Environment Canterbury Regional Council
Kaunihera Taiao ki Waitaha

TECHNICAL REPORT Science Group

Land use and root zone nitrogen loss modelling - Orari-Temuka-Opihi-Pareora Limit Setting Process

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Summary

Background

Environment Canterbury is working with the Orari-Temuka-Opihi-Pareora Zone Committee and local communities to set nitrogen limits for catchments within the zone. The limits are one of the means for managing water quality and ecosystem in the OTOP zone.

The problem

To help inform the impacts of land use, and land use change, on the range of cultural, social, economic and environmental values, we need to connect land use activities and catchment nutrient losses. For nitrogen, we commonly estimate this using a modelling approach.

What we did

This report describes the modelling methods we used to map the land use and the associated nitrogen losses in Orari-Temuka-Opihi-Pareora zone. The estimated losses quantify how much nitrogen is lost from the root zone in an average year, which are the loads, and the average concentrations of nitrogen in the water emanating from the soil root zone. We used spatial modelling tools to predict these losses.

We have described the land use in c.2016 by bringing together different sources of information. In modelling the diffuse nitrogen losses, we assumed that the average losses are dependent on land use, land cover, soil, and climate. We also assumed that at the scale of catchments, we can reduce the complex variation in factors that influence the nitrogen losses, such as land uses and natural processes, by mapping them into simple sets of land use, soil and climate types. The values we used to map losses from the agricultural enterprises are sourced from OVERSEER nutrient budget models, version 6.2.2. We extended the modelled base land use to picture hypothetical planning scenarios in terms of the relative changes to the nitrogen losses.

What we found

We have produced layers that estimate how land use impacts upon the average long-term losses of nitrate-nitrogen from the root zone. These have been used in setting nutrient limits for the OTOP zone.

Table of contents

Summary i

1 Introduction 1

2 Methods 3

2.1 Data sources 3

2.2 Creation of the spatial land use layer 4

2.3 Populating land use map with nutrient losses 8
2.3.1 Climate 10
2.3.2 Soil 10
2.3.3 Irrigated land 10
2.3.4 Nutrient losses 12

2.4 Scenario modelling 12
2.4.1 Permitted activity status 12
2.4.2 Current land use practices 13
2.4.3 Permitted activity development 13
2.4.4 Nitrogen hotspot reductions 14

3 Uncertainty 15

4 Summary 16

5 Acknowledgements 17

6 References 17

List of Figures

Figure 1-1: The Orari, Temuka, Opihi and Pareora zone and the featured freshwater management units 2
Figure 2-2: Modelled dominant farm types across the OTOP zone 7
Figure 2-3: Composite map of dominant farm types and land covers applied in nutrient loss modelling. 9
Figure 2-4: Average nitrogen loss rate lost from the root zone modelled for the base land use map and assuming good management practices 11

List of Tables

Table 2-1: Data sources used in modelling the farm type and nutrient losses........ 3
Table 2-2: Area of dominant farm types in the derived base land use layer by the Freshwater Management Units proposed in the Orari-Temuka-Opihi-Pareora water zone 6
Table 2-3: Count of modelled farms by farm size and dominant land use type within the Orari-Temuka-Opihi-Pareora water zone in the base land use layer........ 6
Table 2-4: Area breakdown of simple land cover classes used in nutrient loss modelling for a subset of farm types in the derived base land use layer by the Freshwater Management Units (FMUs) proposed in the Orari-Temuka-Opihi-Pareora Limit zone 8
Table 2-5: 2016 Irrigation type by area within the different freshwater management units 10
Table 2-6: Summary of 2016 winter forage brassica areas by property. 13
Table 2-7: Farm-type based reductions applied to nitrogen loads in the three nitrogen hotspot zones, expressed as factors........ 14
Table 4-1: Catchment sums of root zone nitrogen loads for the three scenarios modelled in support of Orari-Temuka-Opihi-Pareora limit setting process, broken down across modelled Land and Water Plan activity statuses 16

1 Introduction

I have documented the data inputs, stages, and assumptions applied in producing spatial estimates of land use and root zone nitrogen losses for Orari, Temuka, Opihi and Pareora water zone (Figure 1-1). The layers and any derived products have been used in supporting the zone committee in its decision making. In their overview of the technical work supporting the process, Robson-Williams & Clark (2019) set the context and illustrate how the output data layers fit in the scope of the limit setting process.

