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Land Use Mapping for the Otago Region

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Pearson Environmental Consulting Report 2025/01
Prepared for Otago Regional Council
March 2025

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Document Information

Pearson Environmental Consulting Report No: 2025/01
Report Date: 30.01.2025
Project Number: 24003

Reviewed By: Ben Mackey
Organisation: Otago Regional Council
Position: Science Manager

Reviewed By: Erik Button
Organisation: Otago Regional Council
Position: Scientist – Land and Soil
Review Date: 11.03.2025

Document Status: Final

Citation Advice

Pearson, L. (2025). Land Use Mapping for the Otago Region. Pearson Environmental Consulting Report 2025/01. p55.

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Table of Contents

List of Figures

List of Tables

Summary

A current classification of land use and land cover is necessary for Otago Regional Council (ORC) to adhere to national regulations, including the National Policy Statements and National Environmental Standards concerning Indigenous Biodiversity, Freshwater Management, and Highly Productive Land. The land use map serves as a reference point for measuring future changes and aids in managing the region's natural resources.

The Otago Base Land Use Map is created at the property scale using the council valuation boundaries and LINZ primary parcels as the spatial framework, combined with specific council data supplemented with national public data on land use, land cover, and protected areas and commercial data from Agribase. Land use is classified at primary class, subclass, and secondary land use levels. National data from LUCAS2020 provides additional land cover attributes, however its accuracy is limited to a data resolution of 1:50,000 (1 ha).

The base land use map allows reporting of properties involved in specific land uses and estimating areas of grazable land, serving as a foundational tool that can evolve to meet the council's needs. It is recommended to regularly update land use information through various sources (such as property visits, consent applications, and farm plan etc.), keeping a record of verification dates, observation type, and personnel involved. Significant updates of the Base Land Use Map should correspond with new national LUCAS or land cover (LCDB) data releases. The classification system should adapt to accommodate changes in land use, including adding new classes and subclasses (e.g., specific livestock types or crop types).

A technical land use map is derived by combining the base map with a spatial representation of land cover and biophysical landscape attributes that influence contaminant generation and loss. Additional biophysical and land management data is included within the attribute data to support assessments of land use intensity and contaminant loss estimates. For practical reasons, the Technical Land Use Map is subdivided into the Freshwater Management Units and rohe for both GIS processing and as an output.

1 Introduction

Land use refers to the activities for which land is utilised, and a single piece of land can accommodate various purposes (Rutledge et al., 2009). It specifies the intent behind land usage, encompassing the production of goods (like crops, timber, and livestock) as well as services (including recreation, public services, and conservation of natural resources). This concept is distinct from land cover, which pertains to the physical characteristics of the land, such as types of vegetation, exposed rocks, and bodies of water (Lesslie, 2004). In many classifications, land cover is often considered a proxy or practical category of land use.

This categorisation of land use integrates both urban and rural land use with land cover to create a resource that can be used to inform, monitor, and facilitate reporting on land use and change in the Otago region. The land use map serves as a reference point for measuring future changes and aids in managing the region's natural resources. A current classification of land use and land cover is necessary for Otago Regional Council (ORC) to adhere to national regulations, including the National Policy Statements and National Environmental Standards concerning Indigenous Biodiversity, Freshwater Management, and Highly Productive Land.

There are two land use map versions produced for the Otago Region, a property-scale base map and a technical land use map. In the base property-scale map, land use is classified as the primary land use according to the property boundary (rating area). An associated attribute table summarises subclasses and secondary land uses, as well as land use/cover categories informed by Agribase, LUCAS 2020, LINZ Protected Areas, and other ORC spatial datasets. The base map can be used to summarise land use by the number of properties/land parcels and by area for the region, Freshwater Management Units (FMU) and rohe (sub-FMU). A Technical Land Use Map is produced by combining the base land use with a spatial depiction of land cover. Biophysical characteristics, and remote sensed data are also included to provide landscape context and a metric for measuring intensity changes over time.

This report documents the input datasets, methodology for both the property-scale base map and technical land use map, and metadata of the GIS-based land use maps for the Otago region. Recommendations and limitations for the use of the maps are also provided.

1.1 Spatial Mapping Projection

The Otago Land Use Map uses a 2D spatial mapping projection. 2D mapping provides a straightforward and easily understandable way to represent spatial data on flat surfaces. It is characterised by its use of the x and y coordinates, geometric shapes like lines and polygons, and grid cells for accurate measurements. Accuracy is essential in creating 2D maps, as these representations form the base for essential tasks, such as urban planning, navigation, and resource management. For consistency with datasets used in the development of the Otago Land Use Map area is calculated in 2D for the base land use map.

Three-dimensional (3D) mapping enhances the understanding and interpretation of geographic data by adding depth and volume to the maps. 3D maps introduce the z dimension, which represents height or elevation, allowing for a more realistic representation of geographic features and spatial data. The Technical Land Use Map also includes area calculated in 3D as it is most accurate to use for resource management. For example, calculating the length of fence line or estimating number of trees needed for afforestation at a specific planting density.

As the base land use map is a two-dimensional (2D) plan view of the landscape, the area calculated in 2D can underestimate the surface area of a 3D object. The most significant difference between 2D and 3D projections occurs in areas with high relief and undulating topographies. In areas with little topographical relief the difference is negligeable. As an example, the Otago FMUs and rohe are shown in Figure 1 in both 2D (left) and 3D (right). The area difference between the two projections amounts to an underestimation of land surface area between 2.2 and 14.2% by FMU or rohe and 6.5 % regionally (Table 1).

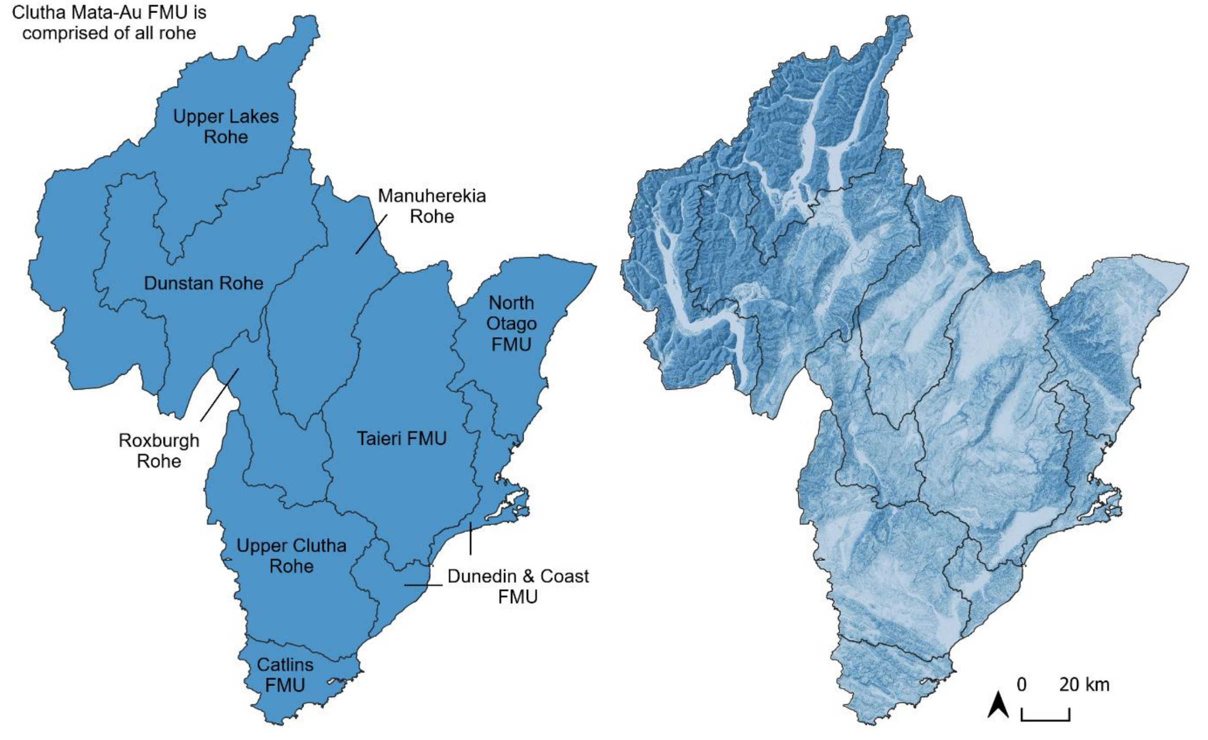

Figure 1. FMU and rohe surface area representation between 2D (left) and 3D (right) where the darker the blue the greater the surface area.

Table 1. Otago Freshwater Management unit areas in 2D and 3D projections.

Freshwater Management Unit and rohe	2D Area (ha)	3D Area (ha)	Difference (Ha)	Difference (%)
Clutha Mata-Au FMU	2,098,410	2,287,793	189,384	8.3
Upper Lakes Rohe	701,189	816,979	115,790	14.2
Dunstan Rohe	508,142	555,144	47,002	8.5
Roxburgh Rohe	181,934	188,087	6,154	3.3
Manuherekia Rohe	303,759	313,986	10,227	3.3
Lower Clutha Rohe	403,386	413,598	10,212	2.5
Taieri FMU	570,260	583,041	12,781	2.2
North Otago FMU	253,925	264,227	10,302	3.9
Dunedin & Coast FMU	156,158	161,317	5,159	3.2
Catlins FMU	108,369	111,593	3,224	2.9
Otago Region	3,187,122	3,407,971	220,849	6.5

2 Base Land Use Map Input Data

The base land use map is collated at the property scale. The spatial framework to host the land use data is developed by combining the Otago Valuation Boundaries (rateable properties) with LINZ Primary Parcels (non-rateable land parcels). This spatial framework is then populated with land use information from numerous sources. The datasets used to classify the Otago Base Land Use Map are described in more detail below.

2.1 Otago Regional Council Data

2.1.1 Great South Land Use Map

Land use was mapped for the region in 2020 and 2022 by Great South following the method of Pearson and Couldrey (2016). The key input dataset in this version is Agribase which is a voluntary farm survey. The limitation with this dataset is the farm boundaries represent managed land area (including lease blocks) and can't always be directly linked to a property boundary. Agribase is discussed further in Section 2.1.5.

2.1.2 Otago Valuation Boundaries and Rates Land Use Class

Land is valuated for rating by Otago Regional Council every three years under the Rating Valuations Act 1998 and the Local Government (Rating) Act 2002. The valuation boundaries provide land use information as specified in Rating Valuations Rules 2008 (Sullivan, 2008). This dataset is used to provide a framework to populate with land use information from multiple data sources. As the parcels represent the legal titles, there shape will not be manually altered during land use mapping. The dataset is current as of September 2021 to 2023 (parcels are not updated annually).

The advantage of this layer is it represents properties, which may be made up of a number of LINZ primary parcels. This will enable the number of properties undertaking a particular land use to be calculated from the resultant land use map. This dataset will be supplemented with LINZ primary parcels to identified areas not mapped in the rating valuation dataset. It is important to note that while a land parcel may be rated for a particular land use, the actual land use may be different, or classes further subdivided in the classification of land use therefore multiple datasets are used to confirm the land use of a property.

2.1.3 Forestry

The forest industry in Otago consists of large companies such as Ernslaw One, Wenita, City Forests, Rayonier Matariki Forests, and Port Blakely plus numerous smaller owners and farmers who have forestry blocks within their farms. Planted forests are mainly made up of introduced species, with Pinus radiata being the dominant species (typically 90% of planted forests). Other exotic species include Douglas-fir, cypress, and eucalypts.

Otago Regional Council provided two spatial layers for plantation forests, Crown Forestry Licence (CFL) Forests and Other Forest Owners South Otago. CFL is a license issued by the Crown to the private sector for former Crown forests granted under the Crown Forests Assets Act and are typically held by large public investors. A CFL has a life of up to 35 years, or until the trees are felled, whichever is sooner. These datasets contain the forest name/owner but no other information. Smaller owners and farmers who have forestry blocks are not identified in these datasets. Farm forestry is considered a secondary land use in the Otago Land Use Map.

2.1.4 Viticulture and Horticulture

Otago Regional Council mapped spatial datasets of viticulture (vineyards) and horticulture (orchards, vegetables, plants and flowers) in the Otago region in conjunction with HortNZ. The dataset was digitised using aerial imagery (Otago 0.3m Rural Aerial Photos (2019-2021). The manual mapping approach has resulted in some minor areas overlapping with neighbouring properties. The horticulture dataset also contains an attribute field for type but is sparsely filled out. Overall, the datasets have a medium to low confidence and ideally further distinction of horticultural land use is desired. These layers are used in combination with other datasets to refine the land use classification.

2.1.5 Dairy Shed Locations

Point locations of dairy sheds were provided to aid in the identification of dairy properties. This dataset contains current consents only with the consent and supply number as additional attributes. This layer is used in conjunction with other datasets to verify the location of dairy as it lacks the spatial extent of the property.

2.2 Land Information New Zealand

2.2.1 Primary Parcels

The primary parcels layer provides the current parcel polygons and some associated descriptive data that details the legal description, purpose, size, and a list of titles that have an interest in the parcel. The primary parcel layer has a nominal accuracy of 0.1-1m in urban areas and 1-100m in rural areas.

A primary parcel is a portion of land that is intended to be:

- Owned by the Crown, except moveable marginal strips
- Held in fee simple (predominately private ownership)
- Public foreshore and seabed
- The bed of a lake or river
- Road or Railway
- Vested in a local authority.

The primary parcels layer is used to supplement the Otago Valuation Boundaries dataset to obtain land parcels for the entire Otago region to develop the spatial framework to host land use information.

2.2.2 Protected Areas

Spatial data for conservation and protected areas is available in the Protected Areas layer from Land Information New Zealand. It contains land and marine areas, most of which are administered by the Department of Conservation Te Papa Atawhai (DOC) and are protected by the Conservation, Reserves, National Parks, Land, and Wildlife Acts. The attributes in this dataset are derived from the National Property and Land Information System (NaPALIS), which is a centralised database for all DOC and LINZ administered land. The protected areas dataset is used to classify conservation and public reserve land uses.

2.3 Statistics New Zealand - Urban Rural Generalised

Urban Rural 2023 maps the extent of urban and rural geography and is publicly available on the Koordinates website. The dataset contains 8 classes in the Otago region to indicate the type and size of urban and rural areas and water bodies. This dataset is used in conjunction with ORC data to map urban areas, rural residential (<0.4ha), and support identification of lifestyle blocks (0.4-5ha).

2.4 Ministry for the Environment – LUCAS land use map 2020

The Land Use and Carbon Analysis System (LUCAS) Land Use Map (LUM) is a national digital temporal map of land use and land use change compiled for nominal dates beginning January 1990. It is provided by the Ministry for the Environment and mapped by Manaaki Whenua Landcare Research (Harris et al., 2023). The Base Otago land use map incorporates land use/cover data from 2020 version 3.

For LUCAS, Sentinel-2 satellite imagery acquired in the summer (October–March) of 2020/21 is used to classify land use at a scale of approximately 1: 50,000 (1 ha minimum size). Land use has been classified into 12 broad land use categories of Natural Forest, Planted Forest - Pre-1990, Post 1989 Forest, Grassland - With woody biomass, Grassland - High producing, Grassland - Low producing, Cropland – Perennial, Cropland – Annual, Wetland - Open water, Wetland - Vegetated non forest, Settlements, and Other. Secondary land use classes provide further detail of grazed pasture, dairy, forestry tree species, etc.

Prior to using this dataset in the Otago land use map, the input information was reclassified to prioritise land use activities, such as dairy grazed and non-dairy grazed land, over land cover classes distinctions of pasture type or forest age (Table 2).

Table 2. Classification of LUCAS land use classes from LUCID and SUBID to medium and basic classes.

LUCID_2020	SUBID_2020	LUCAS Medium Class	LUCAS Basic Class
71 - Natural Forest	120 - Shrubland	Natural Forest - Shrubland	Natural forest and shrubland
71 - Natural Forest	121 - Tall Forest	Natural Forest - Tall forest	Natural forest and shrubland
71 - Natural Forest	122 - Wilding trees	Natural Forest - Wilding trees	Natural forest and shrubland
72 - Planted Forest - Pre 1990	0 - Unknown	Exotic Forest - Unspecified	Exotic forest
72 - Planted Forest - Pre 1990	201 - Pinus radiata	Exotic Forest - Pinus radiata	Exotic forest
73 - Planted Forest - Pre 1990	202 - Douglas fir	Exotic Forest - Douglas fir	Exotic forest
72 - Planted Forest - Pre 1990	203 - Unspecified exotic species	Exotic Forest - Unspecified	Exotic forest
73 - Post 1989 Forest	122 - Wilding trees	Exotic Forest - Wilding trees	Exotic forest
73 - Post 1989 Forest	201 - Pinus radiata	Exotic Forest - Pinus radiata	Exotic forest
73 - Post 1989 Forest	202 - Douglas fir	Exotic Forest - Douglas fir	Exotic forest
73 - Post 1989 Forest	203 - Unspecified exotic species	Exotic Forest - Unspecified	Exotic forest
73 - Post 1989 Forest	204 - Regenerating natural species	Natural Forest - Regenerating	Natural forest and shrubland
74 - Grassland - With woody biomass	0 - Unknown	Grassland - With woody biomass	Grassland - with woody biomass
75 - Grassland - High producing	502 - Grazed - dairy	Dairy - High producing grassland	Dairy
75 - Grassland - High producing	503 - Grazed - non-dairy	Drystock - High producing grassland	Drystock
75 - Grassland - High producing	504 - Ungrazed	Grassland ungrazed - High producing	Grassland ungrazed
76 - Grassland - High producing	0 - Unknown	Grassland ungrazed - High producing	Grassland ungrazed
76 - Grassland - Low producing	502 - Grazed - dairy	Dairy - Low producing grassland	Dairy
76 - Grassland - Low producing	503 - Grazed - non-dairy	Drystock - Low producing grassland	Drystock
76 - Grassland - Low producing	504 - Ungrazed	Grassland ungrazed - Low producing	Grassland ungrazed
76 - Grassland - Low producing	0 - Unknown	Grassland unkown - Low producing	Grassland ungrazed
77 - Cropland - Orchards and vineyards (perennial)	0 - Unknown	Cropland - Orchards and vineyards (perennial)	Cropland - orchards and vineyards
78 - Cropland - Annual	0 - Unknown	Cropland - Annual	Cropland - annual
79 - Wetland - Open water	0 - Unknown	Wetland - Open water	Open water
79 - Wetland - Open water	901 - Naturally occurring	Wetland - Open water natural	Open water
79 - Wetland - Open water	902 - Human induced	Wetland - Open water human induced	Open water
80 - Wetland - Vegetated non forest	0 - Unknown	Wetland - Vegetated non forest	Wetland
80 - Wetland - Vegetated non forest	1001 - Peat mine	Wetland - Peat mine	Wetland
81 - Settlements or built-up area	0 - Unknown	Settlements or built-up area	Settlements or built-up area
82 - Other	0 - Unknown	Bare Ground	Bare ground

2.5 Assure Quality - AgriBase

AgriBase is a national spatial farms database with data describing farm contacts, predominant farm type, size, animal numbers by stock class, and planted areas. It is developed and maintained by Asure Quality, and the data is commercially available under license. A 'farm' is defined as business management units that utilise a defined area of NZ's land and in-land or in-shore water resources in the production of food or other primary products (Sanson, 2005). Spatial representation is based on LINZ cadastral parcels that are aggregated to farms based on ownership detail, and information provided by farmers themselves. This includes the identification of farm type as listed in Table 3. Maintenance is achieved through regular monthly updates of LINZ cadastral - 3 - parcels (identifies sub-divisions and change of ownership), and an online voluntary questionnaire is available to farmers. Updates are also achieved through client- and industry partnerships such as surveys.

Table 3. Agribase farm types in the Otago region.

Code	Farm type name	Code	Farm type name
ALA	Alpaca and/or llama breeding	NAT	Native Bush
API	Beekeeping and hives	NEW	New record – Unconfirmed farm type
ARA	Arable cropping or seed production	NOF	Not farmed (idle or non-farm use)
BEF	Beef cattle farming	NUR	Plant nurseries
CAR	Calf rearing	OAN	Other livestock (not covered by other types)
DIA	Dairy cattle farming	OPL	Other planted types (not covered by other types)
DEE	Deer farming	OTH	Enterprises not covered by other classifications
DOG	Dogs	PIG	Pig farming
DRY	Dairy dry stock	POU	Poultry farming
FIS	Fish, marine fish farming, hatcheries	SLY	Sale yards
FLO	Flower growing	SHP	Sheep farming
FOR	Forestry	SNB	Sheep & beef farming
FRU	Fruit growing	SPO	Sport Grounds
GOA	Goat farming	TOU	Tourism use (campground, motel)
GRA	Grazing external stock	UNS	Unspecified
HOR	Horse farming & breeding	VEG	Vegetable growing
LIF	Lifestyle block	VIT	Viticulture, grape growing, and winemaking
MPL	Manufacturing Plant	ZOO	Zoological gardens
MTM	Meat Slaughter Premises		

For Tier 1 national statistics, records must be less than 5 years old. The Agribase dataset dated March 2024 contains 8339 property records, 8074 are within the Otago Region. Table 4 shows the source date for the dataset, with 70.7% meeting Tier 1 standards. 11% of the records (879) are dated from 2023-2024. Limitations of the Agirbase dataset for land use mapping are detailed in Pearson and Couldrey (2016) and Manderson et al. (2018).

Table 4. Source date and number of records in Agribase for the Otago region.

