for agricultural production, e.g. after significant flood events but actively undergoing recovery operations.

Abandoned land – Land where a previous pattern of agriculture may be observed but which is not currently under production, but not due to physical land degradation.

- **Greenfield development** – land that is actively being transitioned from agricultural or plantation use to e.g. residential or commercial/industrial subdivisions.

3 Intensive production agriculture

Question: is there value in having a separate high-level intensive agricultural production class, versus this being a subclass of agricultural production and plantations?

This class includes agricultural land uses that involve high levels of interference with natural processes and is primarily associated with smaller areas within landscapes generally used for agriculture, and includes associated built structures. Crop and/or animal type can be recorded as commodities. Management practices such as hydroponic systems should be similarly captured when known (e.g. irrigation, bird netting).

3.1 Intensive horticulture

Intensive forms of plant production often with special purpose improvements used for horticultural production. If crop type is known, record this in the commodity field.

- **Production nurseries**

Glasshouses/shadehouses

Question: Are the above land uses useful to identify at this level? Would it be useful to identify hydroponic systems as a land-use (noting this information could still be available as an attribute).

3.2 Intensive animal production

Intensive forms of animal production (excludes associated grazing or pastures), livestock production facilities or animal-holding yards. The animal type can be recorded as a commodity. The management field can be used to record practices such as free range or milking system.

- **Dairy sheds and yards, herd homes, feedlots**
- **Poultry farms**
- **Piggeries**
- **Aquaculture**

- **Horse studs**
- **Saleyards/stockyards**

Question: Are the above land uses useful to identify at this level?

3.3 Water and wastewater

This class captures built water features associated with agricultural use.

- **Stock water** – reservoir or dam on agricultural land for the purpose of supplying drinking water for stock
- **Effluent pond** – Dairy effluent pond

Water treatment *– land application* (effluent disposal), maybe an ancillary use where grazing is the primary use.

- **Water *treatment – wetland***. Constructed or natural wetland used to improve water quality prior to discharge
- **Irrigation reservoirs and canals**

Question: Would it be useful to capture farm buildings that are not associated with any of the uses specified above as an additional class?

4 Built environment

This class includes land uses that involve high levels of interference with natural processes, generally in association with the built environment of closer settlement and supporting infrastructure. The level of intervention may be high enough to completely remodel the natural landscape—the vegetation, surface and groundwater systems, and the land surface. The secondary classes encompass some of the definitions used for the National Planning Standards (Zone Framework Standard) (MfE, 2019).

4.1 Residential, urban, commercial, and industrial

- ***Rural residential*** – Residential properties with low-intensity (non-commercial) land management practices (e.g. hobby farms) on land in rural or peri-urban areas. Concordant with the "Rural lifestyle zone" from the Zone Framework Standard.
- **Low-density residential**
- **Medium-density residential**
- **High-density residential**
- **Mixed residential/commercial**
- **Commercial**
- **Mixed industrial/commercial**
- **Industrial**
- ***Outdoor recreation and culture*** – Parks, sportsgrounds, camping grounds, zoos with a primary purpose of recreation and culture and with considerable unsealed

vegetated areas. Includes caravan parks, tourist parks, mountain bike parks, cemeteries. Parks or reserved with a high-level of native bush or are protected areas should be classified under Conservation and natural environment. Identification of this land is intended to enable more ready identification of urban green space.

Indoor recreation and culture – includes indoor recreational areas, municipal swimming pools, museums, places of worship, district halls, marae

Question: are the proposed classes, with capture of additional more specific land use information as attributes useful? Or is an approach where the more specific land use is used to identify specific classes more useful? E.g. should we instead adopt zone names as per the NZ Planning Standards for the tertiary classes? (See https://environment.govt.nz/assets/publications/national-planning-standards-november-2019-updated-2022.pdf s8, table 13, pp. 36-39.)

Question: is there value in mixed residential/commercial and mixed commercial/industrial as classes, or should these be captured with the use of a primary/secondary class. Does an explicit "mixed" class violate the general structure of this classification, or make it harder or easier to use?

Question: Should "industrial" be divided into light, medium, and heavy industrial? (These could also be captured using alternative means, such as "management practices," rather than through the class structure.)

4.2 Utilities

Land allocated to providing electricity, gas, or water.

- **Fuel powered electricity generation**
- **Hydro electricity generation** – includes dams and canals
- **Wind electricity generation**
- **Solar electricity *generation***
- **Electricity substations and transmission**
- **Gas treatment, storage, and transmission**
- **Water extraction and transmission** – includes drinking water reservoirs

Question: is it useful to identify 'water' features as an attribute under other uses or would it be more useful to group under a specific 'water' class?

4.3 Transport and communication

Land allocated to infrastructure used for transportation of goods or people, or navigation and communication equipment. Zoning of land for roading or rail purposes that has not yet been constructed could be captured as attributes.

- **Airports/aerodromes**
- **Roads –** should differentiate between sealed road areas and unsealed roadside strips and

Railways – should include full rail corridors i.e. track, plus land alongside rail tracks required for safety purposes

- **Ports and water transport**
- **Navigation and communication**

Question: is Navigation and communication useful to identify as an explicit land use, given it is likely to only be an ancillary use?

4.4 Mining

Mining and extractive industries (including salt extraction from evaporation basins). Record the type of mining if known, in the commodity field.

- **Mines**
- **Quarries**
- **Tailings**
- **Evaporation basins**
- **Extractive indus*try not in use*** – land undergoing rehabilitation after mining activities, and unmined land within a mining permit

4.5 Waste treatment and disposal

Waste material and disposal facilities associated with industrial, and urban activities.

- **Landfills**
- **Transfer stations and recycling facilities**
- **Sewage/sewerage** – includes municipal wastewater ponds
- **Wastewater treatment** – land application

Stormwater management – detention basins, stormwater ponds, raingardens, wetlands located in urbanised areas

4.6 Vacant and transitioning land

- **Vacant *land*** – including derelict land and developed land that is idle
- **Brownfield development** – Redevelopment of urban land