I used a modelling approach to first map the dominant land uses and then processed those data to estimate root zone nitrogen losses. The nitrogen refers to NO_3-N, nitrate-nitrogen.

I combined several data sources to model the boundaries and the dominant land use of rural enterprises. The resulting map can be joined to non-spatial dataset of nitrogen and water fluxes. The join and retrieval of data from the dataset is achieved by overlaying the land use map with soil, climate, land cover, and irrigation maps. The approach of combining a number of spatial data sources and using a look-up table of nutrient fluxes is similar to the method followed in other Canterbury limit-setting processes (Lilburne, 2015; Mojsilovic *et al.,* 2015).

The modelling can be reduced to three components:

- modelling land use as a layer at a snapshot in time. I used data available in 2016 to establish the base land use layer and base nutrient losses.
- estimating the nutrient loss rates and drainage at good management practices associated with the modelled land use layer. I used the catchment matrix produced by the Matrix of Good Management (MGM) project for characterising losses under arable, dairy, and sheep, beef & deer farms (Robson *et al.,* 2015).
- altering the modelled base land use and nutrient losses to simulate additional scenarios, main ones being permitted activity development and losses at current management practices.

To show the modelling processes, the report contains a selection of land use and nutrient loss data. I used the freshwater management units (FMUs) incorporated in the water zone, shown in Figure 1-1, to breakdown and summarise the output layers.