Date	Number of records	Percentage (%)
2006-2009	451	5.6
2010-2014	1,320	16.3
2015-2019	595	7.4
2020-2024	5,708	70.7
Total	8,074	100

2.6 Beef and Lamb Livestock Classes

Beef and Lamb NZ have a farm class system that is used to categorise farm types in their economic reports as a way of benchmarking farms. The classes are developed from weighted averages of individual farm class data to correctly portray a whole region or the New Zealand lambing percentage distribution. Although this is not a spatial dataset, the likely type of farm class can be predicted by biophysical factors of the landscape.

The livestock classes relevant to the Otago region are as follows:

> **Class 1 South Island high country:** Extensive run country located at high altitude. These farms run a diverse mix of operations which include breeding sheep, often fine wooled, breeding cows and deer. Stocking rate is typically up to three stock units per hectare.
>
> **Class 2 South Island hill country:** Traditionally store stock producers with a proportion sold prime in good seasons. Carrying between two and seven stock units per hectare, they usually have a significant proportion of beef cattle.
>
> **Class 6 South Island finishing-breeding farms:** Farms which breed or trade finishing stock and may do some cash cropping. A proportion of stock may be sold store, especially from dryland farms. Carrying capacity ranges from 6 to 11 stock units per hectare on dryland farms and over 12 stock units per hectare on wetter or irrigated farms. This is the dominant farm class in Otago.
>
> **Class 7 South Island finishing farms:** High producing grassland farms carrying about 9 to 14 stock units per hectare, with some cash crop. Predominantly located in the south and west in Otago.
>
> **Class 8 South Island mixed cropping and finishing farms:** A high proportion of their revenue is derived from grain and small seed production, as well as stock finishing or grazing.

As this is not a spatial dataset, the physical attributes of the landscape such as topography, can be used to estimate the likely livestock class within grazed pastoral areas to classify lowland dry stock (typically class 6, 7 and 8), hill country dry stock (typically class 2 and some 6), and high country dry stock (class 1). Altitude and slope are used as an indicator to guide the classification of dry stock farms within the Otago region. The following generalised drystock classes for the land use map are:

- Lowland (< 600 m above sea level, slopes < 8 degrees)
- Hill country (< 600 m above sea level, slopes between 8 – 21 degrees)
- High country (majority of property above 600 m above sea level, mixed slope)

Topographic data is sourced from L&WS composite Digital Elevation Model at 15m resolution. High resolution topographical data, such as 1m LiDAR, is not necessary at property scale to assign a general landscape class.

3 Base Map Methodology

The method used to update the Otago Base Land Use Map was adapted from Pearson (2023; 2024a,b) is summarised below. The modifications to the method are to account for the different availability of datasets for the region and improvements to the method. The Land Use Map was developed in QGIS (version 3.22.16) and processing tools used are indicated by italics.

3.1 Spatial Framework

The first step in creating the land use map is to develop the spatial framework. The framework hosts the land use information and supplementary data. The input data to the spatial framework is the ORC valuation boundaries and LINZ primary parcels.

The valuation dataset contains overlapping polygons which need to be removed. A *self-intersection* was performed on the valuation dataset. This splits any duplicate polygon areas from the original polygon. The GIS processing tools *'remove all null geometries'* and *'delete duplicate geometries'* were then run to produce a clean non-overlapping layer.

To create a framework for the Land Use Map with polygons for the whole region, centroid points were processed for the LINZ primary parcel layer and intersected it with the clean ORC valuation layer from above. The resultant data was then joined by parcel ID to the primary parcel layer. The layer was filtered using the definition query 'Assessment' IS NOT NULL and dissolved the selection on Assessment, Property Address, and Rate payer. The query was then reversed to be Assessment IS NULL. The resulting two layers were then *merged* to produce the framework to host land use data. Area fields in both square meters and hectares were calculated for the polygon.

3.2 Classifying Land Use

All datasets listed in Section 2.1 were loaded into QGIS along with the spatial framework developed above. Land use classes are defined in Table 5 in conjunction with ORC staff. The following steps were undertaken to classify land use for the region:

In QGIS:

- Load all datasets in QGIS.
- Open LUCAS attribute table and *Select by Expression* "SUBID_2020" = 0 and update existing field using the *field calculator* for selected features to '100'. Combine 2020 ID and 2020 SUBID to make a LU2020 code. Reclassify according to Table 2 basic classes. *Rasterize* LUCAS with 10 m pixels by class.
- *Rasterize* Protected Areas with 10 m pixels.
- *Rasterize* ORC Horticulture and Viticulture layers with 10 m pixels.
- *Reclassify* DEM slope raster for slopes greater than and less than 8 degrees and altitude greater than and less than 600m above sea level.
- *Zonal histogram* all rasters into spatial framework layer.
- Create *real centroid* point layer for the spatial framework and *intersect* with protected areas, Agribase, Urban rural generalized, and the previous 2022 Base Land Use Map. *Join* the intersects to the spatial framework using ID as the join field.
- Export shapefile as .xls for classification of land use in Excel.
- Export shapefile with id field only to join with classification table after the next stage.

In Excel:

- Add fields for:
    - Primary land use (Land use)
    - Subclass
    - Secondary land use (SecondLU)
    - Secondary Subclass (SecSubLU)
    - Data Source
- Classify Agribase according to rules outlined in Pearson and Couldrey (2016) with the following amendments. In Rule 2 speciality land use types classify PIG and POU as primary land use 'Pigs and Poultry' with a subclass of 'Pigs', 'Poultry' or 'Pigs and poultry'. In Rule 3 Support properties classify DRY, GRA, CAL as 'Livestock support' and DRY with a subcode of 'Dairy support'. Rule 4 assign subclass of No dairy shed for properties without ORC dairy shed points. Rule 6 Add class for Drystock and horticulture where minimum horticulture area is 1ha. Rule 7 reclassify drystock as lifestyle when property area is between 0.4 – 5 ha to retain speciality land uses and classify small land holdings as a secondary land use class only. Rule 9 check livestock class is most appropriate for the property and assign secondary land uses for horticulture classes, pigs and poultry numbers and arable.

- Calculate LUCAS fields as area in hectares and percentage of property and as defined in Table 2. Calculate maximum LUCAS class and identify dominant land use/cover for the property.
- Use mean altitude and slope to assign land parcels to lowland, hill country, and high country according to dominance of land class of property.
- Classify Primary Land Use, Subclass, and any secondary Land use Class according to the following hierarchy of data sets and the land use classes:
    - LINZ Parcel intent for road, railway, and hydro
    - ORC Valuation and zones (primarily urban and rural settlements)
    - ORC horticulture and Viticulture and ORC dairy sheds
    - Protected Areas
    - Agribase
    - LUCAS
- Record input dataset/s under Data Source.
- Assign Land Use Class for 'Road', 'Railway' and 'Open water' by LINZ parcel intent for road, railway, hydro and streambed, respectively.
- Classify natural state areas by land cover. Assign class of 'Conservation' and 'Reserve' for land according to Protected Areas dataset. Assign a subclass from dominant LUCAS land cover class.
- Classify 'Urban' and 'Rural Settlement' using ORC valuation land use and UR23 zones for subclasses of residential (property size <0.4 ha), commercial, industrial. Classify 'Lifestyle' between 0.4 and 8 ha. Classify 'Public use' and 'Utility services' from ORC valuation land use dataset with a subclass of land use distinction.
- Classify agricultural and forestry areas using reclassified Agribase, LUCAS, and ORC valuation land use
- Reclassify 'Lowland drystock', 'Hill country drystock' and 'High country drystock'.
- Save as .csv

In GIS:

- Join .csv file to Otato Spatial Framework by id field.
- Visually inspect the map and make corrections using the previous land use map version and aerial imagery. This was undertaken mostly in areas of new subdivisions where roads and residential properties were classified incorrectly.
- Export as shapefile. Map styles are provided in Appendix A.

An Excel summary table of land use is provided to accompany the Base Otago Land Use Map. The regional land use summary is produced by filtering dataset to exclude Oceanic zone and properties predominantly outside the Otago region.

Table 5. Land use classification for the Otago Region. Not all parcels are assigned a subclass and are left blank if there is no further differentiation for the land parcel.

Land Use	Subclass	Description
Conservation	LUCAS Land cover class based on dominant land cover	Protected under the Conservation Act 1987 and National Parks Act 1980.
Natural forest and shrubland	None, Commercial forest	Private land holdings under natural vegetation. Commercial forest identifies areas mapped in CFL forests or other forest owners.
Reserve	LUCAS Land cover class based on dominant land cover	Designated Reserve under the Reserves Act 1977. Additional use can be found located under 'Res_purpos' field.
Recreation	LUCAS Land cover class based on dominant land cover	Recreation as identified in ORC valuation dataset. Subclass as identified in LUCAS land cover.
Grassland	None	Ungrazed grassland as identified by LUCAS.
Grassland with woody biomass	None	Grassland with woody biomass as identified by LUCAS.
Bareground	None	Bare ground and lightly vegetated land cover as identified by LUCAS.
Wetland	None	Wetland land cover as identified by LUCAS.
Open water	None, Wildlife area, Reserve	LINZ parcels with intent for hydro. Subclass identified by valuation land use or zone.
Commercial forestry	None, Grassland, Grassland with woody biomass, Natural forest and shrubland	Wood production typically Pinus radiata and Douglas Fir as identified in CFL Forests or other forest owner datasets. Land can be in production or currently available for planting (recently harvested). Does not include forest nurseries.
Exotic forest	None	Exotic forest not classified as Commercial forest as identified by LUCAS.
Arable	Annual	Annual cropland as identified by Agribase or LUCAS.
Horticulture	Orchard, Viticulture, Flowers, Nursery, Vegetables, Unknown	Orchards - perennial fruit and nut growing. Viticulture - viticulture, grape growing, and winemaking. Flowers – flowers and bulb growing. Nursery – plant growing. Vegetables – vege growing. As identified in ORC horticulture and viticulture, Agribase or LUCAS.
Drystock and arable	Sheep and beef, Sheep, Beef, Deer, Mixed drystock, Unspecified	Mixed arable and drystock properties where greater than 20 % of the farm area is used for the production of annual crops as identified in Agribase.
Drystock and horticulture	Sheep and beef, Sheep, Beef, Unspecified	Mixed horticulture and drystock properties where greater than 1ha of the farm area is used for the production of horticulture as identified in ORC horticulture and viticulture datasets.
Lowland drystock	Sheep and beef, Sheep, Beef, Deer, Majority deer and other drystock, Mixed drystock, Saleyards, Unspecified	Lowland (below 600 m asl and less than 8 degrees slope) pastoral farming land as specified in Agribase or LUCAS. Subclasses identify Agribase reported stock types.
Hill country drystock	Sheep and beef, Sheep, Beef, Deer, Majority deer and other drystock, Mixed drystock, Unspecified	Hill country (below 600 m asl and greater than 8 degrees slope) pastoral farming land as specified in Agribase or LUCAS. Subclasses identify Agribase reported stock types.
High country drystock	Sheep and beef, Sheep, Beef, Deer, Majority deer and other drystock, Mixed drystock, Unspecified	High country (above 600 m asl mixed slope class) pastoral farming land as specified in Agribase or LUCAS. Subclasses identify Agribase reported stock types.

Land Use	Subclass	Description
Dairy	None, No dairy shed	Milk supply for milk products as defined by ORC valuation, Agribase or LUCAS. Properties without ORC dairy sheds are identified as a subclass.
Livestock support	Dairy support, Cut and carry, none	Grazier or dry dairy as identified in Agribase.
Pigs and poultry	Pigs, Poultry, Pigs and poultry	Pigs or Poultry as identified by Agribase.
Other animals	Alpaca and llamas, Aquaculture, Beekeeping and hives, Dogs, Goats, Horses, Unknown	Other animals as identified by Agribase.
Lifestyle	Sheep and beef, sheep, Beef, Deer, Mixed drystock, Residential, Unspecified, None	Property size between 0.4 and 5 ha in rural or rural settlement zone that are not classified by a speciality land use.
Urban	Residential, Commercial, Industrial, Unspecified, Vacant utility services	Zoned small, medium, and major urban zone with subclass defined by valuation land use.
Rural settlement	Residential, Commercial, Industrial, Unspecified, Vacant utility services	Zoned rural settlement or rural with subclass defined by valuation land use
Public Use	Hall, Education, Multi-use, Religious, Cemeteries and crematoria, Medical, Personal and property protection, Vacant	Public use areas. Subclasses defined by valuation data and protected areas.
Utility services	Water supply, Electricity, Sanitary, Communication, Gas, Multi-use, Other	Utility services. Subclass defined by valuation dataset.
Transport	Air transport, Road transport, Rail transport, Water transport, Multi-use, None	Transport use. Subclass defined by valuation data.
Road		LINZ designated roads. Includes paper roads.
Railway		LINZ designated railway.
Mineral extraction		Land used for mineral extraction as defined by valuation dataset and aerial imagery.

4 Otago Base Land Use Map

4.1 Base Land Use Map Output

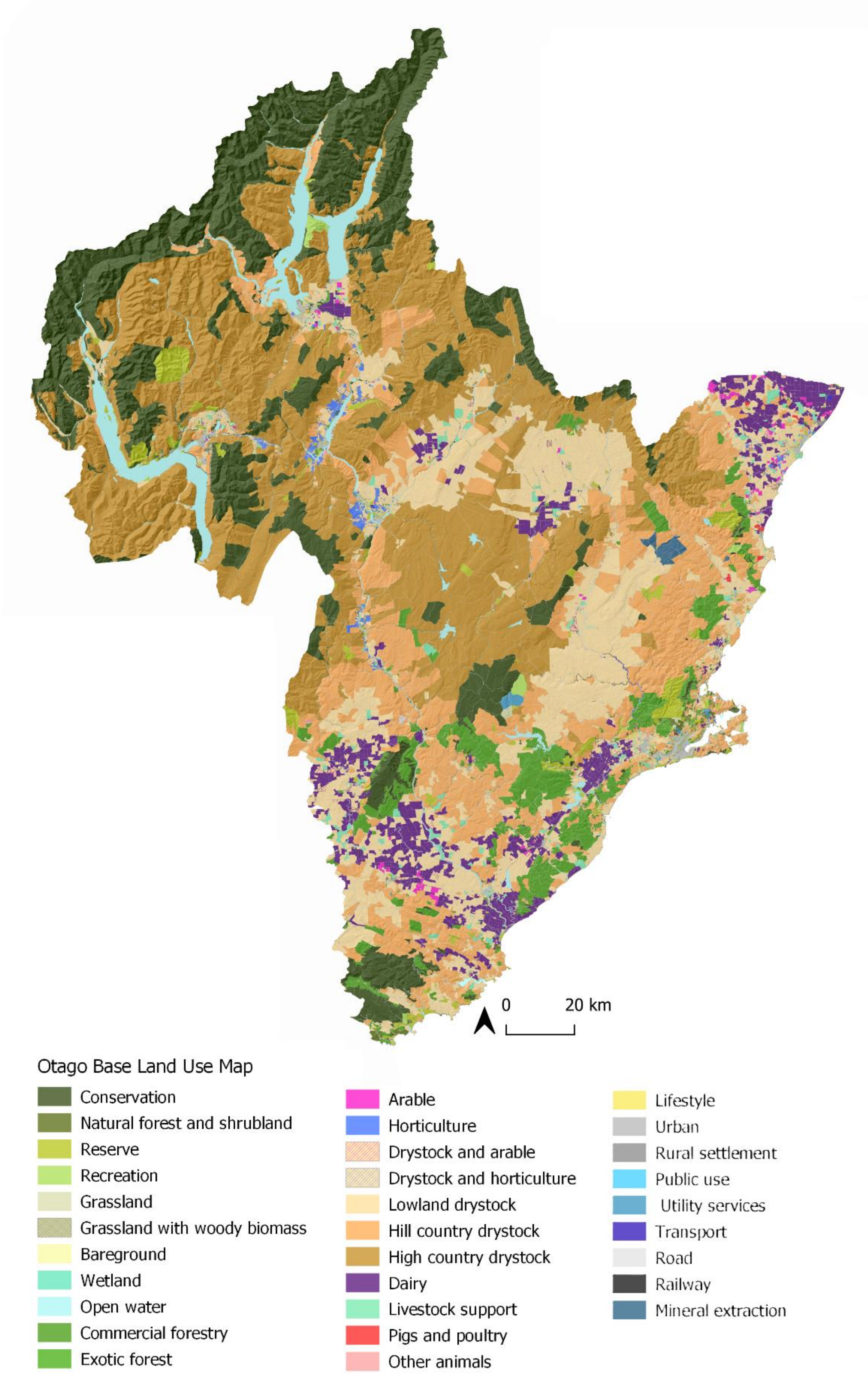

Figure 2. Otago base land use land use map. Map is symbolised to the primary land use in 2024. The land use map is best viewed in GIS.

4.2 Regional Land Use Summary

Land use in the Otago region by land area is predominantly used for drystock grazing with an estimated 60 % of land area (1,600,500 ha) across lowland, hill and high country (Table 5). Approximately half of all drystock grazing is undertaken in the high country. Dairy grazing makes up another 4.5% of the land area (on approximately 132,380 ha). Conservation and other non-developed land use classes are the second largest land use with 24 % (766,550 ha) used for this purpose (Table 5). Commercial forestry accounts for 4.2% (115,430 ha currently under exotic forest land cover). Exotic forest on other other rural land uses adds an additional 30,000 ha of forest cover that contributes to the commercial forest area in Otago. Other land uses such as horticulture make up a minor proportion of land use regionally. Urban areas cover approximately 8,450 ha of land with a further 2,870 ha in rural settlements and 13,740 ha in lifestyle properties (0.4-5 ha property size).

Table 6. Primary land use summary by number of properties and area (hectares) in the Otago Region. Area of exotic forest, grazed pasture, orchards and vineyards, and cropping are estimated within each property type from LUCAS 2020.

	No. of properties/ land parcels	Primary land use area (ha)	Exotic forest (ha)	Grazed pasture (ha)	Orchards and vineyards (ha)	Cropping (ha)
Conservation	2,635	689,718	1,806	25,696	19	81
Natural forest and shrubland	984	6,455	159	401		4
Reserve	2,891	63,718	967	3,068	3	35
Recreation	639	8,904	157	2,649	3	32
Grassland	468	3,178	36	164		0
Grassland with woody biomass	944	2,947	127	550	3	17
Bareground	67	164	3	13	1	
Wetland	55	367	6	59		0
Open water (inc. coastal marine)	1,504	97,727	1,249	7,701	35	51
Commercial forestry	979	137,589	115,434	10,210	18	24
Exotic forest	684	2,130	1,523	316	0	4
Arable	473	8,929	202	4,005	9	4,562
Horticulture	1,100	11,822	230	5,710	4,362	875
Drystock and arable	104	7,101	112	5,519	32	1,264
Drystock and horticulture	55	2,492	3	2,030	241	107
Lowland drystock	7,506	475,139	7,265	434,843	248	11,032
Hill country drystock	3,015	515,181	15,479	425,853	30	1,377
High country drystock	514	952,161	1,872	732,263	78	2,728
Dairy	1,407	141,110	2,525	132,383	19	986
Livestock support	453	23,751	1,177	20,184	56	1,058
Pigs and poultry	52	1,416	44	1,305		7
Other animals	176	2,015	245	1,526	4	37
Lifestyle	8,404	13,738	542	10,451	148	218
Urban	82,275	8,451	75	834	13	14
Rural settlement	13,661	2,869	50	1,291	12	27
Public use	806	613	20	178	0	19
Utility services	293	3,471	166	271	2	7
Transport	92	999	51	265		2
Road	32,363	43,319	2,404	30,848	136	379
Railway	414	1,044	27	698		27
Mineral extraction	42	4,955	53	2,855	3	8
Total	165,055	3,233,475	154,008	1,864,140	5,474	24,981

4.3 Metadata

Layer Name: Otago Base Land Use Map – December 2024

Feature Layer Type: Vector (polygon)

Geographical Extent: Otago Region (inc. properties crossing the regional boundary)

Coordinate System: New Zealand Transverse Mercator 2000 (NZTM2000)

Purpose: To identify land use by property title

Resource Reference Date: 16.12.2024

Edition: version 1

Access Constraints: None

Use Constraints: None

Data Set Credit: Otago Regional Council, LINZ, LUCAS Land Use Map 2020v3, Statistics NZ, Land and Water Science.

Attribute Details:

Attribute field	Name	Description	Source
Poly_ID	Polygon ID (join field)	Polygon unique identifier	Generated
Land use	Primary land use	Current land use (symbolise for base LUM)	Pearson EC
Subclass	Primary land use subclass	Provides more detail for primary land use class	Pearson EC
SecondLU	Secondary land use	Secondary land use	Pearson EC
SecSubLU	Secondary land use subclass	Subclass of secondary land use	Pearson EC
Data Sourc	Data source	Identifies data source/s used to identify land use	Pearson EC
Area_m2	Area meters squared	Area of the parcel in square meters	Pearson EC
Area_ha	Area hectares	Area of the parcel in hectares	Pearson EC
LINZ ID	LINZ parcel ID	Identification number from LINZ	LINZ LINZ primary parcels
appellatio	Appellation	Textual descriptions that describe a parcel (centroid parcel only in multi parcel properties)	LINZ primary parcels
affected_s	Affected surveys	Surveys plans that affect this parcel.	LINZ primary parcels
parcel_int	LINZ parcel intent	Intent use of land parcel (centroid parcel only in multi parcel properties), e.g., Fee Simple Title, Road, Hydro, Maori, Railway.	LINZ primary parcels
statutory_	LINZ statutory action	Statutory action on land parcel	LINZ primary parcels
land_distr	Land district	Primary district of property	LINZ primary parcels
titles	Titles of property	A comma separated list of Titles numbers associated to the parcel.	LINZ primary parcels
UR2023_Nam	Name of urban or rural area	Urban rural type	StatsNZ Urban Rural
IUR2023_Ty	Type of area	Urban rural area name	StatsNZ Urban Rural
RATING ID	Property number	Property identification	ORC valuation
Valuation_	Assessment no	Assessment number of valuation	ORC valuation
Valuation1	Assessment no 1	Assessment number of valuation	ORC valuation

Attribute field	Name	Description	Source
current_ef	Assessment date	Date of assessment	ORC valuation
actual_pro	Rating Land Use Code	Land use code for land rating (see Sulivan - Appendix C)	ORC valuation
RatingLU	Rating Land Use Code	Land use code for land rating (see Sulivan - Appendix C)	ORC valuation
Zone_Code	ORC zone code	ORC planning zone code	ORC valuation
ORC Zone	ORC Zone	Denotes residential, commercial, industrial, recreational, rural, coastal and reserve planning zones	ORC valuation
PolySource	Polygon source	Source of polygon for spatial framework	ORC valuation boundaries/LINZ
napalis_id	Protected areas ID	Protected area ID field	Protected Areas
PA_start	Start date	Protection start date	Protected Areas
PA_name	Protected area name	Name of protected area	Protected Areas
PA_type	Protected area type	Identifies conservation, reserve and wildlife protection types	Protected Areas
Legislatio	Legislation	Legislation providing protection	Protected Areas
Section	Section	Section of legislation providing protection	Protected Areas
Res_purpos	Reserve purpose	Reserve land use purpose	Protected Areas
PA prop%	Percent protected	Percentage of protected area on property	Protected Areas
ForestID	Forest ID	Crown forest license and other forest owners ID	ORC land use data
FOR_type	Forest type	Crown forest license or other forest owners	ORC land use data
FOR_name	Forest name	Name of forest	ORC land use data
Hort_m2	Horticulture m^2	Area of horticulture in square meters	ORC land use data
Hort_ha	Horticulture ha	Area of horticulture in hectares	ORC land use data
Vine_m2	Vineyard area in m^2	Area of vineyards in square meters	ORC land use data
Vine_ha	Vineyard ha	Area of vineyards in hectares	ORC land use data
DaiShed	Dairy shed	Dairy shed located on property	ORC land use data
ABFarmID	Agribase Farm ID	Agribase record unique identification	Agribase
ABFarm_ha	Agribase Farm ha	Agribase farm area in hectares	Agribase
ABF_Type	Agribase Farm Type	Agribase farm type classification (Table 4)	Agribase
AB_Date	AB Record Date	Agribase date of farm record	Agribase
OTO_Code	Otago Code 1	Reclassifed Agribase farm type (Table 4)	Pearson EC
OTO_C2	Otago Code 2	Reclassifed Agribase farm type secondary land use (Table 4)	Pearson EC
LUCAS_NDha	LUCAS no data ha	Area of property in hectares with no LUCAS data	LUCAS2020v3
NAT_ha	LUCAS Natural ha	Area of property in hectares classified as natural forest and shrubland	LUCAS2020v3
EXFOR_ha	LUCAS Exotic forest ha	Area of property in hectares classified as exotic forest	LUCAS2020v3
GRASS_ha	LUCAS Grassland ha	Area of property in hectares classified as grassland (ungrazed)	LUCAS2020v3
GRASSWB_ha	LUCAS Grassland WB ha	Area of property in hectares classified as grassland with woody biomass	LUCAS2020v3
DAI_ha	LUCAS Dairy ha	Area of property in hectares classified as dairy	LUCAS2020v3
DRYS_ha	LUCAS Drystock ha	Area of property in hectares classified as drystock (non-dairy grazed)	LUCAS2020v3

Attribute field	Name	Description	Source
ORCVIN_ha	LUCAS Orchard vineyard ha	Area of property in hectares classified as orchards and vineyards	LUCAS2020v3
CROP_ha	LUCAS Cropland ha	Area of property in hectares classified as annual cropland	LUCAS2020v3
WATER_ha	LUCAS Water ha	Area of property in hectares classified as open water	LUCAS2020v3
WETL_ha	LUCAS Wetland ha	Area of property in hectares classified as wetland	LUCAS2020v3
URBAN_ha	LUCAS Urban ha	Area of property in hectares classified as settlements or built-up area	LUCAS2020v3
BARE_ha	LUCAS Bareground ha	Area of property in hectares classified as bare ground and lightly vegetated surfaces	LUCAS2020v3
LUCAS_ND%	LUCAS no data %	Percentage of property with no LUCAS data	LUCAS2020v3
NAT_%	LUCAS Natural %	Percentage of property classified as natural forest and shrubland	LUCAS2020v3
EXFOR_%	LUCAS Exotic forest %	Percentage of property classified as exotic forest	LUCAS2020v3
GRASS_%	LUCAS Grassland %	Percentage of property classified as grassland (ungrazed)	LUCAS2020v3
GRASSWB_%	LUCAS Grassland WB %	Percentage of property classified as grassland with woody biomass	LUCAS2020v3
DAI_%	LUCAS Dairy %	Percentage of property classified as dairy	LUCAS2020v3
DRYS_%	LUCAS Drystock %	Percentage of property classified as drystock (non-dairy grazed)	LUCAS2020v3
ORCVIN_%	LUCAS Orchard vineyard %	Percentage of property classified as orchards and vineyards	LUCAS2020v3
CROP_%	LUCAS Cropland %	Percentage of property classified as annual cropland	LUCAS2020v3
WATER_%	LUCAS Water %	Percentage of property classified as open water	LUCAS2020v3
WETL_%	LUCAS Wetland %	Percentage of property classified as wetland	LUCAS2020v3
URBAN_%	LUCAS Urban %	Percentage of property classified as settlements or built-up area	LUCAS2020v3
BARE_%	LUCAS Bareground %	Percentage of property classified as bare ground and lightly vegetated surfaces	LUCAS2020v3
LUCASmax%	Maximum land use percentage	Maximum percentage of LUCAS class	Pearson EC
LUCAS_LC	LUCAS Class name	Name of land use class with maximum area	Pearson EC
Lowland	Lowland percentage	Percentage of property in lowland (<600 masl, <8 degrees)	Pearson EC
Hill Count	Hill country percentage	Percentage of property in hill country (<600 masl, >8 degrees)	Pearson EC
Hill Count	High country percentage	Percentage of property in high country country (>600 masl, mixed slopes)	Pearson EC
Max_LandC	Max Landscape class	Maximum landscape class as a percentage	Pearson EC
SA_Class	Slope Altitude Landscape Class	Main landscape class for the property/land parcel	Pearson EC

5 Technical Land Use Map Input Data

A technical land use map is created by combining the base land use with a spatial representation of land cover and biophysical landscape attributes that influence contaminant generation and loss. Additional biophysical and land management data is included within the attribute data to support assessments of land use intensity and contaminant loss estimates. For practical reasons, the Technical Land Use Map is subdivided into the Freshwater Management Units and rohe for both GIS processing and as an output. Collectively the FMU maps are named the Technical Land Use Map.

5.1 Otago Base Land Use Map

The Otago Base Land Use Map provides the main classification of land use for a property (Figure 2). The poly_id field are maintained along with the land use classification fields and data source to identify land parcel and property boundaries. All other attribute data has been removed to reduce complexity and improve the useability of the technical map.

5.2 Land Cover

5.2.1 LUCAS 2020

Land cover information is compiled from LUCAS 2020v3 instead of using the land cover database (LCDBv5) due to LUCAS being derived from the most recent satellite imagery. The land cover data is simplified to the medium and basic land cover classes (Table 2). LCDB or LUCAS datasets can be used interchangeably depending on which dataset has the most recent classification of land cover.

5.2.2 Viticulture and Horticulture

Otago Regional Council's mapped spatial datasets of viticulture (vineyards) and horticulture (orchards, vegetables, plant nursery and flowers) were used to supplement the LUCAS land cover classification. Prior to use, these layers were edited to property boundaries by intersecting with the Otago base map and removing the areas that are outside the property boundary.

5.3 Landscape Factors

Landscape factors are the biophysical controls influencing both land use type and land management decisions and the impact these activities have on the environment. Landscape factors include the climate, topography, geology, and soil type.

5.3.1 Biophysical Data

Biophysical landscape factors of average altitude, slope, rainfall, and soil drainage for a polygon are provided as supporting attribute data within the technical land use map (Figure 3). These factors have been identified as the main landscape components used in the Physiographic Environments classification to identify the hydrological pathway water will take to leave the land and the amount of interaction drainage water has with the landscape (Pearson and Rissmann, 2021).

The biophysical data is sourced from:

- Altitude and slope: Land and Water Science Composite DEM
- Rainfall: annual average 1972-2016 (Ministry for the Environment & Stats NZ, 2017)
- Soil drainage: Average soil drainage utilising Fundamental Soils Layer and Smap (Pearson and Rissmann, 2021).

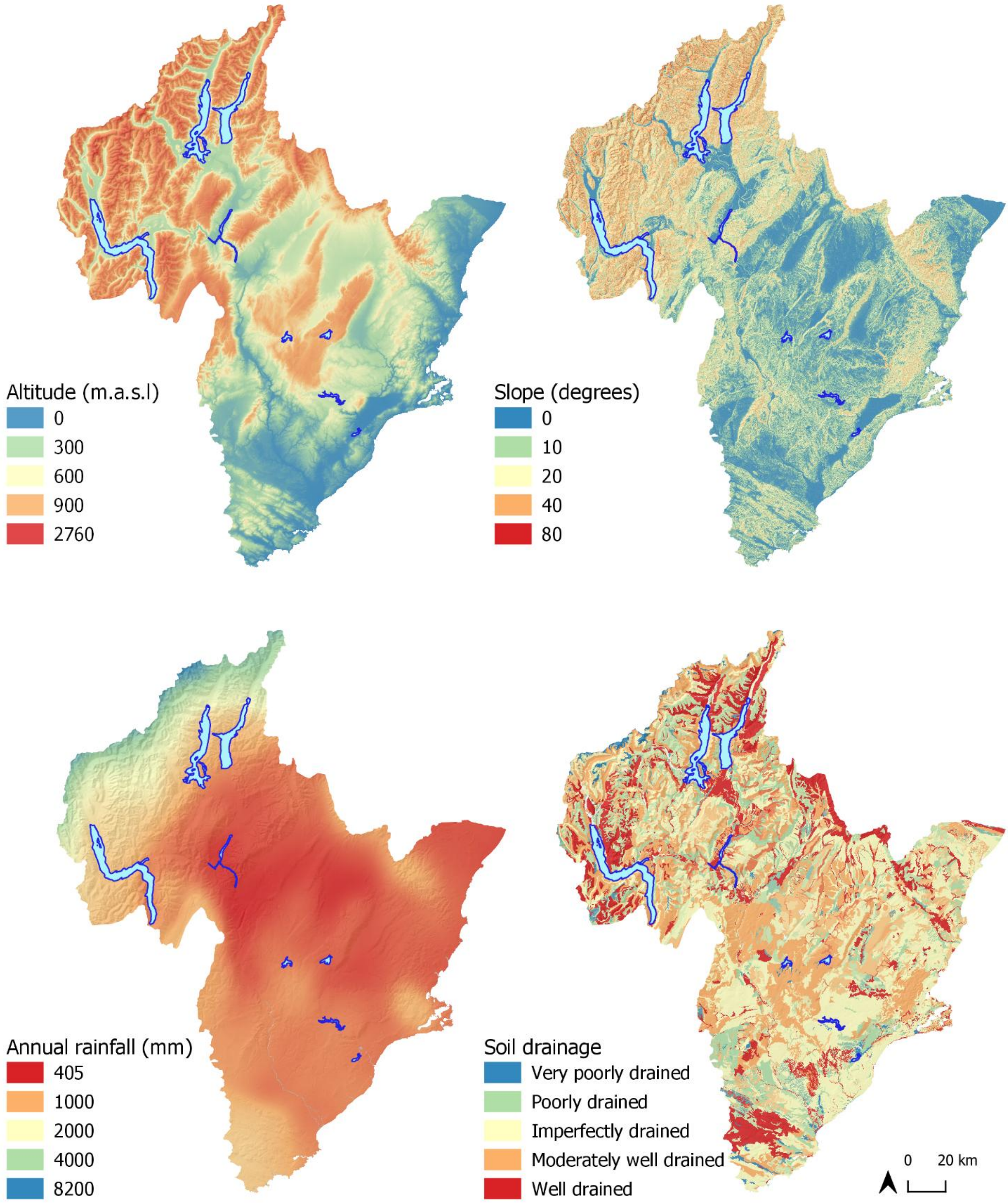

Figure 3. Biophysical landscape factors of altitude, slope, annual rainfall, and soil drainage in the Otago Region. Lakes greater than 500 ha are shown for reference.

To spatially represent the drystock lowland, hill, and high country landscape classes within a property, simplification of the landscape classes produced for the Base Land Use Map is required to reduce necessary complexity. To generalise these areas the NZ Land Resource Inventory polygons were used to establish landscape polygons at 1:50,000 scale. These polygons were combined with the high country polygons (minimum area 50 ha) previously generated and lowland and hill country was assigned according to the average slope as described in Section 2.6. See Figure 4 for landscape classes within the Otago region.

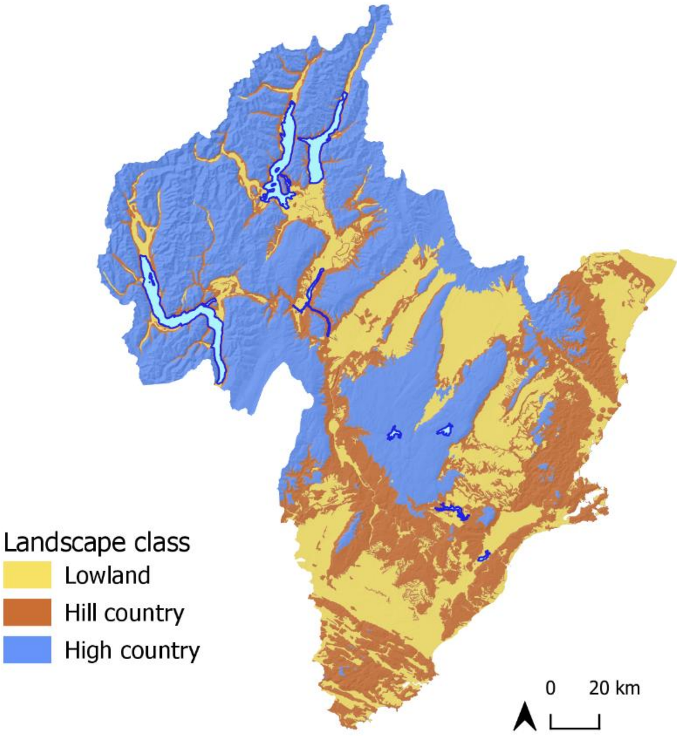

Figure 4. Landscape classes of lowland, hill country, and high country in the Otago Region. Lakes greater than 500 ha are shown for reference.

5.3.2 Land and Water Science - Physiographic Environments

The Physiographic Environments of New Zealand were produced as part of the Our Land and Water National Science Challenge and are an integration of landscape factors controlling water quality outcomes. Physiographic Environments are classified as areas that have similar landscape characteristics based on hydrological, redox (chemical processes), and weathering processes. Physiographics can be used to explain the 'how' and 'why' water quality varies across a catchment, region, or nationally and provide inherent landscape risk to water quality. The classification has been developed through the integration of nationally available datasets for climate, topography, geology, and soil (typically at 1:50,000 to 1:250,000 scale). At this resolution, it is suitable to help inform land use policy options and decision making but does not replace the need for catchment or farm-specific assessments and other due diligence.

The Physiographic Environments Classification is hierarchical with a basic 10 class *family* classification, and a more technical (28 class) *sibling* classification, which provides more resolution over gradients within the broader *'families'* classification (Table 7). The

Physiographic Environments each have a defining set of landscape characteristics that impact water quality in a predictable manner and can be used to show contaminant risk to water quality from multiple contaminants (Pearson and Rissmann, 2021). For example, the Environments include classifications that describe the potential of the landscape to physically filter out contaminants, or biogeochemically remove or transform contaminants through redox processes (e.g. nitrate removal through denitrification).

In addition to the main classification, variants are used to spatially depict where hydrology has been modified for land use and where climatic seasonality and/or episodic events may result in divergence from the steady-state depiction of the general classification. Specifically, the variants include consideration of likely artificial drainage density (anthropogenic), soil macropore bypass in response to soil moisture deficit (natural) and overland flow risk associated with episodic climatic events all of which may modify the dominant hydrological flow path and contaminants form and quantity exported to water.

The risk to water quality for each Physiographic Environment is determined according to the dominant hydrological pathway and contaminant form. A risk matrix is populated according to both the inherent (unmodified) and modified (artificial drainage) characteristics of the landscape and includes consideration of both transport and attenuation of nitrogen as nitrate nitrite nitrogen, ammoniacal nitrogen, and organic nitrogen, phosphorus as particulate phosphorus and dissolved reactive phosphorus, sediment (particulate), and microbial contamination (Pearson and Rissmann, 2021). The physiographic risk matrix assumes a source load for all contaminants irrespective of the land cover or enterprise type. Therefore, combining the Physiographic Environments with land use and land cover provides the council with a dataset that can be used to predict water quality outcomes. The risk matrix is provided in Appendix A from Pearson and Rissmann (2021). Interactive map of the Physiographic Environments, shown in Figure 5, are available online at www.landscapedna.org. A summary of the Physiographic Environments in the Otago Region is provided in Table 7.

Table 7. Summary of Physiographic Environments in the Otago Region.

		Family Area (Ha)	Family Percent (%)	Sibling Area (Ha)	Sibling Percent (%)
Alpine	Alpine	531,979	17.09	531,979	17.09
Strong bedrock		1,459,649	46.89		
	Subalpine			343,787	11.04
	Hill			808,208	25.96
	Low relief			307,655	9.88
Weak bedrock		250,757	8.05		
	Subalpine			63,620	2.04
	Hill			132,463	4.25
	Low relief			54,674	1.76
Oxidising soil & aquifer		349,656	11.23		
	High deep drainage			35,322	1.13
	Increased lateral & overland flow			155,166	4.98
	Strong bedrock			98,787	3.17
	Weak bedrock			60,382	1.94
Reducing soil oxidising aquifer		336,433	10.81		
	High soil reduction			70,087	2.25
	Moderate soil reduction			83,912	2.70
	Strong bedrock			125,837	4.04
	Weak bedrock			56,598	1.82
Oxidising soil reducing aquifer		55,396	1.78		
	High aquifer reduction			15,232	0.49
	Moderate aquifer reduction			4,490	0.14
	Strong bedrock			18,616	0.60
	Weak bedrock			17,058	0.55
Reducing soil & aquifer		54,137	1.74		
	High soil reduction			5,156	0.17
	Moderate soil reduction			9,938	0.32
	Strong bedrock			19,432	0.62
	Weak bedrock			19,612	0.63
Riverine		57,430	1.84		
	High deep drainage			17,428	0.56
	Increased overland flow			40,003	1.28
Wetlands		7,323	0.24		
	Lowland			5,275	0.17
	Hill and Alpine			2,048	0.07
Urban	Urban	10,398	0.33	10,398	0.33

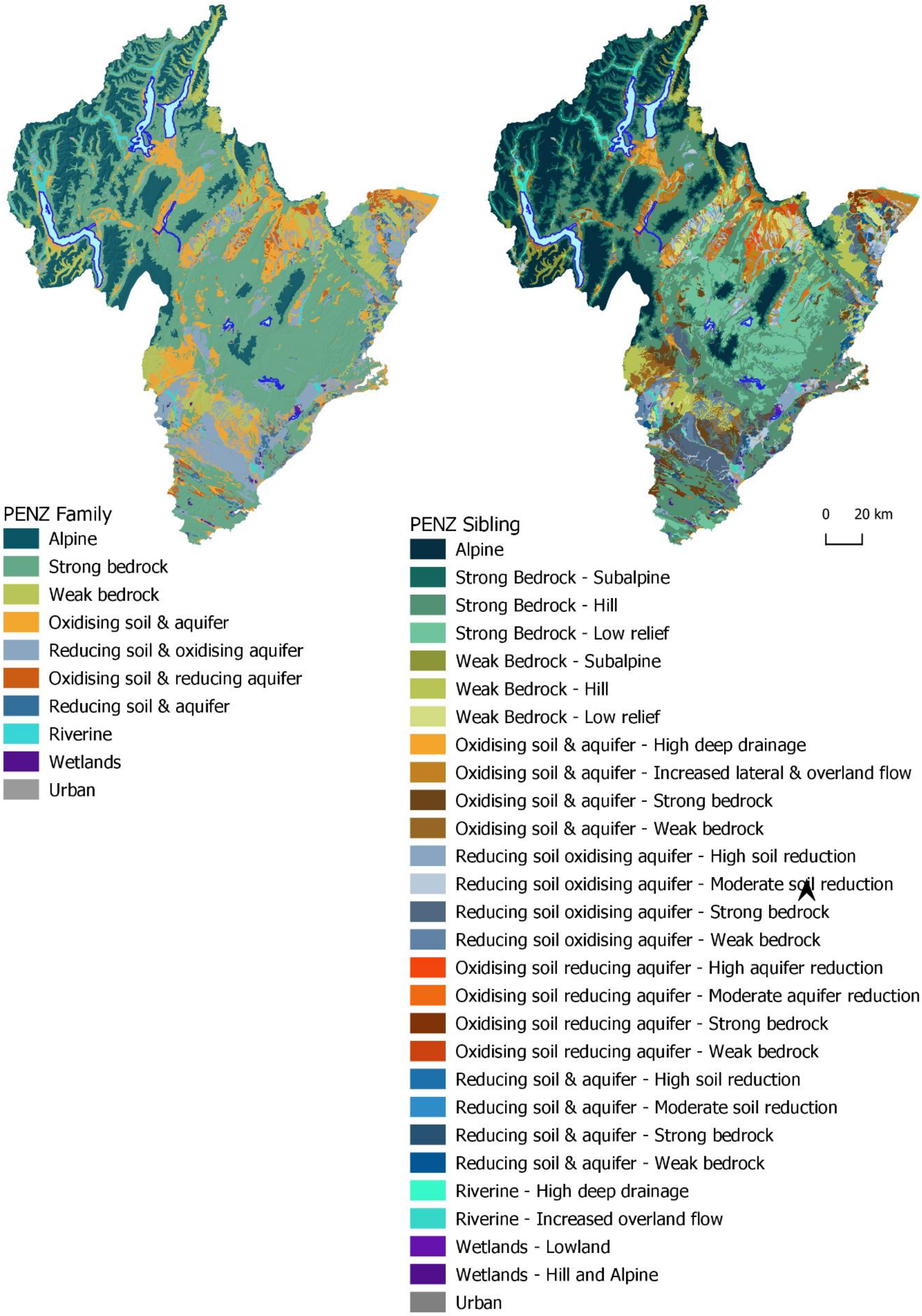

Figure 5. Physiographic Environments in the Otago Region. See www.landscapedna.co.nz for an interactive version of this map.