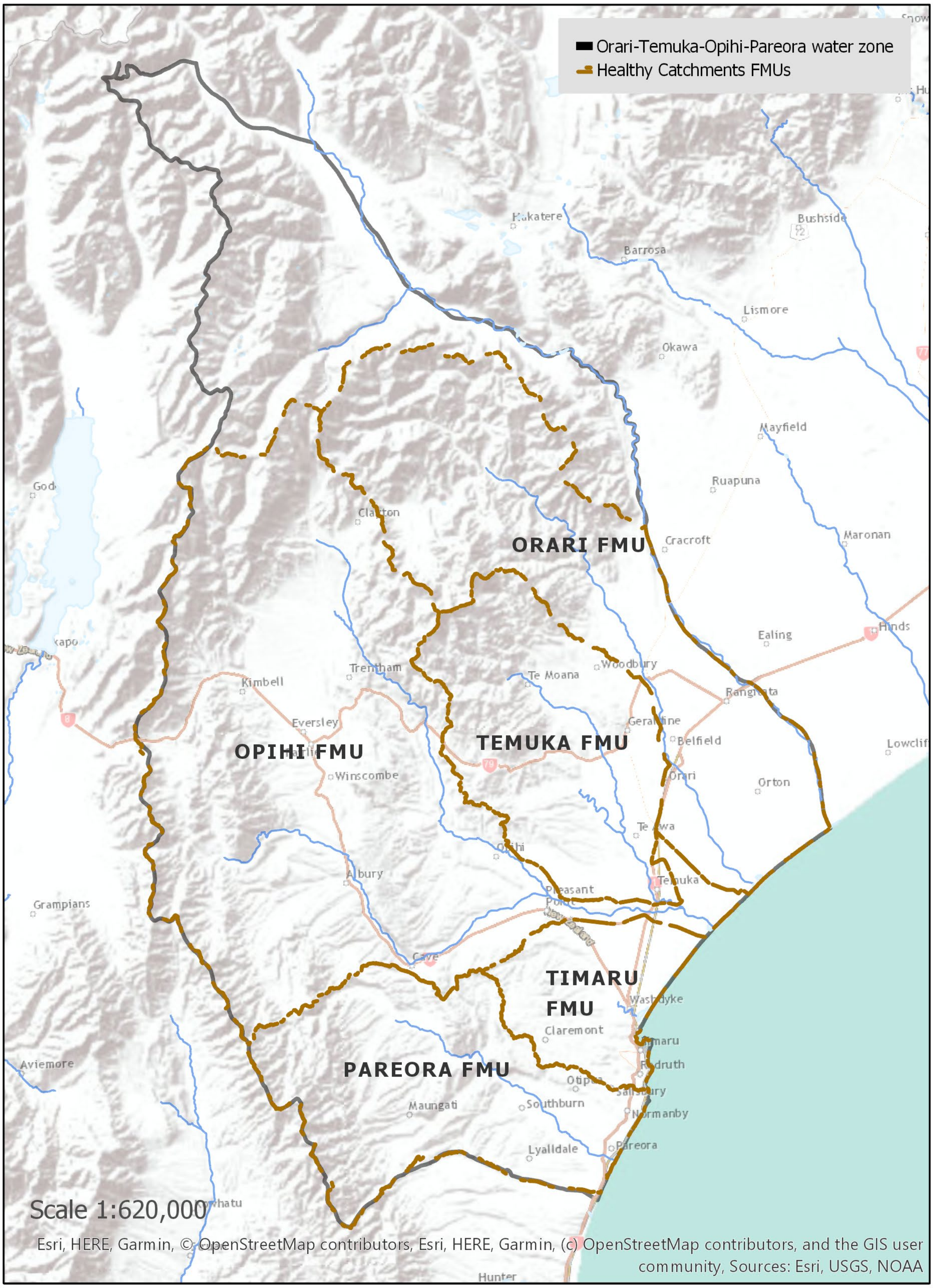

Figure 1-1: The Orari, Temuka, Opihi and Pareora zone and the featured freshwater management units (Healthy Catchments FMUs)

2 Methods

The land use and nutrient loss modelling process was implemented using the ArcGIS desktop software and the python programming language. The model used in the zone was an early version of a generic land use and nitrogen root zone loss model being developed by Environment Canterbury. It that has since gone through some minor refinements.

Modelling was split into separate components that successively process a fixed set of data inputs. The sub-modules and data sources are summarised in the following sections. Most of the steps implemented by the model were simple analyses, like spatial operations (e.g. union overlays), tabular aggregations of the resulting data over farm boundaries, and conditional expressions that classify the farm-level information into a set number of farm types.

The nutrient loss and drainage rates are drawn from works modelling representative land uses, typically assuming long-term equilibrium, long-term average climatic conditions, and good management practices. For modelling nutrient loss rates associated with farming activities, the main source was the catchment matrix from the Matrix of Good Management (MGM) Project (Robson *et al.,* 2015). The matrix compiles OVERSEER nutrient budgets modelling a variety of farming systems across a fixed range of climate and soil groups. For speciality farming systems, such as orchards, vineyards, pig farms, which account for minor parts of the catchments, the nutrient losses are sources from the Lilburn *et al.* (2013) look-up tables. Lastly, non-productive, native and artificial land covers were masked with uniform and low loss rates.

2.1 Data sources

Table 2-1: Data sources used in modelling the farm type and nutrient losses

Dataset name	Use
Agribase (AsureQuality, 2016)	For land within its coverage, the layer is the primary source of data on the farming boundaries and farm-level land use information. AgriBase covers 95% of productive land in the zone. AgriBase includes information on dominant land use label, type and count of livestock, and type and area of crops, although the level of detail and accuracy varies from farm to farm. Dominant land use was validated during initial community engagement workshops.
Dairy Effluent Discharge Consents	Database queried to identify active consent locations, and the number of dairy cows, consented and recorded during consent compliance.
Canterbury Valuation Roll	In the absence of AgriBase, a spatial view of the roll, maintained by Environment Canterbury, was used for defining property boundaries and high-level land use data, including identification of small lifestyle properties.
NZ Primary Parcels polygons	Primary parcels served as a minimum spatial unit for the land use layer. AgriBase, Valuation Roll and Dairy Effluent Discharge Consents records were all mapped onto the primary parcel polygon units, and this layer defines the minimal spatial unit for rural enterprises. Data used in masking road, rail and hydrological features.
Irrigated land layer (Brown, 2016)	Layer maps location and type of irrigation systems. Boundaries of irrigated areas validated during initial community engagement workshops. Layer is used in modelling nutrient losses and in scenario modelling, e.g. assessing the permitted activity status of modelled farms.
Land Cover Database (LCDB) v4.1	National and standardised land cover classification on satellite imagery. Latest version classifies imagery captured from c.2012. Used in combination with the irrigated land layer to understand the effective area on farms, and as a secondary source of information of crop/arable