5.4 Land Management

Land management inputs are calculated for the polygon within the attribute table of the Technical Land Use Map. Activities like irrigation and winter grazing are often a rotational activity around a property and highly detailed therefore for practical reasons they are not shown spatially with the technical map itself. This also allows for easy updating of management practices which can be more frequently updated than the underlying base land use map. It also gives the ability to make comparisons between multiple years.

5.4.1 Irrigation - Aqualink

ORC commissioned a regionally specific irrigation map based on the existing national map produced by Aqualink for the Ministry of the Environment (Dark et al., 2017; Dark, 2020, Kashima, 2023). Irrigation was initially mapped nationally in 2017 with an updated layer available in 2020. The ORC irrigation layer for 2023 utilises satellite imagery obtained over a drought year to get a high contrast between irrigated and non-irrigated land. Aqualinc mapped irrigated land area for Otago using:

- Aerial photographs
- ORC specific data for vineyards and horticulture
- Multispectral satellite analysis of Normalised Difference Vegetation Index (a remote-sensing measurement of whether an image contains live green vegetation) imagery during summer (mostly January to March)
- Resource consent records of current irrigation consents
- Property boundary extents (from land ownership and title data from Land Information New Zealand).

Irrigation system types were identified from high resolution aerial or satellite photos (preferably 0.5m pixel or less). The system type was estimated by considering factors such as visual sighting of travelling irrigators, marking on the ground, or irrigation patterns. System types include spray (pivot, lateral, roto-rainer, linear boom, K-line/long lateral, solid set, gun, and side-roll), flood systems (border dyke and wild flooding), and micro or drip irrigation (Kashima, 2023).

The Otago region has a high visual contrast between irrigated and non-irrigated land resulting in a high mapping accuracy. Accuracy may vary due to uncertainty about a property's irrigation system capacity (litres of water per second per hectare), which can result in a whole property being mapped as irrigated when only part of the property can be irrigated at any one time.

5.4.2 Intensive Winter Grazing

ORC Intensive Winter Grazing Consented Area

Otago Regional Council issues resource consent under Section 88 of the Resource Management Act for intensive winter grazing if farms can not meet the following conditions:

- At all times the area of the farm that is used for intensive winter grazing must be no greater than 50 ha or 10% of the area of the farm, whichever is greater.

- The slope of any land under an annual forage crop that is used for intensive winter grazing must be 10 degrees or less, determined by measuring the slope over any 20m distance of the land.

- Livestock must be kept at least 5m away from the bed of any river, lake, wetland, or drain (regardless of whether there is any water in it at the time).

- On and from 1 May to 30 September of any year, in relation to any critical source area that is within, or adjacent to, any area of land that is used for intensive winter grazing on a farm:
    i. the critical source area must not be grazed; and
    ii. vegetation must be maintained as ground cover over all of the critical source area; and
    iii. maintaining that vegetation must not include any cultivation or harvesting of annual forage crops.

The spatial extent of the contented area is recorded and provided as a data layer into the Technical Land Use Map. Visual inspection of the mapped areas identified the accuracy is not sufficient to be mapped using the current dataset. The consented areas will need to be refined to the parcel boundaries, removing overlaps and roads from the consented areas. Therefore, the data will be used as an overlay with consented area reported for a property/parcel in the attribute table.

Manaaki Whenua Landcare Research Winter Forage Crops

Winter forage data comes from a national map produced by Manaaki Whenua Landcare Research (MWLR) for Regional Councils for winter 2022 (Belliss et al., 2023). MWLR mapped winter forage from Sentinel-2 satellite imagery acquired between October 2021 to mid-September 2022.The GIS vector dataset contains the paddock polygons that have been identified as likely to be grazed intensively. They have been classified at three certainty levels from 3 (good) down to 1 (low) depending on the strength of evidence visible in the imagery.

MWLR recommends that map users take note of the certainty rating (‘CertRating’) attribute of each polygon in order to treat each with the appropriate level of trust. Intensively grazed high-production pasture has been included in the map (polygon attributes of CertRating 1 – Case II,) but users should decide whether they wish to include this as ‘Intensive Winter Grazing’ or leave it out of their analysis.

For the reasons noted by MWLR and the high variability from year to year, the dataset is used as an overlay to accompany the Technical Land Use Map with forage area calculated as attribute data.

5.4.3 Proxy for Primary Production - Near InfraRed Vegetation Index

There are several satellite derived vegetation indices used to measure vegetation (Chenzong, et al., 2017; Xing et al., 2021). Among these indices, the normalised difference vegetation index (NDVI) is the most common measure of vegetation cover (see Huang et al., 2021). However, NDVI is also known to saturate fast when the vegetation is dense which is often the case in New Zealand.

As an alternative to NDVI, the near infra-red vegetation index (NIRv) is particularly useful for assessing photosynthetic activity and vegetation health, offering improved accuracy over traditional NDVI (Chenzong et al., 2017; Sharifi, 2020; Huang et al., 2021). Spectral information from Copernicus Sentinel-2 satellite data (processed by the European Space Agency) can be used to calculate the NIRv, an index specifically designed to enhance vegetation monitoring. NIRv is the product of total scene NIR reflectance (NIRT) and NDVI, which is calculated as follows (Badgley et al., 2017):

$$NIRv = ((NIR - Red) / (NIR + Red)) * NIR \qquad \text{(Equation 1)}$$

In a field study, Camps-Valls et al. (2021) used the near-infrared reflectance of vegetation to generate a high-resolution proxy of gross primary production. A strength of the method is the ability to estimate effective area, the area used for production, and track change over time.

NIRv is produced for summer (December to March 2019-2024) and winter (June – August 2019-2023). The index for each time period is derived from a composite of images collated over the summer and winter months, where each image is a stack of 12 raster layers corresponding to the 12 bands in Sentinel-2 (Table 8). Each composite layer is built from 80% cloud-free data, with any pixels obscured by cloud and clouds' shadows removed from the resulting composite. An example output is provided in Figure 6.

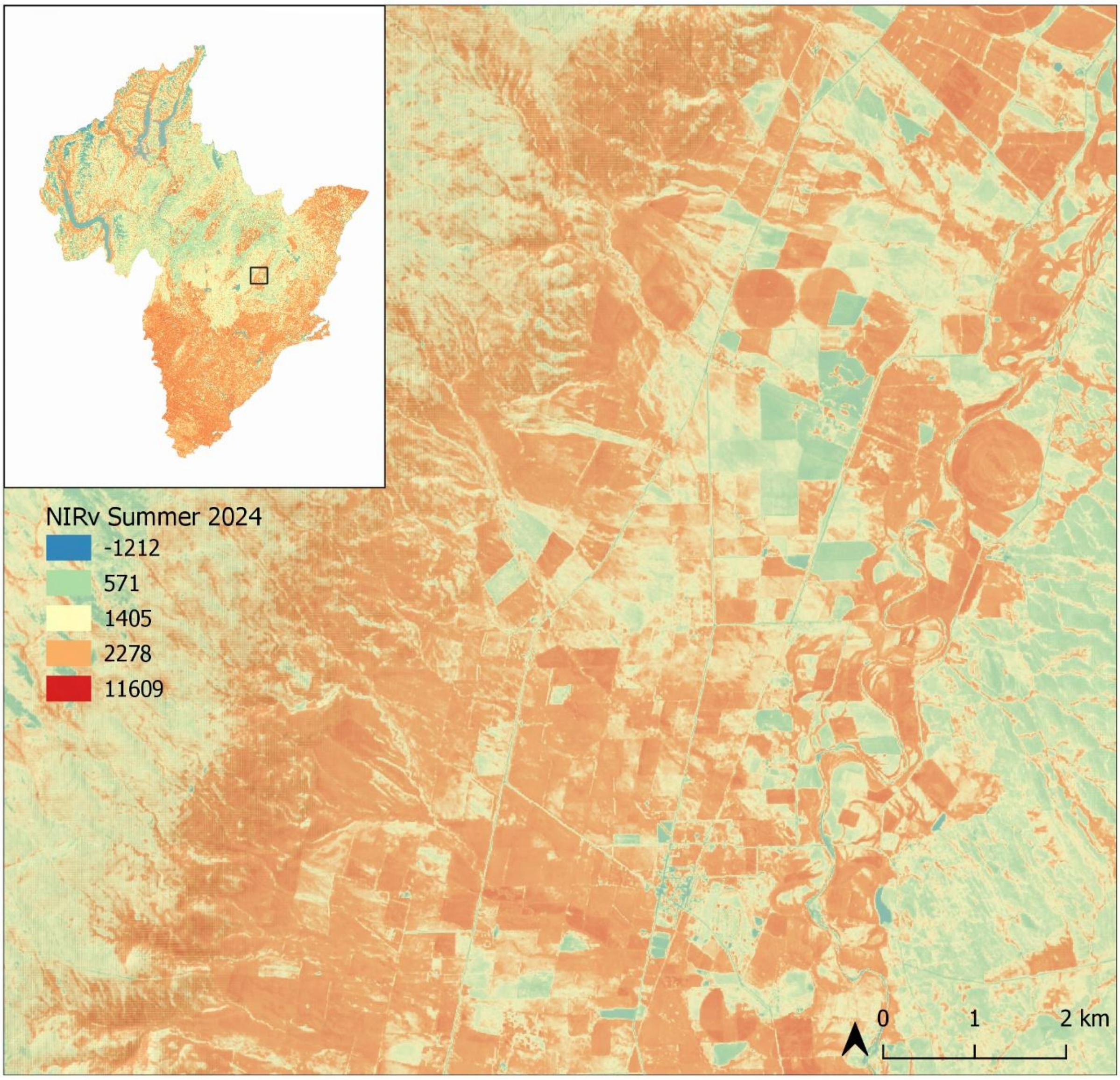

Figure 6. Example of Near Infra-red Vegetation Index (NIRv) for the Otago region summer 2024. Output range is expressed as a quantile.

Table 8. Band spatial resolution, central wavelength and bandwidth of the Sentinel-2 image.

Band	Spatial Resolution	Central Wavelength (μm)	Description
B1	60 m	0.44	Ultra-blue (Coastal and Aerosol)
B2	10 m	0.49	Blue
B3	10 m	0.56	Green
B4	10 m	0.66	Red
B5	20 m	0.70	Visible and Near Infrared (VNIR)
B6	20 m	0.74	Visible and Near Infrared (VNIR)
B7	20 m	0.78	Visible and Near Infrared (VNIR)
B8	10 m	0.84	Visible and Near Infrared (VNIR)
B8a	20 m	0.86	Visible and Near Infrared (VNIR)
B9	60 m	0.94	Short Wave Infrared (SWIR)
B10	60 m	1.37	Short Wave Infrared (SWIR)
B11	20 m	1.61	Short Wave Infrared (SWIR)
B12	20 m	2.19	Short Wave Infrared (SWIR)

6 Technical Map Methodology

The method used to create the Otago Technical Land Use Map is detailed below with the QGIS processing tools used indicated by italics.

In QGIS:

- Load all datasets in QGIS.
- *Intersect* the Freshwater Management Units with the Base Land Use Map.
- The LUCAS dataset was classified by the medium and basic land cover class detailed in Table 2.
- *Intersect* each FMU Base Land Use Map to LUCAS 2020 land cover class.
- *Intersect* ORC Vineyards and Horticulture with FMU layer and *Union* to each respective base land cover.
- *Union* Landscape Class (Lowland, Hill Country, High Country) (see Section 5.3.2 for additional methodology)
- *Add* UID field and populate with row number.
- Calculate polygon area. Delete sliver polygons with an area less than 1 m^2.
- Calculate 3D area using *Real surface area* from the LiDAR derived DEM (10m). Sum using *Zonal statistics* surface area for each FMU or rohe.
- Calculate irrigation area, winter crop and consented winter grazing areas using *Overlap analysis* for each FMU or rohe.
- Calculate summer and winter NIRv for 2019 to 2024 using *Zonal Statistics.*
- Calculate average biophysical factors of altitude, slope, precipitation, and soil drainage using *Zonal Statistics.*
- Calculate physiographic family and sibling assignment using *Zonal Histogram*.
- *Export* as excel table and UID field as a shapefile for each FMU and rohe.

In Excel:

- Add field for Land use and cover (LULC) and classify agricultural land uses and lifestyle by land cover classes exotic forest, natural forest and shrubland, small water bodies, and wetlands. Activities that are rotational around an agricultural land use are not classified by land cover but can be used to estimate extent in the resulting map by the land cover classes. Grasslands could be further subdivided by high and low producing if required in future.

- Classify hill and high country horticultural land uses by LC basic class and assign landscape class to drystock.
- Classify Commercial forestry and Exotic forest LULC field by the land cover classes of natural forest and shrubland, grasslands, small water bodies, and wetlands.
- Classify Horticulture and Vineyards by ORC dataset as ‘Orchards and horticultural use’ and ‘Viticulture’, respectively. This land use is not present in all FMUs or rohe.
- Classify unknown land uses of bare ground, grassland, wetland, exotic forest, and natural forest and shrubland by land cover class.
- Classify all remaining land uses by the primary land use class.
- Update Lowland drystock, Hill country drystock, and High country drystock by landscape class. This results in a mix of landscape classes shown across a property and can be used to assign variable stocking rates according to Beef and Lamb data (Pearson, 2023). When viewed in GIS the ‘effective area’ of the property will display the land use class and the ‘non-effective’ areas the land cover class.
- Calculate Physiographic Environments into hectares.
- Save as .csv

In QGIS:

- Join .csv file to UID for each respective FMU or rohe shapefile.
- *Export* as FMU Name Technical Land Use shapefile and symbolise according to Appendix A.
- Overlay with supporting datasets such as irrigation area, winter forage consented areas and paddocks as required.

7 Technical Land Use Maps

7.1 Technical Land Use Summary and Maps

7.1.1 Clutha Mata-Au Freshwater Management Unit

The Clutha Mata-Au Freshwater Management Unit is divided into 5 rohe. The largest of the rohe is the Upper Lakes rohe accounting for 33.4% of the FMU, followed by Dunstan at 24.2%, the Lower Clutha at 19.2%, Manuherekia at 14.4%, and Roxburgh is the smallest making up 8.6% of the FMU. The total area of the FMU is 2,098,370 ha.

Land use changes from the high altitude rohe of the Upper Lakes which is dominated by Conservation Estate and natural land covers to hill country and lowland drystock and dairy in the Lower Clutha rohe.

Upper Lakes Rohe

The Upper Lakes rohe is the largest of the 5 sub-catchments with a total area of 701,161 ha. The average altitude is 588 meters above sea level with moderately steep terrain and an average slope of 16.6 degrees (Table 9). Rainfall is high averaging 1770 mm annually (Ministry for the Environment & Stats NZ, 2017).

Half the Upper Lakes Rohe is Conservation Estate (349,728 ha) with High country drystock accounting for the largest agricultural land use with 72,413 ha (14.7 % of the rohe). A further 10% (72,414 ha) is classified as open water. Other developed land uses make up less than 4.25 % of the total rohe area (Figure 7, Table 9). A total of 966 ha has been identified as irrigated, with the majority occurring on lowland and hill country drystock land uses. Urban areas include Queenstown and Wanaka.

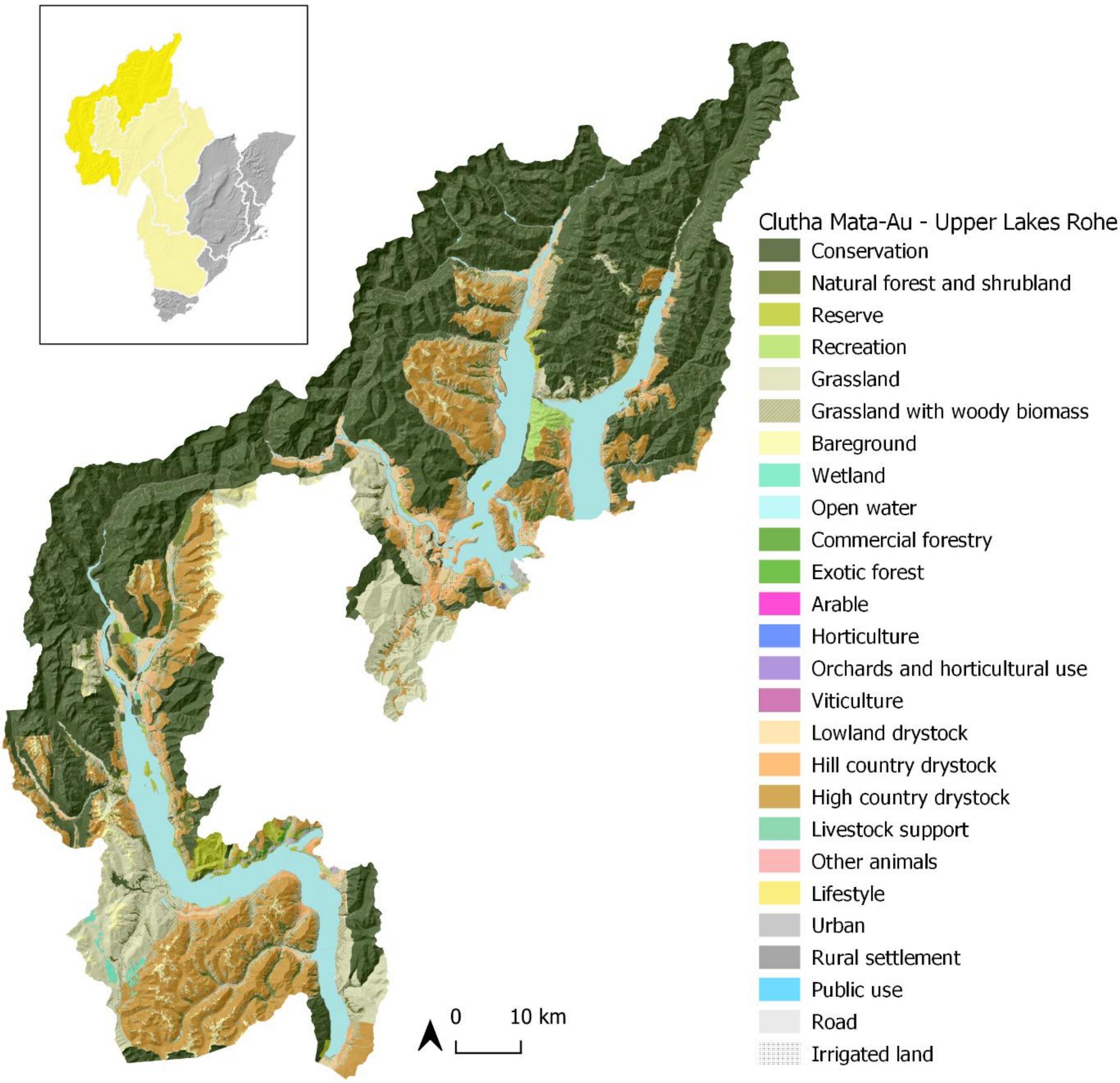

Figure 7. Land use and land cover of the Clutha Mata Au – Upper Lakes Rohe. Inset shows the Upper Lakes Rohe within the Clutha Mata-Au FMU extent.

Table 9. Land use land cover by area for the Upper Lakes Rohe and supporting biophysical data. Soil drainage is a score from 1- very poorly drained to 5- well drained.

Land use land cover class	Area (Ha)	Area percent (%)	Irrigated land (Ha)	Winter forage (Ha)	Average altitude (m.a.s.l)	Average slope (degrees)	Average rainfall (mm/year)	Average soil drainage class
Conservation	349,728.0	49.88	1.8	0.0	810.1	22.0	2586	3.5
High country drystock	102,885.3	14.67	0.0	15.6	948.8	24.5	1566	3.5
Open water	72,413.7	10.33	2.0	2.9	387.2	9.6	1788	2.6
Grassland	52,898.2	7.54	7.6	91.8	706.1	16.9	1506	3.5
Grassland with woody biomass	38,430.2	5.48	6.0	3.8	612.3	23.4	1399	3.5
Natural forest and shrubland	21,018.4	3.00	1.5	0.3	575.1	21.6	1626	3.6
Hill country drystock	16,264.9	2.32	141.3	84.3	450.4	17.8	1446	3.5
Bareground	15,964.6	2.28	0.0	4.3	1219.4	22.5	1674	3.4
Lowland drystock	13,506.0	1.93	738.2	489.9	351.6	7.7	1658	3.3
Reserve	7,950.4	1.13	0.1	0.0	416.2	17.2	1253	3.4
Recreation	3,369.5	0.48	34.3	14.8	460.8	21.2	1325	2.7
Road	1,993.1	0.28	8.2	6.6	369.8	9.9	1487	3.3
Wetland	1,755.8	0.25	0.0	0.0	414.1	4.7	1817	3.1
Urban	1,257.4	0.18	0.0	0.0	349.5	7.6	902	3.7
Exotic forest	1,084.7	0.15	4.7	0.1	396.5	12.9	1083	3.5
Lifestyle	320.2	0.05	0.0	0.1	363.5	6.3	1091	4.2
Rural settlement	80.2	0.01	0.0	0.0	321.0	3.0	1335	4.9
Other animals	72.7	0.01	0.0	0.0	321.4	3.1	1276	4.8
Horticulture	68.4	0.01	3.2	0.0	325.2	7.5	929	4.8
Livestock support	50.7	0.01	0.0	0.0	368.2	13.5	1053	3.2
Commercial forestry	22.2	0.00	0.0	0.0	413.6	13.5	1357	3.3
Viticulture	17.9	0.00	16.8	0.0	325.1	4.5	844	5.0
Arable	7.8	0.00	0.0	0.0	355.2	1.2	825	3.1
Orchards and horticultural use	0.2	0.00	0.0	0.0	318.8	10.4	869	5.0
Public use	0.2	0.00	0.0	0.0	320.4	2.9	1045	3.0
Upper Lakes Rohe	701,160.8	100.00	965.9	714.4	587.9	16.6	1769	3.4

Dunstan Rohe

The Dunstan rohe has an area of 508,256 ha and its catchment starts at the Clutha Mata-Au River to the Clyde Dam. The average altitude is 493 meters above sea level with rolling terrain and an average slope of 10.3 degrees (Table 10). Rainfall is relatively low compared to the Upper Lakes rohe averaging 834 mm annually (Ministry for the Environment & Stats NZ, 2017).

The predominant land use is high country drystock (39% or 197,790 ha) followed by Conservation Estate (84,628 ha) and ungrazed grassland (54,920 ha) (Figure 8, Table 10). A further 10 % and 6.6 % if the rohe is used for hill and lowland drystock. Although minor in extent, dairy, viticulture and orchards are located on the flatter areas of the rohe. A total of 23,188 ha has been identified as irrigated, with the majority occurring on lowland drystock, dairy and viticulture land uses. Urban areas include Cromwell and Arrowtown.

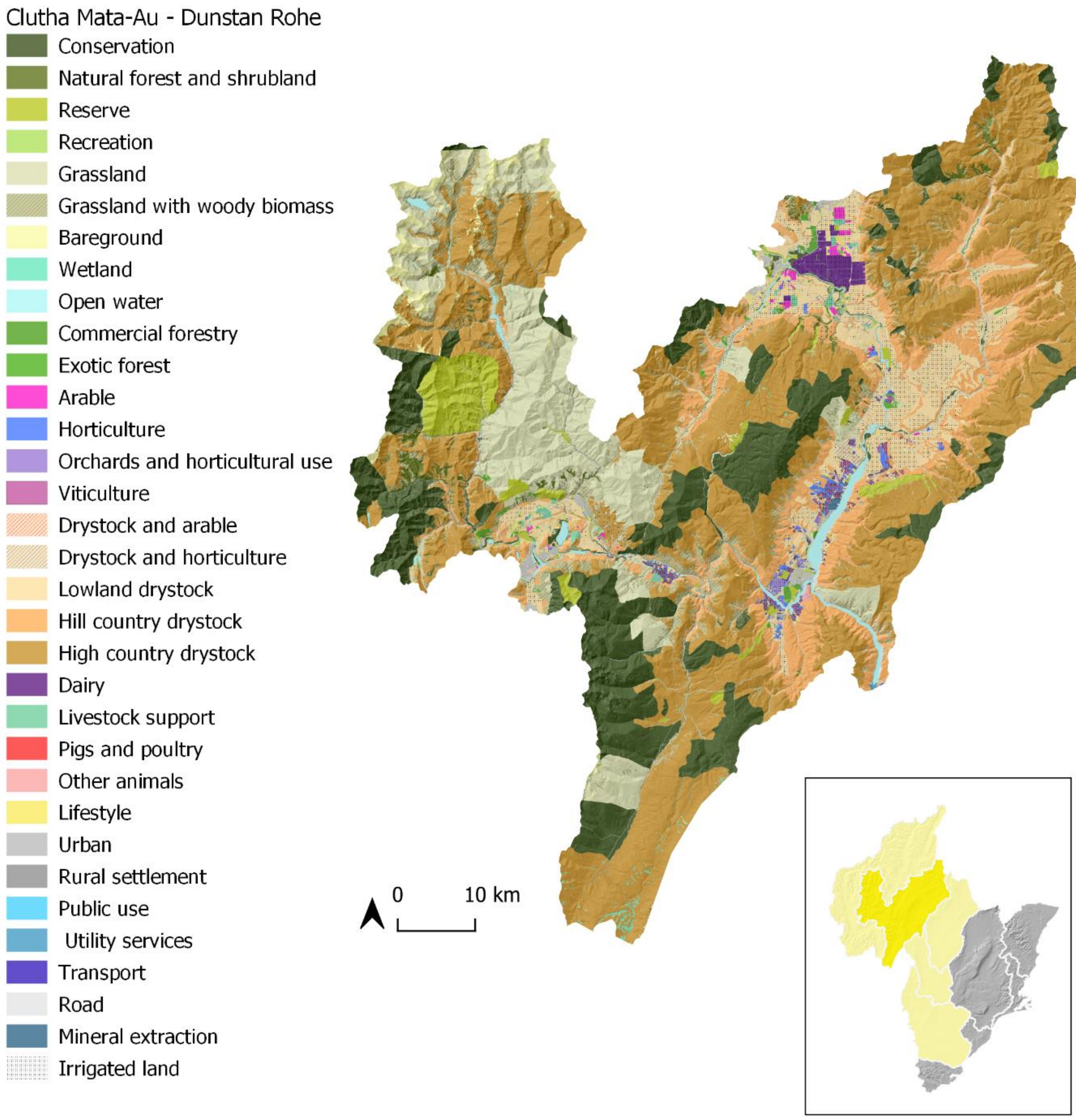

Figure 8. Land use and land cover of the Clutha Mata Au – Dunstan Rohe. Inset shows the Dunstan Rohe within the Clutha Mata-Au FMU extent.

Table 10. Land use land cover by area for the Dunstan Rohe and supporting biophysical data. Soil drainage is a score from 1- very poorly drained to 5- well drained.

Land use land cover class	Area (Ha)	Area percent (%)	Irrigated land (Ha)	Winter forage (Ha)	Average altitude (m.a.s.l)	Average slope (degrees)	Average rainfall (mm/year)	Average soil drainage class
High country drystock	97,789	38.92	427.9	48.0	936.3	20.6	1123	3.3
Conservation	84,628	16.65	36.1	2.6	740.8	14.5	1061	3.4
Grassland	54,920	10.81	282.8	55.2	775.6	15.4	1012	3.4
Hill country drystock	50,665	9.97	1239.1	423.4	441.2	14.1	722	3.7
Lowland drystock	33,385	6.57	13769.5	2660.4	361.4	6.5	691	3.9
Grassland with woody biomass	25,200	4.96	51.5	1.2	597.9	20.1	923	3.4
Reserve	15,436	3.04	57.2	0.0	597.8	15.9	961	3.5
Bareground	8,524	1.68	162.4	49.0	1028.5	19.0	1205	3.4
Open water	7,397	1.46	23.3	3.4	483.1	9.3	952	3.2
Natural forest and shrubland	5,344	1.05	2.1	0.0	585.7	22.7	1017	3.6
Road	4,327	0.85	229.8	16.4	430.1	8.2	753	3.8
Dairy	3,289	0.65	2421.6	309.8	349.0	6.2	713	4.8
Lifestyle	2,422	0.48	102.4	3.1	341.5	5.4	723	4.3
Exotic forest	2,195	0.43	46.7	4.0	385.7	9.1	797	3.8
Viticulture	2,130	0.42	2117.7	47.2	296.6	6.1	558	4.3
Horticulture	1,963	0.39	396.2	16.8	287.4	5.7	555	4.3
Urban	1,683	0.33	7.9	0.0	318.1	2.5	737	4.4
Drystock and horticulture	1,369	0.27	379.3	32.4	261.3	6.3	507	4.2
Livestock support	1,161	0.23	420.6	36.6	374.6	7.5	735	4.2
Arable	1,028	0.20	373.3	80.2	359.9	4.1	769	4.4
Wetland	913	0.18	0.0	0.0	1189.1	9.9	1143	3.2
Orchards and horticultural use	684	0.13	607.3	87.6	250.9	4.3	500	4.2
Commercial forestry	662	0.13	3.8	0.0	319.4	6.6	646	4.4
Rural settlement	357	0.07	2.1	0.0	288.5	3.6	599	4.3
Other animals	229	0.05	5.8	0.0	299.6	9.3	599	3.9
Mineral extraction	212	0.04	11.0	0.0	219.9	1.8	495	4.2
Recreation	122	0.02	9.9	0.1	267.1	2.6	529	4.3
Drystock and arable	86	0.02	0.0	0.0	366.1	6.7	817	4.3
Utility services	81	0.02	0.2	0.0	233.7	8.5	478	3.3
Transport	34	0.01	0.0	0.0	251.0	1.5	498	4.8
Public use	15	0.00	0.1	0.0	236.9	2.8	496	3.2
Pigs and poultry	5	0.00	0.0	0.0	387.0	8.4	722	5.0
Dunstan Rohe	508,256	100	23,187.6	3,877.2	492.9	10.3	834	3.8

Manuherekia Rohe

The Manuherekia is a tributary catchment to the Clutha Mata-Au and has an area of 303,642 ha. The average altitude is 441 meters above sea level with typically flat and undulating to rolling terrain and an average slope of 5.7 degrees (Table 10). Rainfall is very low averaging 530 mm annually (Ministry for the Environment & Stats NZ, 2017).

The predominant land use in the rohe is drystock across high country (44% or 132,998 ha), hill country (8.8% or 26,717 ha) and lowland (26% or 79,224 ha). Conservation Estate comprises 35,454 ha (11.7%) (Figure 9, Table 11). Dairy (5,099 ha) and livestock support (2,211 ha) are relatively minor in extent however can be significantly higher in intensity. A total of 28,412 ha has been identified as irrigated, with the majority occurring on lowland drystock, dairy, and livestock support land uses across the lowland. The town of Alexandra is the significant urban population in the Manuherekia rohe.

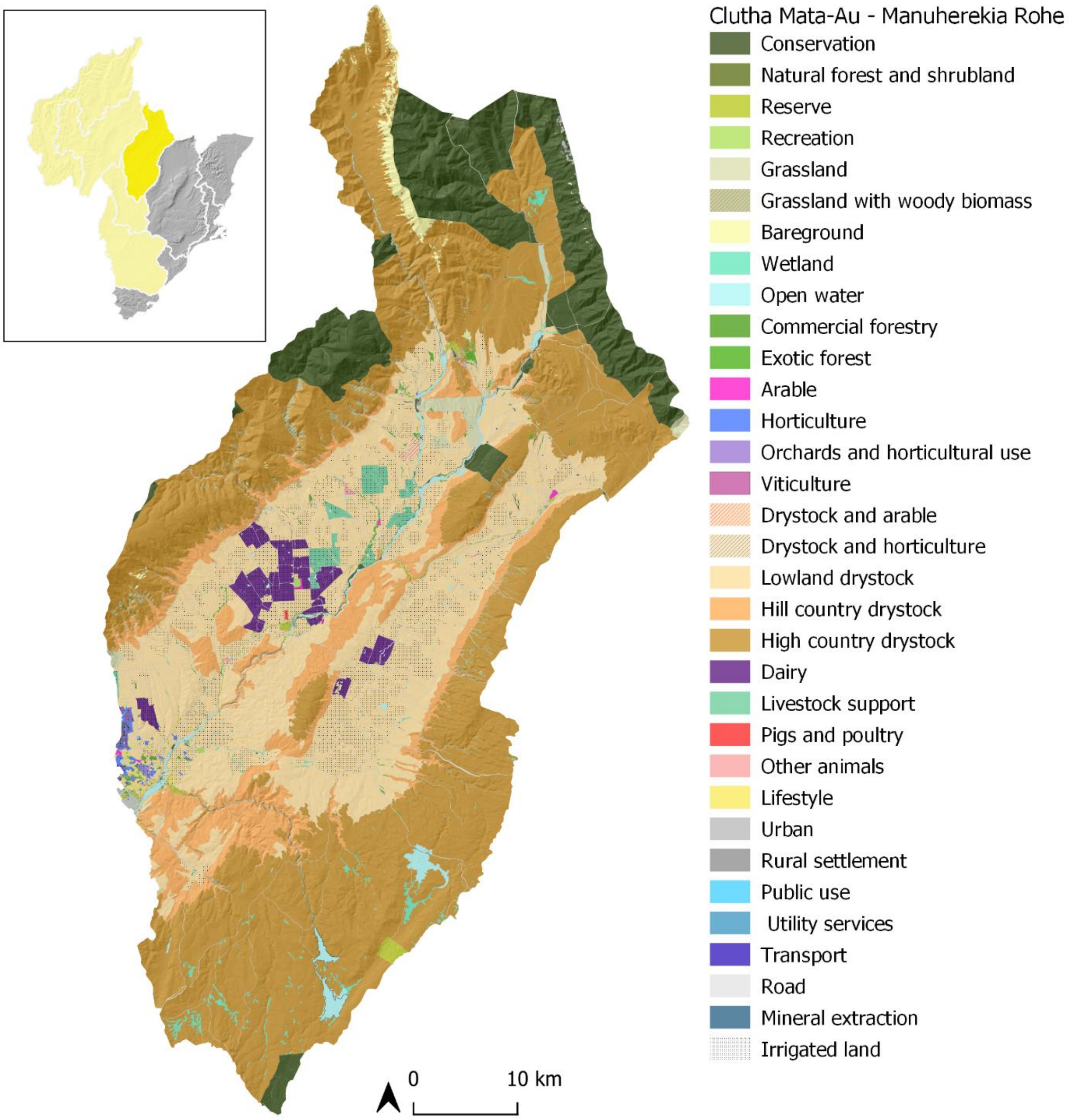

Figure 9. Land use and land cover of the Clutha Mata Au – Manuherekia Rohe. Inset shows the Manuherekia Rohe within the Clutha Mata-Au FMU extent.

Table 11. Land use land cover by area for the Manuherekia Rohe and supporting biophysical data. Soil drainage is a score from 1- very poorly drained to 5- well drained.

Land use land cover class	Area (Ha)	Area percent (%)	Irrigated land (Ha)	Winter forage (Ha)	Average altitude (m.a.s.l)	Average slope (degrees)	Average rainfall (mm/year)	Average soil drainage class
High country drystock	132,998	43.80	154.7	182.0	757.5	9.2	653	3.3
Lowland drystock	79,224	26.09	21057.6	3685.9	400.7	3.8	510	3.3
Conservation	35,454	11.68	15.3	0.0	649.8	8.9	632	3.2
Hill country drystock	26,717	8.80	133.4	37.5	474.0	11.2	533	3.4
Dairy	5,099	1.68	3947.3	331.5	360.4	2.0	479	3.2
Open water	3,620	1.19	147.0	21.7	455.0	4.0	547	3.0
Road	3,438	1.13	269.3	24.5	433.3	4.1	536	3.5
Grassland with woody biomass	3,340	1.10	32.5	0.5	554.1	14.6	567	3.4
Bareground	2,640	0.87	104.7	27.6	1002.2	16.6	646	3.4
Grassland	2,290	0.75	148.7	99.3	538.6	7.2	568	3.4
Livestock support	2,211	0.73	1392.4	275.5	366.2	2.3	504	2.6
Wetland	1,613	0.53	40.6	0.0	662.3	3.3	596	3.2
Reserve	1,136	0.37	77.8	6.7	348.5	6.1	483	3.5
Lifestyle	943	0.31	240.1	0.9	281.8	4.1	456	3.7
Exotic forest	828	0.27	50.3	1.9	361.5	3.7	514	3.0
Horticulture	575	0.19	89.8	2.6	229.5	3.2	418	4.0
Drystock and arable	226	0.07	59.5	20.2	427.8	1.5	575	4.0
Viticulture	220	0.07	208.9	0.0	240.0	3.2	419	4.0
Urban	183	0.06	5.2	0.0	150.0	2.0	406	4.9
Commercial forestry	141	0.05	15.4	0.4	258.8	7.1	443	4.1
Arable	141	0.05	27.1	9.0	372.4	2.1	491	3.2
Other animals	140	0.05	66.9	3.7	326.6	4.6	492	3.3
Orchards and horticultural use	128	0.04	118.1	0.0	206.1	3.8	413	4.0
Rural settlement	106	0.03	6.4	0.3	367.6	3.7	499	3.2
Recreation	86	0.03	0.2	0.0	214.5	4.3	430	3.6
Natural forest and shrubland	70	0.02	0.0	0.0	578.7	20.2	540	3.8
Pigs and poultry	32	0.01	0.2	0.0	304.8	1.8	457	2.2
Public use	19	0.01	2.6	0.3	306.0	3.3	481	3.9
Transport	10	0.00	0.0	0.0	303.9	1.6	456	3.5
Drystock and horticulture	6	0.00	0.0	0.0	192.4	4.9	410	4.4
Utility services	6	0.00	0.0	0.0	271.2	1.8	449	3.5
Mineral extraction	1	0.00	0.1	0.0	351.2	3.8	486	2.1
Manuherekia Rohe	303,642	100	28,411.9	4,731.9	441.1	5.7	530	3.4

Roxburgh Rohe

The Roxburgh rohe is the smallest of the Clutha Mata-Au FMU with an area of 181,951 ha. The catchment extent starts at the outlet of Lake Dunstan to the boundary of the Clutha District. The average altitude is 302 meters above sea level with undulating to rolling terrain and an average slope of 8.4 degrees (Table 12). Rainfall is low averaging 599 mm annually (Ministry for the Environment & Stats NZ, 2017).

The predominant land use in the rohe is drystock across high country (30% or 54,564 ha), hill country (32% or 58,740 ha) and lowland (6.8% or 12,380 ha). Conservation Estate comprises 16,354 ha (9%) (Figure 10, Table 12). Commercial forestry is undertaken on 3,350 ha with a further 2,036 ha of exotic forest on other land uses. Orchards and other horticultural land uses area also significant around the main urban areas of Clyde and Roxborough. A total of 4,818 ha has been identified as irrigated, with the majority occurring on lowland drystock, and orchards.

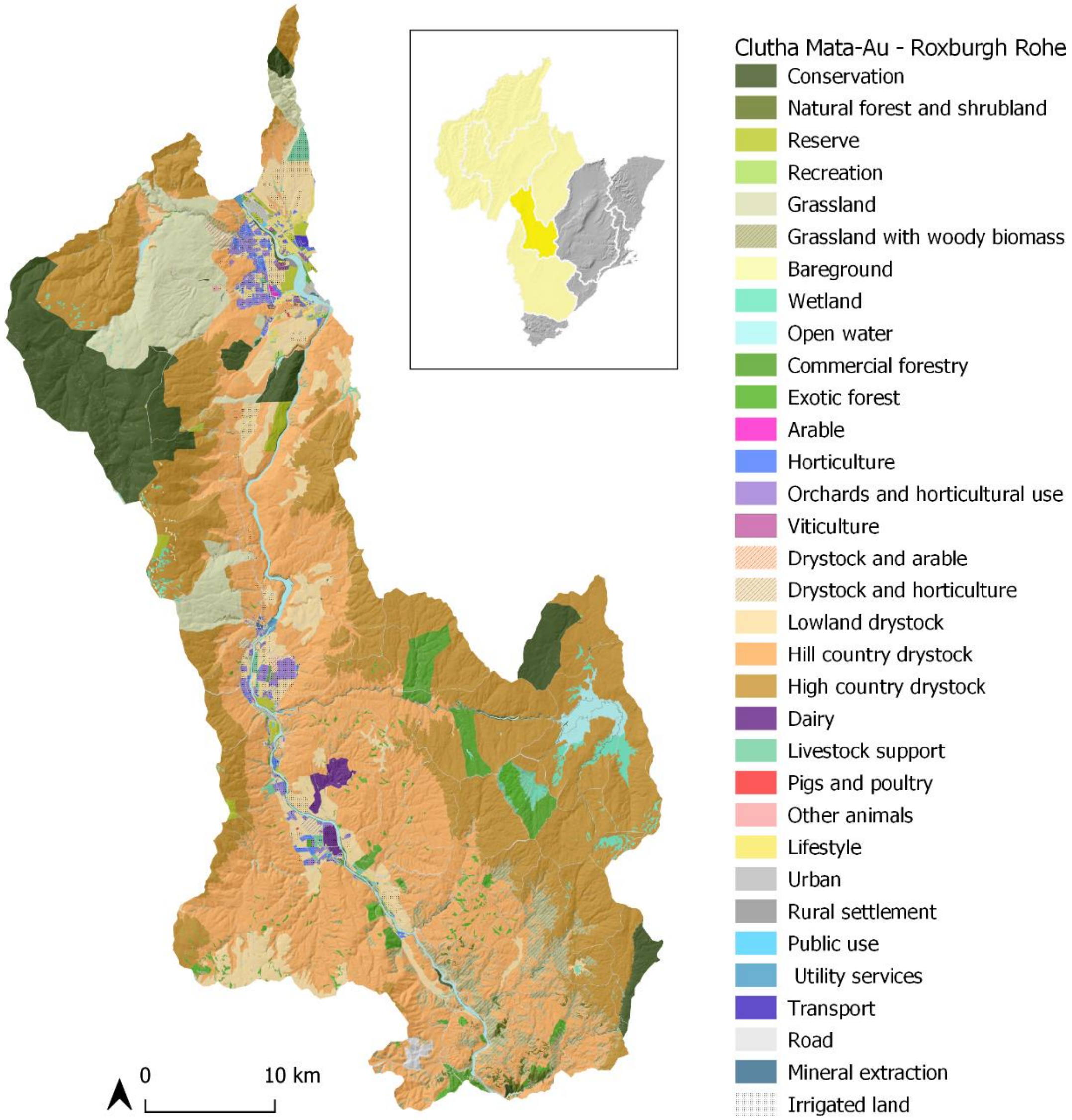

Figure 10. Land use and land cover of the Clutha Mata Au – Roxburgh Rohe. Inset shows the Roxburgh Rohe within the Clutha Mata-Au FMU extent.