Dataset name	Use
	areas. The land cover data was also used to disaggregate effective and ineffective land within modelled farms in mapping nutrient losses.
NZ Golf courses & NZ Ponds, 1:50k TOPO	Supplemented land use and land cover information.
Department of Conservation estate and grazing concessions	Department of Conservation estate, with exception of land with the grazing concessions, is filtered out from the land use analysis. All associated polygons are also masked from nutrient loss modelling and labelled with uniform and low nitrogen loss rates.
Crop classification of Temuka (North *et al.*, 2016)	Paddock scale crop classification of summer and winter satellite imagery of 2013. Crop classification used as another source of farm-level information on cropped areas, as well as the type, and areas of crop groups, including winter forage.
Soil layer mapping MGM clusters	Layer populates a spatial dimension linking modelled land use and the nutrient loss dataset. Layer is produced by combining two datasets with different coverages: S-map[1] and an improved Land Resource Inventory soil layer for the areas outside the S-map coverage[2]. A model classifies the soil layer into groups based on attributes likely to influence soil water dynamics and nitrogen cycling (profile water storage and drainage characteristics, and slope). These clusters are directly tied to the soil input data in OVERSEER nutrient budgets which populate the MGM catchment matrix. Methodology detailed in Lilburne & Webb (2015)
Climate layer mapping MGM clusters	Layer populates a spatial dimension linking modelled land use and the nutrient loss dataset. A layer clustering long-term climate surfaces derived from NIWA Virtual Climate Network. Methodology is detailed in Lilburne & Webb (2015).
2016 Winter Forage Classification North *et al.* (2017)	In modelling of a property activity status in relation to a planning provision and consequent development scenarios, the 2016 winter forage crop classification was used to represent the existing uptake of winter forage crops.

2.2 Creation of the spatial land use layer

The steps to derive a farm type map using data from Table 2-1 are as follows.

1. *Modelling farm boundaries.*

   We combined AgriBase, NZ Primary Parcels and the valuation roll database to model property boundaries and identify whether properties will be modelled as farming activities or represent other land uses. These were masked and excluded from further analysis in the form of a property mask layer. These include small lifestyle or residential properties (< 6 ha), Department of Conservation estate (excluding grazing licences), and parcels linked to road or rail infrastructure or hydrological features.

2. *Summarising available spatial data for each farming enterprise.*

   Where provided, AgriBase livestock inventory were translated into revised standard units, and grouped into dairy, deer, sheep, beef and other classes. Similarly, crop area data were grouped into vegetable, grain, seed, and forage crops.

   The Land Cover Database and Irrigated land layer were combined into a simplified land cover layer. The layer is used to summarise the effective farm area, as well as land area in pasture,

[1] https://smap.landcareresearch.co.nz/
[2] https://apps.canterburymaps.govt.nz/lrisupport/

crops, and irrigated land. Effective cover, and area, refers to land that is considered productive from the point of view of primary production, and vice versa for land masked as ineffective.

The paddock-scale data in the crop classification layers was spatially related to modelled farms, and the mapped crops were grouped into high-level classes (seed, grain and root and green vegetable crops), and aggregated to express the area of each at the farm level.

Finally, the different sources of processed data were combined and used to estimate secondary metrics for each modelled farm, including the average percentage of farms in crop or pasture cover, maximum area of farm in fodder or vegetable crops, and effective livestock and dairy stocking rates.

3. *Identifying primary land use and calculate farm enterprise metrics.*

Farms identified by AgriBase, or by the valuation roll in the absence of AgriBase, as vineyards, orchards, pig farms, lifestyle, and forestry blocks retained those codes as their primary land uses.

- Dairy: Modelled farm identified as dairy if milking cows are present on the AgriBase record or if the dominant farm type is identified as Dairy, or if the modelled boundary intersects an active farm dairy effluent discharge consent, or if land use is coded as dairy in the valuation roll.
- Arable: Other farms, where the primary AgriBase type is arable or horticultural, or farms where more than half of the available data sources - AgriBase, LCDB, or the 2013 paddock-scale crop classification - estimate that more than 50% of the farm effective area is in crop.
- All other farms are treated as primarily sheep, beef & deer enterprises. For land use description purposes, properties are also identified as primarily dairy support if AgriBase labels their dominant land use as contract grazing.