Table 12. Land use land cover by area for the Roxburgh Rohe and supporting biophysical data. Soil drainage is a score from 1- very poorly drained to 5- well drained.

Land use land cover class	Area (Ha)	Area percent (%)	Irrigated land (Ha)	Winter forage (Ha)	Average altitude (m.a.s.l)	Average slope (degrees)	Average rainfall (mm/year)	Average soil drainage class
Hill country drystock	58,740	32.28	261.8	1,491.6	311.8	11.7	661	3.5
High country drystock	54,564	29.99	-	276.5	786.0	10.8	696	3.6
Conservation	16,354	8.99	6.0	-	478.4	10.2	692	3.3
Lowland drystock	12,380	6.80	1,797.1	683.1	241.9	6.8	556	3.5
Grassland	10,550	5.80	24.8	22.9	437.4	12.3	646	3.5
Grassland with woody biomass	7,523	4.13	13.3	11.1	324.0	13.7	683	3.5
Commercial forestry	3,349	1.84	23.4	34.7	390.3	10.4	680	4.1
Open water	3,173	1.74	4.2	1.1	299.7	8.3	614	3.0
Road	2,877	1.58	70.0	19.2	306.7	7.3	602	3.6
Exotic forest	2,036	1.12	2.8	6.4	327.1	9.9	689	3.4
Wetland	1,659	0.91	4.3	-	893.9	5.6	745	3.5
Orchards and horticultural use	1,474	0.81	1,387.9	60.2	151.6	4.4	508	3.7
Reserve	1,357	0.75	77.8	-	232.4	6.4	494	4.2
Lifestyle	982	0.54	107.1	1.0	175.2	5.2	474	4.1
Horticulture	913	0.50	256.5	31.0	154.5	4.2	493	4.0
Livestock support	888	0.49	367.3	187.6	314.7	4.6	619	4.0
Dairy	787	0.43	136.0	42.9	193.7	6.4	609	3.6
Natural forest and shrubland	646	0.36	-	1.2	307.1	17.3	838	3.7
Drystock and horticulture	546	0.30	35.2	9.0	156.0	7.7	560	3.7
Urban	214	0.12	0.1	-	168.3	4.0	417	4.7
Rural settlement	191	0.11	19.8	0.0	107.4	5.2	598	2.8
Bareground	151	0.08	4.9	-	825.2	11.4	634	4.0
Utility services	130	0.07	4.4	-	146.0	11.8	527	3.8
Viticulture	130	0.07	125.6	-	182.3	5.7	410	4.3
Transport	88	0.05	0.0	-	181.9	5.3	537	4.0
Drystock and arable	69	0.04	46.5	35.6	156.1	5.6	559	4.0
Recreation	51	0.03	-	-	171.0	3.1	453	4.3
Arable	35	0.02	26.6	-	125.1	2.5	512	4.0
Mineral extraction	31	0.02	0.1	3.5	141.7	4.1	508	4.7
Public use	28	0.02	-	-	123.5	3.2	533	3.3
Other animals	24	0.01	9.6	-	196.3	5.3	491	3.8
Pigs and poultry	12	0.01	4.9	-	150.6	3.8	487	4.3
Roxburgh Rohe	181,951	100	4,817.8	2,918.6	302.0	8.4	599	3.6

Lower Clutha Rohe

The Lower Clutha rohe has an area of 403,360 ha. The catchment extent starts at the upper boundary of the Clutha District and extends to the coast. The average altitude is 302 meters above sea level with undulating to rolling terrain and an average slope of 8.4 degrees (Table 13). Rainfall is low averaging 599 mm annually (Ministry for the Environment & Stats NZ, 2017).

The predominant land use in the rohe is hill country (24% or 97,951 ha) and lowland drystock (24% or 97,624 ha). Dairy is also a significant land use of the rohe with 15% land area (60,334 ha) (Figure 11, Table 13). Commercial forestry is undertaken on 37,553 ha with a further 9,026 ha of exotic forest on other land uses. A total of 4,818 ha has been identified as irrigated, with the majority occurring on lowland drystock and orchards. The main urban area of the rohe is Balclutha.

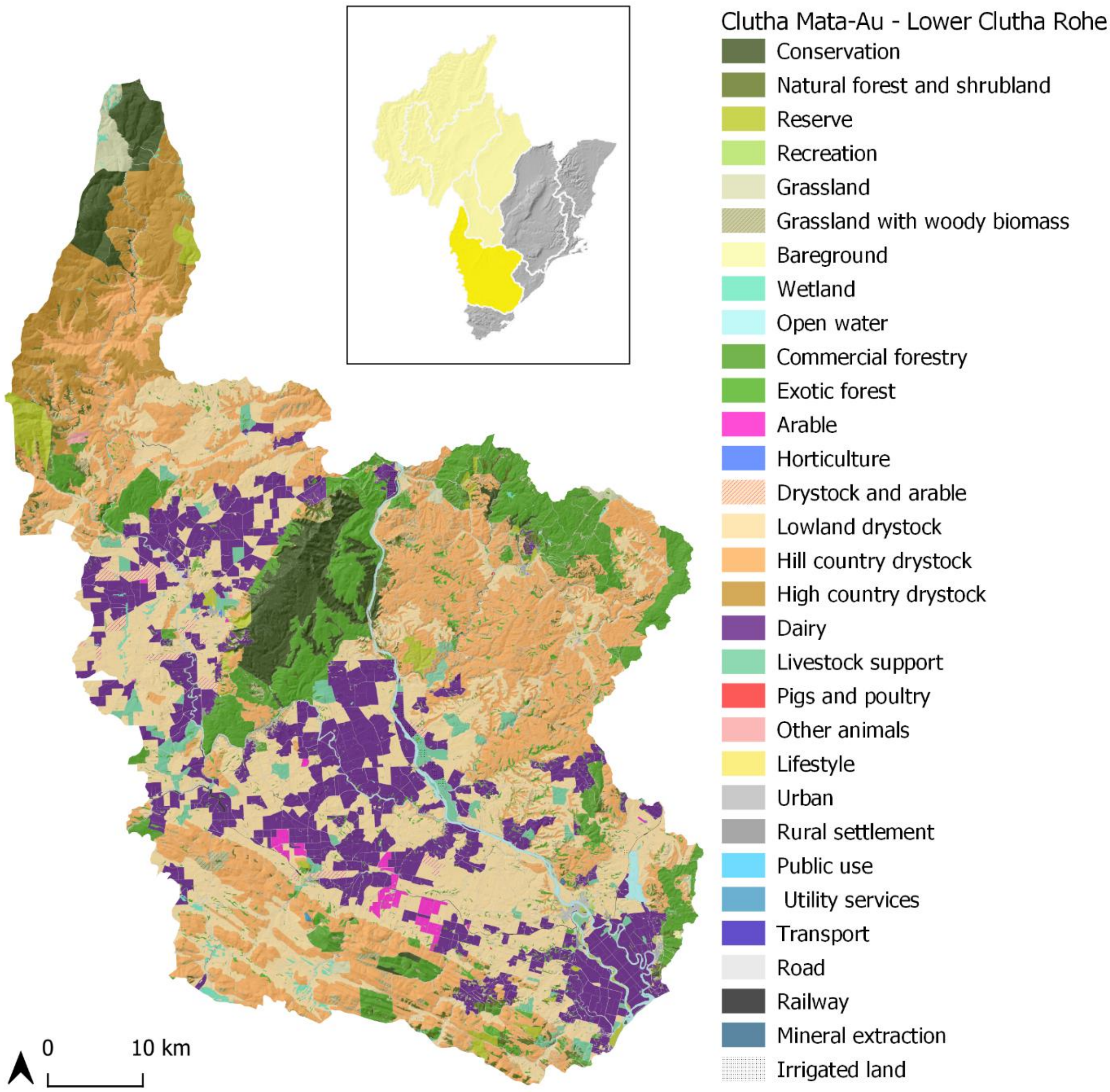

Figure 11. Land use and land cover of the Clutha Mata Au – Lower Clutha Rohe. Inset shows the Lower Clutha Rohe within the Clutha Mata-Au FMU extent.

Table 13. Land use land cover by area for the Lower Clutha Rohe and supporting biophysical data. Soil drainage is a score from 1- very poorly drained to 5- well drained.

Land use land cover class	Area (Ha)	Area percent (%)	Irrigated land (Ha)	Winter forage (Ha)	Average altitude (m.a.s.l)	Average slope (degrees)	Average rainfall (mm/year)	Average soil drainage class
Hill country drystock	97,951	24.28	-	2,921.4	222.0	10.9	858	3.3
Lowland drystock	97,624	24.20	34.1	6,254.4	144.6	5.5	864	3.0
Dairy	60,334	14.96	491.2	2,796.0	102.5	3.9	827	2.9
Commercial forestry	37,553	9.31	-	23.6	262.2	10.9	848	3.6
High country drystock	21,613	5.36	-	94.6	723.0	15.3	915	3.6
Conservation	21,027	5.21	-	0.0	312.8	9.7	854	3.3
Grassland with woody biomass	11,577	2.87	0.3	39.7	192.0	10.8	853	3.2
Exotic forest	9,026	2.24	1.3	13.0	182.4	10.0	853	3.2
Road	8,305	2.06	3.9	78.9	147.4	4.8	846	3.0
Livestock support	8,132	2.02	187.9	794.2	120.8	6.5	832	3.0
Natural forest and shrubland	7,091	1.76	-	1.6	297.5	15.6	867	3.6
Reserve	6,260	1.55	-	33.6	246.5	9.5	850	3.2
Open water	4,455	1.10	0.9	8.1	131.4	3.8	862	3.0
Grassland	3,036	0.75	-	62.6	240.1	7.3	836	3.2
Drystock and arable	2,867	0.71	-	288.7	118.4	2.3	867	2.7
Arable	2,288	0.57	-	205.0	98.3	2.9	903	2.6
Wetland	1,542	0.38	-	1.1	250.6	3.2	940	2.8
Lifestyle	844	0.21	0.1	4.5	94.6	4.2	813	2.8
Rural settlement	486	0.12	-	0.0	101.2	3.1	822	2.1
Railway	325	0.08	0.1	4.5	74.1	1.8	871	2.8
Other animals	276	0.07	-	0.5	327.0	7.6	866	3.6
Urban	240	0.06	-	-	28.9	3.2	766	0.7
Recreation	162	0.04	-	0.0	56.0	2.9	790	2.2
Bareground	137	0.03	-	5.6	89.9	4.9	804	2.7
Utility services	67	0.02	-	-	137.3	5.7	845	3.0
Public use	47	0.01	0.0	0.0	102.8	2.2	827	2.2
Mineral extraction	44	0.01	-	-	60.1	8.7	783	2.8
Horticulture	27	0.01	-	-	138.2	3.6	835	2.6
Pigs and poultry	13	0.00	-	-	93.1	3.3	783	2.4
Transport	11	0.00	-	-	87.3	5.0	801	2.3
Lower Clutha Rohe	403,360	100	719.9	13,631.7	174.1	7.1	847.4	3.0

7.1.2 North Otago Freshwater Management Unit

The North Otago Freshwater Management Unit has an area of 254,007 ha. The average altitude is 132 meters above sea level with undulating to rolling terrain and an average slope of 7.2 degrees (Table 14). Rainfall is low averaging 627 mm annually (Ministry for the Environment & Stats NZ, 2017).

The predominant land use in the North Otago FMU is hill country drystock (27% or 67,758 ha), lowland drystock (17% or 43,298 ha) and high country drystock (10.3% or 26,188). Dairy is also a significant land use with 13% land area (34,070 ha) (Figure 12, Table 13). Commercial forestry is undertaken on 17,993 ha with a further 5,830 ha of exotic forest on other land uses. This FMU also has a high proportion of the regions arable land (4,400 ha) and pigs and poultry (1,224 ha). A total of 45,362 ha has been identified as irrigated, with the majority occurring on dairy and lowland drystock. The main urban area in the FMU is Oamaru. Part of the Macraes gold mine is also in this FMU.

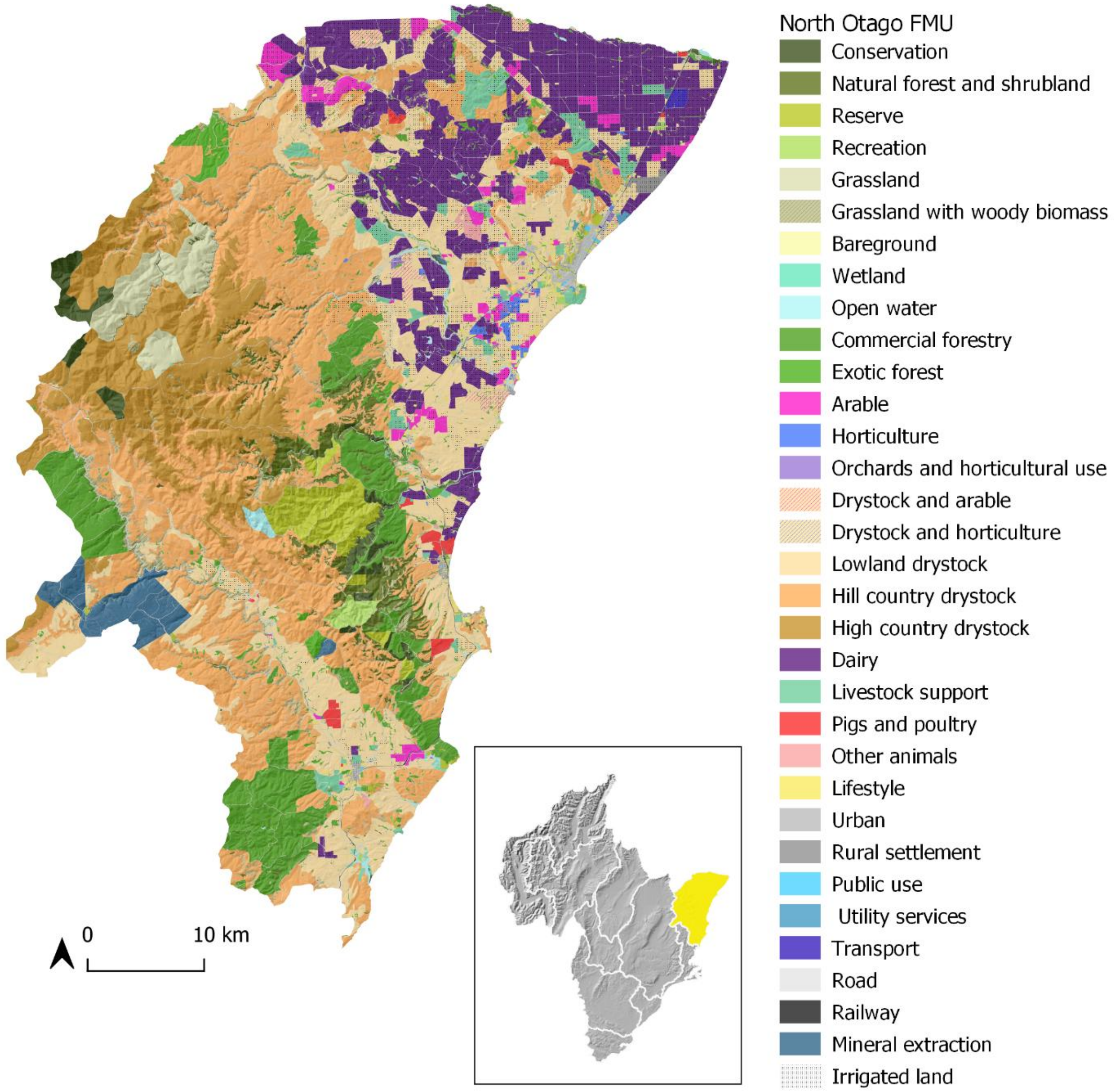

Figure 12. Land use and land cover of the North Otago Freshwater Management Unit. Inset shows the extent of the North Otago FMU within the Otago Region.

Table 14. Land use land cover by area for the North Otago Freshwater Management Unit and supporting biophysical data. Soil drainage is a score from 1- very poorly drained to 5- well drained.

Land use land cover class	Area (Ha)	Area percent (%)	Irrigated land (Ha)	Winter forage (Ha)	Average altitude (m.a.s.l)	Average slope (degrees)	Average rainfall (mm/year)	Average soil drainage class
Hill country drystock	67,758	26.68	2,221.0	1,537.3	226.5	11.0	667	3.3
Lowland drystock	43,298	17.05	8,707.8	3,020.3	109.9	5.1	620	3.3
Dairy	34,070	13.41	27,286.3	1,804.2	98.8	4.4	577	3.2
High country drystock	26,188	10.31	-	1.9	723.1	16.5	844	3.6
Commercial forestry	17,993	7.08	6.9	2.4	187.2	12.0	650	3.3
Natural forest and shrubland	6,689	2.63	0.2	1.6	267.9	18.5	729	3.4
Grassland with woody biomass	6,205	2.44	125.3	4.9	201.0	12.7	666	3.5
Exotic forest	5,830	2.30	142.8	7.8	129.7	9.0	624	3.3
Grassland	5,518	2.17	19.4	5.7	270.1	10.1	704	3.5
Reserve	5,465	2.15	5.0	0.0	202.5	12.8	662	3.2
Livestock support	4,999	1.97	1,778.3	379.8	78.9	5.7	586	3.3
Road	4,678	1.84	254.5	26.5	120.1	5.5	620	3.1
Mineral extraction	4,531	1.78	1.9	27.4	412.2	10.6	668	3.4
Arable	4,400	1.73	2,011.0	614.8	100.9	4.0	587	3.1
Conservation	4,224	1.66	61.0	-	262.4	12.0	722	3.5
Lifestyle	2,192	0.86	126.4	6.5	59.9	4.6	593	3.1
Drystock and arable	2,076	0.82	1,119.3	285.9	109.5	4.3	588	3.2
Open water	1,863	0.73	84.4	8.6	110.2	6.7	660	3.4
Pigs and poultry	1,224	0.48	170.1	63.6	85.1	5.9	625	3.0
Recreation	934	0.37	44.7	0.0	135.1	8.9	625	3.1
Rural settlement	770	0.30	272.0	12.6	39.0	4.5	624	2.6
Urban	674	0.27	32.4	5.7	43.1	3.9	555	2.3
Horticulture	607	0.24	274.3	81.0	43.7	2.8	589	3.2
Other animals	437	0.17	173.4	41.5	64.0	4.2	590	3.0
Railway	301	0.12	13.2	2.6	30.6	3.2	612	3.0
Transport	262	0.10	219.7	0.0	22.3	2.7	564	3.0
Orchards and horticultural use	201	0.08	188.1	34.0	55.4	2.3	580	3.8
Wetland	180	0.07	2.6	3.2	57.1	2.9	618	2.6
Utility services	138	0.05	8.7	0.0	76.6	4.2	572	3.3
Bareground	123	0.05	3.4	0.9	78.5	7.3	599	3.9
Public use	115	0.05	1.2	-	49.8	3.1	587	2.4
Drystock and horticulture	66	0.03	6.3	3.3	90.8	5.7	569	3.5
North Otago FMU	254,007	100	45,362	7,984	132.0	7.2	627	3.1

7.1.3 Taiari Freshwater Management Unit

The Taiari Freshwater Management Unit has an area of 570,361 ha. The average altitude is 322 meters above sea level with typically undulating to rolling terrain and an average slope of 6.7 degrees (Table 15). Rainfall is low averaging 688 mm annually (Ministry for the Environment & Stats NZ, 2017).

The predominant land use in the Taiari FMU is lowland drystock (32% or 182,957 ha), high country drystock (23% or 133,820 ha) and hill country drystock (13.7% or 78,303). Dairy is also a significant land use in the upper Taiari and near the coast with 3% of the FMU land area (16,586 ha) (Figure 13, Table 15). Commercial forestry is undertaken on 28,070 ha with a further 5,780 ha of exotic forest on other land uses. Conservation is established on 40,539 ha (7% of the FMU). A total of 25,614 ha has been identified as irrigated, with the majority occurring on lowland drystock, dairy, and livestock support. The main urban area in the FMU is Mosgiel.

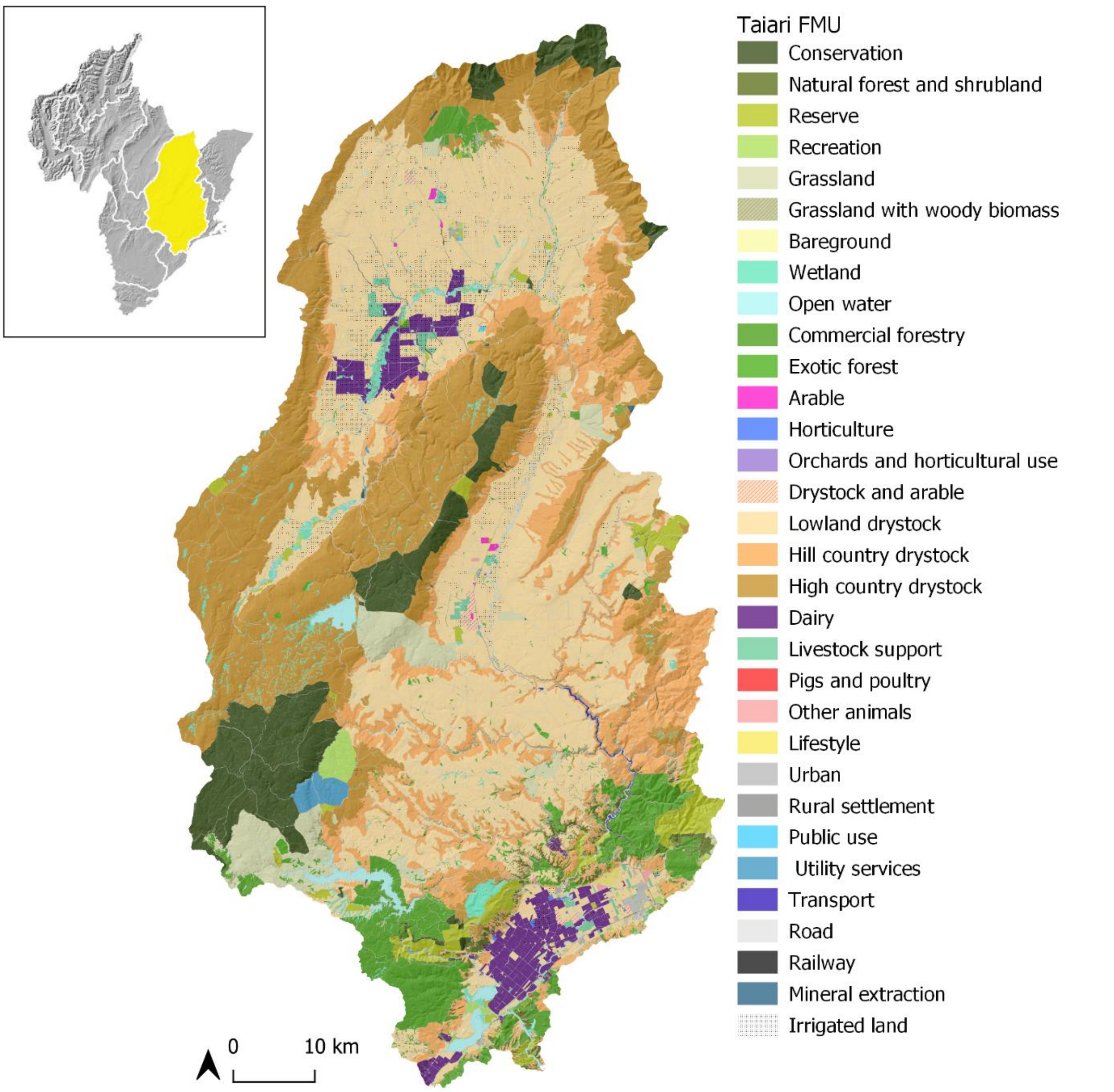

Figure 13. Land use and land cover of the Taiari Freshwater Management Unit. Inset shows the extent of the Taiari FMU within the Otago Region.

Table 15. Land use land cover by area for the Taiari Freshwater Management Unit and supporting biophysical data. Soil drainage is a score from 1- very poorly drained to 5- well drained.

Land use land cover class	Area (Ha)	Area percent (%)	Irrigated land (Ha)	Winter forage (Ha)	Average altitude (m.a.s.l)	Average slope (degrees)	Average rainfall (mm/year)	Average soil drainage class
Lowland drystock	182,957	32.08	18,116.3	8,180.4	359.0	5.0	626	3.2
High country drystock	133,820	23.46	121.2	285.0	715.7	8.9	685	3.4
Hill country drystock	78,303	13.73	213.5	801.1	341.8	11.0	680	3.3
Conservation	40,539	7.11	55.6	-	552.1	8.3	657	3.5
Commercial forestry	28,070	4.92	65.3	11.7	301.8	9.3	800	3.1
Grassland	18,351	3.22	47.0	255.0	463.4	7.7	646	3.5
Dairy	16,586	2.91	5,140.8	998.5	106.2	2.2	692	2.6
Reserve	14,733	2.58	100.5	16.6	402.5	10.9	719	3.2
Road	9,705	1.70	296.0	86.5	304.0	5.4	681	3.1
Open water	8,360	1.47	119.9	25.4	355.3	5.2	655	3.0
Wetland	7,392	1.30	83.1	2.4	581.6	4.1	666	2.9
Grassland with woody biomass	6,935	1.22	29.6	3.7	308.5	12.0	719	3.3
Exotic forest	5,780	1.01	8.8	2.9	328.1	8.5	712	3.2
Natural forest and shrubland	5,466	0.96	0.3	0.8	222.3	15.0	808	3.4
Recreation	2,713	0.48	28.6	0.5	244.0	5.8	763	3.0
Livestock support	2,404	0.42	805.4	182.2	199.9	4.0	647	3.0
Utility services	2,350	0.41	2.1	0.5	397.9	7.5	678	3.0
Lifestyle	1,562	0.27	13.7	5.4	131.5	4.3	722	2.7
Drystock and arable	1,024	0.18	157.2	126.0	142.3	1.2	645	2.7
Urban	647	0.11	0.0	0.0	23.8	1.9	776	1.5
Transport	564	0.10	1.5	0.1	131.4	16.0	721	3.1
Other animals	434	0.08	-	4.7	181.2	5.4	716	3.1
Rural settlement	402	0.07	13.0	0.3	237.3	3.2	649	3.3
Bareground	396	0.07	119.7	30.5	472.2	4.9	629	3.4
Arable	337	0.06	1.2	29.7	245.5	1.2	577	3.4
Horticulture	156	0.03	39.5	23.7	47.1	1.8	734	2.4
Public use	146	0.03	27.0	2.8	229.6	3.0	641	2.7
Railway	117	0.02	-	0.3	21.4	2.8	772	2.2
Mineral extraction	69	0.01	-	-	215.9	12.6	718	3.4
Pigs and poultry	34	0.01	-	-	18.8	4.1	776	2.3
Orchards and horticultural use	9	0.00	7.4	-	11.5	1.1	741	2.7
Taiari FMU	70,361	100	25,614	11,077	322.2	6.7	688	3.0

7.1.4 Dunedin and Coast Freshwater Management Unit

The Dunedin and Coast Freshwater Management Unit has an area of 155,521 ha. The average altitude is 106 meters above sea level with typically undulating to rolling terrain and an average slope of 8.3 degrees (Table 16). Rainfall is moderately low relative to other FMU or rohe in the Otago region averaging 861 mm annually (Ministry for the Environment & Stats NZ, 2017).

The predominant land use in the Dunedin and Coast FMU is hill country drystock (27% or 42,415ha), followed by commercial forestry (21% or 33,217 ha) with an additional 4,006 ha of exotic forest on other land uses. On the lowlands, Lowland drystock adds additional 17,023 ha (11% of FMU) of grazed land. 5.5% of the FMU is used for dairy (8,519 ha) (Figure 14, Table 16). Irrigated land is minor with 250 ha mapped predominantly on dairy. The major urban area of Dunedin City is in this FMU.

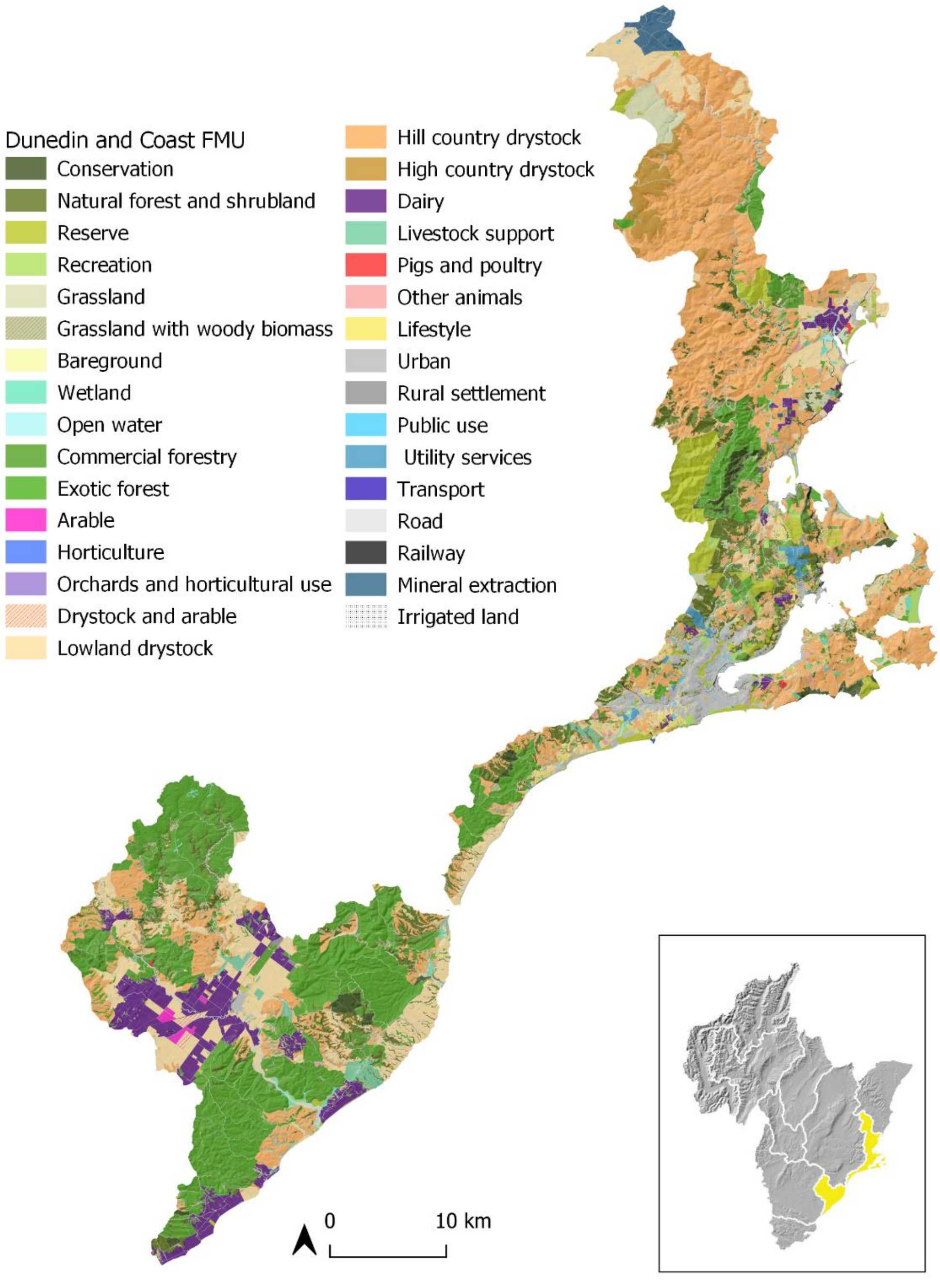

Figure 14. Land use and land cover of the Taiari Freshwater Management Unit. Inset shows the extent of the Taiari FMU within the Otago Region.

Table 16. Land use land cover by area for the Dunedin and Coast Freshwater Management Unit and supporting biophysical data. Soil drainage is a score from 1- very poorly drained to 5- well drained.

Land use land cover class	Area (Ha)	Area percent (%)	Irrigated land (Ha)	Winter forage (Ha)	Average altitude (m.a.s.l)	Average slope (degrees)	Average rainfall (mm/year)	Average soil drainage class
Hill country drystock	42,415	27.27	21.8	450.3	166.3	11.3	810	3.2
Commercial forestry	33,217	21.36	-	30.8	181.8	9.9	812	3.2
Lowland drystock	17,023	10.95	3.4	595.4	125.4	6.6	774	3.1
Natural forest and shrubland	12,135	7.80	0.1	0.7	170.8	14.2	883	3.2
Dairy	8,519	5.48	197.1	336.7	87.6	7.0	799	3.2
Reserve	6,666	4.29	-	0.0	161.8	9.7	842	3.3
Grassland with woody biomass	6,179	3.97	2.9	3.3	143.3	11.7	825	3.3
Road	4,966	3.19	0.4	15.6	113.3	7.6	849	3.0
Exotic forest	4,006	2.58	2.3	1.8	149.4	10.9	820	3.3
Urban	3,513	2.26	16.8	-	74.7	6.6	908	2.8
High country drystock	2,342	1.51	-	1.3	640.8	7.5	664	2.9
Grassland	2,300	1.48	0.6	2.6	146.6	10.3	830	3.1
Conservation	2,154	1.38	2.3	-	128.6	12.5	805	3.4
Lifestyle	2,120	1.36	0.1	0.5	100.1	8.1	848	3.2
Mineral extraction	1,251	0.80	-	0.0	494.0	5.7	675	3.1
Livestock support	1,240	0.80	-	30.4	107.6	9.0	806	3.0
Recreation	1,020	0.66	-	-	102.4	9.2	900	3.1
Open water	898	0.58	0.2	0.3	33.3	8.9	786	3.0
Utility services	726	0.47	1.0	-	165.9	8.3	905	3.0
Wetland	615	0.40	-	0.1	90.4	5.2	773	2.8
Rural settlement	416	0.27	-	0.6	36.6	5.9	763	3.5
Other animals	392	0.25	-	0.1	136.4	10.3	828	3.1
Drystock and arable	320	0.21	-	5.6	36.1	3.6	829	3.2
Railway	284	0.18	-	0.3	44.2	9.3	784	2.9
Arable	279	0.18	-	5.0	19.2	2.1	768	3.0
Public use	233	0.15	-	0.8	70.6	4.5	897	2.9
Bareground	127	0.08	-	3.2	81.6	8.1	813	3.3
Pigs and poultry	98	0.06	-	-	90.3	9.7	806	3.4
Horticulture	38	0.02	-	-	91.0	7.0	860	3.2
Transport	24	0.02	-	-	22.6	3.5	904	1.1
Orchards and horticultural use	3	0.00	-	-	26.4	2.5	812	3.1
Dunedin and Coast	55,521	100	249.0	1,485	105.8	8.3	861	3.0

7.1.5 Catlins Freshwater Management Unit

The Catlins is the smallest of the Freshwater Management Units with an area of 108,245 ha. The average altitude is 109 meters above sea level with undulating to rolling terrain and an average slope of 8.5 degrees (Table 17). Rainfall is moderate with 1,155 mm annually (Ministry for the Environment & Stats NZ, 2017).

The predominant land use in the Catlins Freshwater Management Unit is Conservation (32,479 ha or 30 %) (Figure 15, Table 17). Hill country and lowland drystock are the main agricultural land use (25,546 ha and 17,580 ha respectively). Dairy is also undertaken in the lowland with a total area of 4,071 ha (3.8 % of the FMU). Commercial forestry is undertaken on 6,224 ha with a further 1,164 ha of exotic forest on other land uses. Irrigated land is minimal. The main settlement is Owaka.

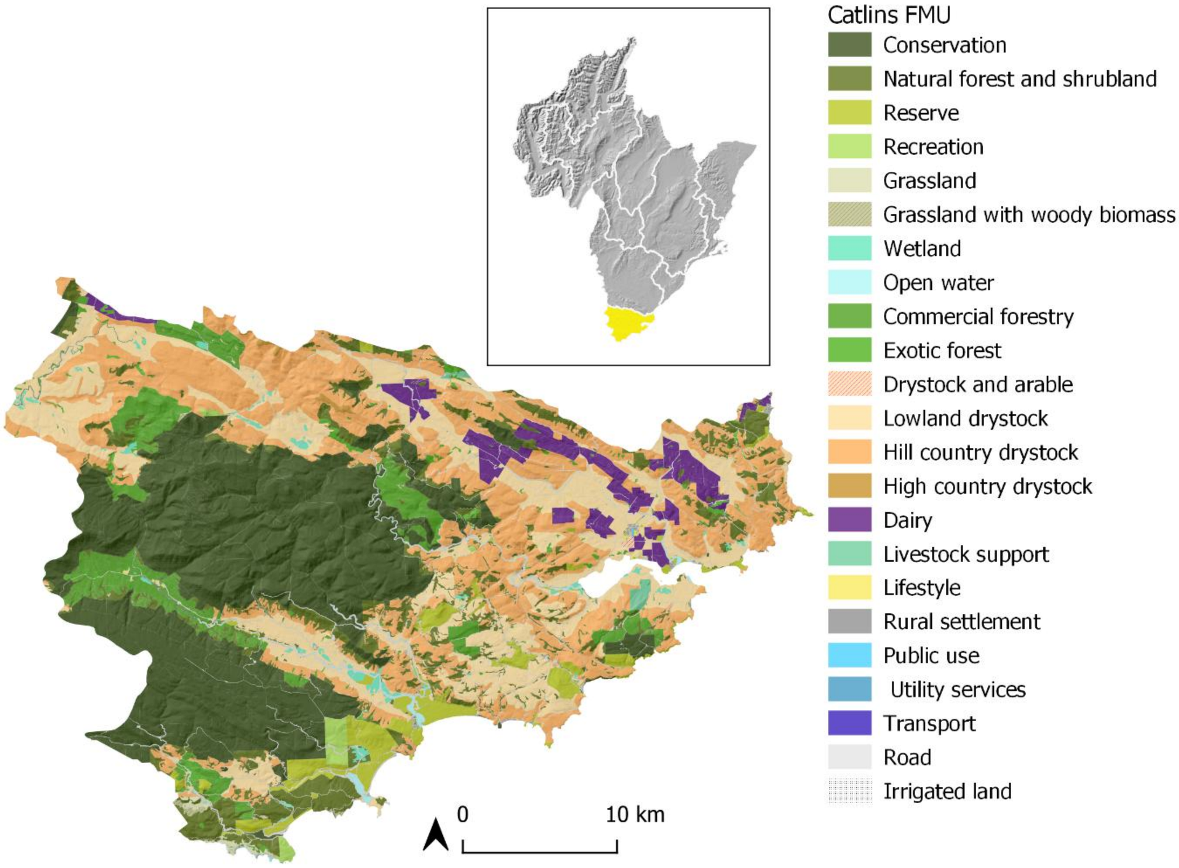

Figure 15. Land use and land cover of the Catlins Freshwater Management Unit. Inset shows the extent of the Catlins FMU within the Otago Region.

Table 17. Land use land cover by area for the Catlins Freshwater Management Unit and supporting biophysical data. Soil drainage is a score from 1- very poorly drained to 5- well drained.

Land use land cover class	Area (Ha)	Area percent (%)	Irrigated land (Ha)	Winter forage (Ha)	Average altitude (m.a.s.l)	Average slope (degrees)	Average rainfall (mm/year)	Average soil drainage class
Conservation	32,479	30.00	-	-	205.4	10.2	1,311.5	3.4
Hill country drystock	25,546	23.60	-	604.4	166.1	11.7	1,132.5	3.6
Lowland drystock	17,580	16.24	7.3	750.7	104.4	6.4	1,151.4	3.2
Natural forest and shrubland	10,720	9.90	-	1.8	153.9	10.7	1,214.6	3.4
Commercial forestry	6,224	5.75	-	-	152.4	8.3	1,383.7	2.7
Reserve	4,297	3.97	-	-	59.0	9.1	1,096.4	3.0
Dairy	4,071	3.76	-	111.3	99.2	8.5	994.9	3.1
Road	2,898	2.68	-	11.3	74.1	6.7	1,139.6	3.0
Exotic forest	1,164	1.08	-	0.2	155.7	9.1	1,188.9	3.3
Wetland	729	0.67	-	0.2	90.0	3.3	1,252.4	3.3
Recreation	621	0.57	-	-	134.7	10.4	1,265.0	3.4
Open water	594	0.55	-	0.4	30.3	9.1	1,101.9	2.3
Grassland	366	0.34	-	-	129.5	8.6	1,224.5	2.9
Livestock support	243	0.22	-	-	150.1	9.9	1,037.6	3.4
Grassland with woody biomass	185	0.17	-	-	182.4	10.8	1,264.4	3.4
High country drystock	175	0.16	-	-	600.3	19.4	1,302.9	4.9
Lifestyle	158	0.15	-	0.4	30.9	4.7	1,005.9	2.4
Rural settlement	117	0.11	1.8	0.2	19.0	3.4	946.6	2.0
Drystock and arable	44	0.04	-	0.1	21.4	1.9	920.0	1.3
Bare ground	20	0.02	-	-	12.0	11.4	1,034.9	2.7
Public use	10	0.01	-	-	21.3	1.6	1,109.3	1.5
Utility services	3.3	0.00	-	-	15.2	2.7	889.3	1.7
Transport	0.5	0.00	-	-	15.5	1.9	915.8	2.0
Settlements or built-up area	0.1	0.00	-	-	4.3	7.1	804.0	-
Catlins FMU	108,245	100	9.1	1,480.8	109	8.5	1,155	3.1

7.2 Technical Land Use Metadata

Layer Names: TLUM Upper Lakes 2024
TLUM Dunstan 2024
TLUM Manuherekia 2024
TLUM Roxburgh 2024
TLUM Lower Clutha 2024
TLUM North Otago 2024
TLUM Taiari 2024
TLUM Dunedin and Coast 2024
TLUM Catlins 2024

Feature Layer Type: Vector (polygon)

Geographical Extent: Otago Region split into the 9 freshwater management units and rohe

Coordinate System: New Zealand Transverse Mercator 2000 (NZTM2000)

Purpose: To spatially depict land use and land cover supported by biophysical and land management data to inform land use impacts on water quality.

Resource Reference Date: 16.01.2025

Edition: version 1

Access Constraints: None

Use Constraints: None

Data Set Credit: Otago Base Land Use Map, LUCAS Land Use Map 2020 (version 3), Protected Areas, Land and Water Science, Ministry for the Environment, Aqualink, Manaaki Whenua Landcare Research, Sentinel Satellite 2019-2024.

Attribute Details:

Attribute table description of fields and data sources for Otago Technical Land Use Map. The date represents the date the land use source information is accurate to.

Attribute field	Name	Description	Source	Date
TLUM_UID	UID (join field)	Polygon Identification number for the Technical Land Use Map for each FMU or rohe	Pearson EC	
Poly_ID	Polygon ID Base Map	Polygon Identification number for the Base Land Use Map	Base LUM	2024
LULC Class	Land use Land cover class	Combination of land use and land cover (symbolise for TLUM)	Pearson EC	2020-2024
Land Use	Primary land use	Current land use from base map	Base LUM	2020-2024
Subclass	Primary land use subclass	Provides more detail for primary land use class	Base LUM	2020-2024
Secondary	Secondary land use	Secondary land use from base map	Base LUM	2020-2024
Sec Subcla	Secondary land use subclass	Subclass of secondary land use	Base LUM	2020-2024
Data Sourc	Data source	Identifies data source/s used to identify base land use	Base LUM	2020-2024
LC_medium	Land cover medium class	Medium LUCAS land cover class (see Table 2)	LUCAS2020	2020
LC_basic	Land cover basic class	Basic LUCAS land cover class (see Table 2)	LUCAS2020	2020
Parcel_m2	Area meters squared	Area of Base Land Use Map parcel in square meters	Base LUM	2020-2024

Attribute field	Name	Description	Source	Date
Parcel_Ha	Area hectares	Area of Base Land Use Map parcel in hectares	Base LUM	2020-2024
Poly_m2	Area meters squared	Area of the polygon (land use land cover class) in square meters	Pearson EC	
Poly_Ha	Area hectares	Area of the polygon (land use land cover class) in hectares	Pearson EC	
3Darea_m2	3D Area m2	Real surface area of the polygon (land use land cover class) in square meters	Pearson EC	
3D_ha	3D Area hectares	Real surface area of the polygon (land use land cover class) in hectares	Pearson EC	
Name	Name	FMU or rohe simple name	ORC	2024
FMULabel	FMU Label	FMU or rohe name	ORC	2024
LS_Class	Landscape Class	Generalised classification of lowland (<600 masl, <8 degrees), hill country (<600 masl, >8 degrees), and high country (>600 masl, mixed slopes)	NZLRI/DEM	2020-2024
ORC_Hort	ORC Horticulture	Specifies horticulture or viticulture	ORC/Pearson EC	2022
Hort_m2	Horticulture area m2	Horticulture area in square meters	ORC/Pearson EC	2022
Hort_Ha	Horticulture area Ha	Horticulture area in hectares	ORC/Pearson EC	2022
Irrig_Ha	Irrigation Area Ha	Area of irrigation in 2023 in hectares	Aqualink	2023
WF2023_Ha	Winter forage 2023	Area of winter forage in 2023 in hectares	Manaaki Whenua	2023
ConWG_Ha	Consented Winter Grazing hectares	Area of consented winter grazing in hectares	ORC	2023
NIRv19S_me	NIRv 2019 Summer	Average Near Infra-Red Vegetation index summer 2019	Sentinel/Pearson EC	2019
NIRv19W_me	NIRv 2019 Winter	Average Near Infra-Red Vegetation index winter 2019	Sentinel/Pearson EC	2019
NIRv20S_me	NIRv 2020 Summer	Average Near Infra-Red Vegetation index summer 2020	Sentinel/Pearson EC	2020
NIRv20W_me	NIRv 2020 Winter	Average Near Infra-Red Vegetation index winter 2020	Sentinel/Pearson EC	2020
NIRv21S_me	NIRv 2021 Summer	Average Near Infra-Red Vegetation index summer 2021	Sentinel/Pearson EC	2021
NIRv21W_me	NIRv 2021 Winter	Average Near Infra-Red Vegetation index winter 2021	Sentinel/Pearson EC	2021
NIRv22S_me	NIRv 2022 Summer	Average Near Infra-Red Vegetation index summer 2022	Sentinel/Pearson EC	2022
NIRv22W_me	NIRv 2022 Winter	Average Near Infra-Red Vegetation index winter 2022	Sentinel/Pearson EC	2022
NIRv23S_me	NIRv 2023 Summer	Average Near Infra-Red Vegetation index summer 2023	Sentinel/Pearson EC	2023
NIRv23W_me	NIRv 2023 Winter	Average Near Infra-Red Vegetation index winter 2023	Sentinel/Pearson EC	2023
NIRv24S_me	NIRv 2024 Summer	Average Near Infra-Red Vegetation index summer 2024	Sentinel/Pearson EC	2024
Alt_mean	Altitude mean	Average altitude in meters above sea level	LWS DEM	
Slope_mean	Slope mean	Average slope in degrees	LWS DEM	
Rainfall_m	Rainfall mean	Average rainfall in millimetres	MfE/Stats NZ	1972-2016
SoilDrain_	Soil Drainage mean	Average soil drainage with 1 - very poorly drained and 5 - well drained	LWS	2018
PEFAM_0	PENZ No Data	PENZ No Data	LWS	2021
PEFAM_1	PENZ Family 1	Alpine (area in hectares)	LWS	2021
PEFAM_2	PENZ Family 2	Strong bedrock	LWS	2021
PEFAM_3	PENZ Family 3	Weak bedrock	LWS	2021

Attribute field	Name	Description	Source	Date
PEFAM_4	PENZ Family 4	Oxidising soil & aquifer	LWS	2021
PEFAM_5	PENZ Family 5	Reducing soil & oxidising aquifer	LWS	2021
PEFAM_10	PENZ Family 10	Urban	LWS	2021
PESIB_10	PENZ Sibling 10	Alpine	LWS	2021
PESIB_21	PENZ Sibling 21	Strong Bedrock - Subalpine	LWS	2021
PESIB_22	PENZ Sibling 22	Strong Bedrock - Hill	LWS	2021
PESIB_31	PENZ Sibling 31	Weak Bedrock - Subalpine	LWS	2021
PESIB_32	PENZ Sibling 32	Weak Bedrock - Hill	LWS	2021
PESIB_41	PENZ Sibling 41	Oxidising soil & aquifer - High deep drainage	LWS	2021
PESIB_42	PENZ Sibling 42	Oxidising soil & aquifer - Increased lateral & overland flow	LWS	2021
PESIB_43	PENZ Sibling 43	Oxidising soil & aquifer - Strong bedrock	LWS	2021
PESIB_44	PENZ Sibling 44	Oxidising soil & aquifer - Weak bedrock	LWS	2021
PESIB_51	PENZ Sibling 51	Reducing soil & oxidising aquifer - High soil reduction	LWS	2021
PESIB_52	PENZ Sibling 52	Reducing soil & oxidising aquifer - Moderate soil reduction	LWS	2021
PESIB_53	PENZ Sibling 53	Reducing soil & oxidising aquifer - Strong bedrock	LWS	2021
PESIB_54	PENZ Sibling 54	Reducing soil & oxidising aquifer - Weak bedrock	LWS	2021
PESIB_100	PENZ Sibling 100	Urban	LWS	2021

Overlays: Irrigated land, intensive winter forage, and consented winter grazing areas. See Appendix A for layer symbolisation.

8 Summary and Recommendations

8.1 Base Land Use Map

The Otago Land Use Map is produced at property scale according to the regional council's valuation boundaries supplemented with LINZ primary parcels for complete regional coverage. A hierarchy of data sources is used to classify land use with council data superior to Agribase or national scale publicly available data. Land use is assigned at the property scale by primary class, subclass, and secondary land use (if required). National land use and land cover sourced from LUCAS2020v3 provides additional attribute data for the property by calculating area of use or land cover class. It is recommended that the LUCAS land use classes are used as a guide only due to accuracy and minimal scale of 1ha (1,50,000 scale). The property scale land use map can be used to report number of properties undertaking a particular land use in conjunction with the land cover fields to estimate effective area or grazable land.

It is recommended that land use information is kept up-to-date when land use information is received for a property, such as through the valuation database, resource consent applications or farm environment plans. Recording of land use information does not have to be spatial and could be retained in a database associated with the property ID used for rating and land valuation. It is recommended to record the date the land use was verified, by who, and what method (site visit, consent application, farm plan etc.). This would then allow for land use information to be extracted, and maps produced annually or when required. Major updates to the map attributes should occur when new releases of LUCAS or LCDB are available to update the area of land use/cover on the property. A procedure to define classes, validate, and update the map should be developed internally to best align with the councils' databases and record keeping systems. Future updates should build on this existing information. There is also value in retaining the prior land uses for a property to support assessments of land use change.

As land use changes in the region or new data becomes available, the classification of land use needs to adapt to support this. This could mean the addition of new classes and subclasses. For example, subclasses to specify crop types within orchards and horticultural land uses. Grassland used for 'cut and carry' type feed supply is difficult to classify using the current data sources. This land use could be refined from direct sources, such as council staff visiting properties, farm plans, or resource consents. National reporting will also guide future needs for specific information to be derived from a land use database in various formats.

Validation should focus on identifying the land use properties with Agribase records older than 5 years or land cover classes that are not specific about the use. These classes include those classified as grassland, exotic forest, and bare ground. Grassland is currently any high producing grassland that is not grazed by livestock that has not been classified by other data sources.

Quality control of verification and recording of land use information needs to be undertaken. The manual editing of land use classes can introduce issues in GIS as it is case and text specific (e.g., Orchard, orchard, orchards, etc). It is recommended a set of defined classes and subclasses be used, possibly through a dropdown list, to avoid the introduction of duplicate classes for the same land use.

8.2 Technical Land Use Map

The technical land use map shows the spatial extent of land use (2020-2024) and land cover (2020) within a property. It does this by depicting the land cover not associated with the primary land use as the land use land cover class. For example, within pastoral grazing land uses, the primary land use is depicted on grazable land while ineffective areas of the farm such as exotic forest is displayed as exotic forest. On drystock properties, grazable pastoral land is shown by the landscape classes of lowland, hill and high country as opposed to the dominant landscape class that the property is classified as. Plantation Forestry is depicted by other land cover classes if not exotic forest.

The result is a more spatially refined depiction of both the land use and land cover information on the property. Included in the attribute table of the map is the area of irrigation (2023), annual grazed crop and pasture (2023), biophysical summary of altitude, slope, precipitation, and soil drainage, and the Physiographic Environments of New Zealand classification (Pearson and Rissmann, 2021). Overlays are used to support the spatial representation of land management, that may change from year to year. Medium land cover classes from LUCAS2020 are also included in the attribute table if more detailed land cover information is required, such as defining high and low producing grassland, and forest type or tree species.

One key use of the Technical Land Use Map is to assess intensity of land use. The intensity of land use is important to understand the impact the land use has on the environment, and the role the landscape plays in reducing contaminant losses. As the recording of farm specific data will improve over time, the Technical LUM provides a basis for initial assessments which can be supplemented and refined with actual property information over time. Near infra-red vegetation index (NIRv) calculated from Sentinel-2 satellite data can also be used to infer nitrogen uptake by vegetation providing a measure of gross primary production (Sharifi, 2020).

It is important to note that to create the Technical Land Use Map the most recent datasets available were collated. However, these range in date between 2020 to 2023. Spatial accuracy is also variable, with LUCAS land cover and Physiographic Environments at 1:50,000 scale. It is recommended that council use this data with caution until verification can be undertaken and follow the recommendations of the input datasets around appropriate use. Overall, the technical map provides a good spatial representation of land use, land cover, and landscape factors to support community engagement and Freshwater Management Unit scale analysis.

References

Kashima, A. (2023). Otago irrigated area spatial dataset: 2023 update. Aqualink memorandum prepared for Otago Regional Council RD23024. p5.

Harris L, Shepherd J, Pairman D, Belliss S, Martin B. (2023). Establishing New Zealand's LUCAS 2020 Land Use Map. Contract report prepared for the Ministry for the Environment by Landcare Research New Zealand Ltd. Lincoln: Manaaki Whenua Landcare Research New Zealand Ltd.

Lesslie, R. (2004). Land Use and Land Management Practices: Concepts, Terms and Classification Principles. Australian Department of Agriculture, Fisheries, and Forestry, Bureau of Rural Sciences, Canberra.

Manderson, A., Jolly, B., and Ausseil, AG. (2018). The NZ land Use Classifier. Manaaki Whenua Landcare Research Contract Report LC3335. p47.

Pearson, L. (2023). Marlborough Land Use Map: Metadata Report. Land and Water Science Report 2023/16. p36.

Pearson, L. (2024a). Technical Land Use Map for the Te Hoiere Pelorus Catchment. Land and Water Science Letter Report 2024/12. p31.

Pearson, L. (2024b). Land Use Mapping for the Tasman Region. Land and Water Science Report 2024/08. p97.

Sullivan, N. (2008). Rating Valuations Rules 2008. Land Information New Zealand LINZS30300. https://www.linz.govt.nz/sites/default/files/30300-Rating%2520Valuations%2520Rules%25202008-%2520version%2520date%25201%2520October%25202010%2520-%2520LINZS30300_0.pdf

Sanson, R. (2005). The Agribase™ farm location database. Proceedings of the New Zealand Society of Animal Production 65: 93–96

Camps-Valls, G., Campos-Taberner, M., Moreno-Martínez, Á., Walther, S., Duveiller, G., Cescatti, A., Mahecha, M.D., Muñoz-Marí, J., García-Haro, F.J., Guanter, L. and Jung, M. (2021). A unified vegetation index for quantifying the terrestrial biosphere. Science Advances, 7(9), p.eabc7447.

Chenzong, L., Jinru, X., Baofeng, S. (2017). Significant Remote Sensing Vegetation Indices: A Review of Developments and Applications, Journal of Sensors, 1687-725X.

Dark, A., Birendra, K., & Kashima, A. (2017). National Irrigated Land Spatial Dataset: Summary of methodology, assumptions and results. Ministry for the Environment, C17042-1. Aqualinc Research Limited.

Dark, A. (2020). National Irrigated Land Spatial Dataset: 2020 Update. Ministry for the Environment, RD21004-1. Aqualinc Research Limited.

Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice, and J. R. G. Townshend. (2013). High-Resolution Global Maps of 21st-Century Forest Cover Change. Science 342 (15 November): 850-53. Data available on-line from: https://glad.earthengine.app/view/global-forest-change.

Manaaki Whenua Landcare Research. (2019). LCDB v5.0 - Land Cover Database version 5.0, Mainland New Zealand. https://lris.scinfo.org.nz/layer/104400-lcdb-v50-land-cover-database-version-50-mainland-new-zealand/

Ministry for the Environment & Stats NZ (2017). New Zealand's Environmental Reporting Series: Our atmosphere and climate 2017. Retrieved from www.mfe.govt.nz and www.stats.govt.nz.

Pearson, L., & Couldrey, M. (2016). Methodology for GIS-based land use maps for Southland. Technical Report-Environment Southland Publication 2016-10, 167p.

Pearson, L. and Rissmann, C. (2021). Physiographic Environments of New Zealand: Inherent susceptibility of the landscape for contaminant loss. Land and Water Science Report 2021/25. p60.

Pearson, L. (2023). Marlborough Land Use Map: Metadata Report. Land and Water Science Report 2023/16. p36.

Sharifi, A. (2020). Using sentinel-2 data to predict nitrogen uptake in maize crop. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 13, 2656-2662.

Appendix A: Map Symbolisation

Base Map

Table A1. Layer style used for symbolisation of the Base Otago Land Use Map at primary level. Stroke style: solid line black 0.06 hairline. Hatch style: BDiagonal 0.66 width. Transparency: 70% over laying shade model.

Primary Land Use	Order	HTML Solid	R	G	B	HTML Hatch	R	G	B
Conservation	1	#233c00	35	60	0				
Natural forest and shrubland	2	#4c6300	76	99	0				
Reserve	3	#b2c205	178	194	5				
Recreation	4	#a6de47	166	222	71				
Grassland	5	#d7dca5	215	220	165				
Grassland with woody biomass	6	#b1b87d	117	184	125	#95630d	149	99	13
Bare ground	7	#f9f99d	249	249	157				
Wetland	8	#54e5b5	84	229	181				
Open water	9	#a7f6f6	164	246	246				
Commercial forestry	10	#389500	56	149	0				
Exotic forestry	11	#38a800	56	168	0				
Arable	12	#ff00c5	225	0	197				
Horticulture	13	#3168ff	49	104	225				
Drystock and arable	14	#ffdd94	225	221	148	#ff00c5	225	0	197
Drystock and horticulture	15	#ffdd94	225	221	148	#3168ff	49	104	225
Lowland drystock	16	#ffdd94	225	221	148				
Hill country drystock	17	#ffa545	255	165	69				
High country drystock	18	#c28411	194	132	17				
Dairy	19	#4d0074	77	0	116				
Livestock support	20	#6ce8a6	108	232	166				
Pigs and poultry	21	#fc1313	252	19	19				
Other animals	22	#fb9a99	251	154	153				
Lifestyle	23	#f9e84d	249	232	77				
Urban	24	#b2b2b2	178	178	178				
Rural settlement	25	#828282	130	130	130				
Public use	26	#31ccff	49	204	255				
Utility services	27	#2d8ebe	45	142	190				
Transport	28	#1f02b4	31	2	180				
Road	29	#e1e1e1	225	225	225				
Railway	30	#010000	1	0	0				
Mineral extraction	31	#15527b	21	82	123				

Technical Map

It is recommended that the Base Land Use Map Outline be used over the technical map to show property boundaries. Spatial location of irrigation, winter forage, and consented winter grazing should be used as a map overlay (Table A3).

Table A2. Layer style used for symbolisation of the Otago Technical Land Use Map. Stroke style: none.

Land Use Land Cover (LULC)	Order	HTML Solid	R	G	B	HTML Hatch	R	G	B
Conservation	1	#233c00	35	60	0				
Natural forest and shrubland	2	#4c6300	76	99	0				
Reserve	3	#b2c205	178	194	5				
Recreation	4	#a6de47	166	222	71				
Grassland	5	#d7dca5	215	220	165				
Grassland with woody biomass	6	#b1b87d	117	184	125	#95630d	149	99	13
Bare ground	7	#f9f99d	249	249	157				
Wetland	8	#54e5b5	84	229	181				
Open water	9	#a7f6f6	164	246	246				
Commercial forestry	10	#389500	56	149	0				
Exotic forestry	11	#38a800	56	168	0				
Arable	12	#ff00c5	225	0	197				
Horticulture	13	#3168ff	49	104	225				
Orchards and horticultural use	14	#916acf	145	106	207				
Viticulture	15	#be4197	190	65	151				
Drystock and arable	16	#ffdd94	225	221	148	#ff00c5	225	0	197
Drystock and horticulture	17	#ffdd94	225	221	148	#3168ff	49	104	225
Lowland drystock	18	#ffdd94	225	221	148				
Hill country drystock	19	#ffa545	255	165	69				
High country drystock	20	#c28411	194	132	17				
Dairy	21	#4d0074	77	0	116				
Livestock support	22	#6ce8a6	108	232	166				
Pigs and poultry	23	#fc1313	252	19	19				
Other animals	24	#fb9a99	251	154	153				
Lifestyle	25	#f9e84d	249	232	77				
Urban	26	#b2b2b2	178	178	178				
Rural settlement	27	#828282	130	130	130				
Public use	28	#31ccff	49	204	255				
Utility services	29	#2d8ebe	45	142	190				
Transport	30	#1f02b4	31	2	180				
Road	31	#e1e1e1	225	225	225				
Railway	32	#010000	1	0	0				
Mineral extraction	33	#15527b	21	82	123				

Table A3. Land management overlay.

	Pattern Fill	Size	Spacing	Offset
Irrigated Land	Point	0.1	1.2	1.2
Consented winter grazing area	Cross hatch	0.06	1.5	0
	HTML Solid	R	G	B
Winter forage area	#2b331c	43	51	28