4. *Matching primary land use against MGM base files*

The primary land uses were matched to a base, also referred to a reference, MGM farm type using the farm-level data and average primary industry statistics (e.g. Dairy NZ and Beef & Lamb surveys). These steps introduce additional assumptions and extend a greater dependence on the accuracy and timeliness of data contained in the input data sources. Map of the dominant farm type is in Figure 2-1 and the areas are tabled in Table 2-2 and Table 2-3.

- *Dairy farms:*
    - Farms were matched to the MGM dairy systems via an intermediary step. First, the estimated cow stocking rates are translated into estimates of farm's milksolid production, MS/ha, by assuming the district level MS/cow averages (Livestock Improvement Corporation Limited and DairyNZ Limited, 2016).
    - Then, using a simplification of logic from a Farm Portal[3] permitted activity N loss estimate tool, known as NCHECK, the MS/ha production estimate was matched to a dairy MGM farm type. The NCHECK logic was simplified due to lack of data on farm-level supplement imports. I introduced an assumption that the imported supplements will tend to increase with increasing MS/ha (Pinxterhuis *et al.,* 2015).
    - The MGM dairy farm wintering profiles, being either kale, pasture or wintered off, were selected based on a simple reconciliation analysis of the farm's fodder crop area and the stocking rates.
- Arable farms:
    - Arable farms were assigned to an MGM crop farm type based on the percentage of the effective farm area in vegetable and fodder crops, relative to the balance of

[3] https://farmportal.ecan.govt.nz

seed and grain crops. The percentages were matched to the crop rotation make-up of the MGM crop base files. Horticultural farms were linked to an MGM farm type with an intensive vegetable rotation. If areas of root and green crops were not distinguishable, green vegetables were favoured over root vegetables in selecting the MGM farm types with a significant vegetable proportion.
    - Except for market gardens or horticultural operations, the *Grazed* MGM farm type variants were selected, indicating that the forage and fodder crops in the OVERSEER scenarios are grazed by livestock.
    - All available residue removal options are applied via simple averaging within the group of options (Removed, Retained, Grazed, Burnt).

- Sheep, beef and deer farms:
    - Farms were matched to an MGM farm type based on the estimated stocking rate, the dominant stock type, and the area of winter forage crops.

Table 2-2: Area (ha) of dominant farm types in the derived base land use layer by the Freshwater Management Units (FMUs) proposed in the Orari-Temuka-Opihi-Pareora water zone

Dominant Land Use	Opihi	Orari	Pareora	Temuka	Timaru	Total
Arable	6,300	4,100	5,500	4,500	4,100	24,500
Dairy	25,200	22,200	3,900	9,400	2,400	63,100
Dairy support & beef	1,300	1,800	1,200	900	300	5,500
Deer	9,700	3,400	2,000	4,600	1,700	21,400
Sheep & beef	111,400	58,500	43,400	24,100	10,500	247,900
Forestry	1,300	200	200	6,500	0	8,200
Lifestyle	1,000	400	600	1,300	2,200	5,500
Orchard	0	0	0	100	100	200
Pigs	0	200	0	100	200	500
Viticulture	0	0	0	0	0	0
Other (incl. native)	11,700	6,700	4,900	6,600	3,600	33,500

Table 2-3: Count of modelled farms by farm size and dominant land use type within the Orari-Temuka-Opihi-Pareora water zone in the base land use layer

Farm area	arable	dairy	dairy support & beef	deer	sheep & beef	forestry	lifestyle	orchard	pigs	viticulture	other (incl. native)
< 5 ha	2	0	2	0	59	0	989	0	1	0	4
5-10 ha	6	1	6	4	100	2	146	5	1	1	1
10-20 ha	10	0	13	12	165	4	80	2	1	1	2
20-50 ha	32	3	18	26	162	9	13	2	2	0	0
50-100 ha	20	11	7	18	99	7	2	2	0	0	0
100-300 ha	44	98	11	44	185	9	0	0	3	0	1
300-500 ha	17	30	1	9	73	2	0	0	0	0	1
500-1000 ha	8	12	1	3	63	0	0	0	0	0	0
>1000 ha	2	10	1	4	47	1	0	0	0	0	2

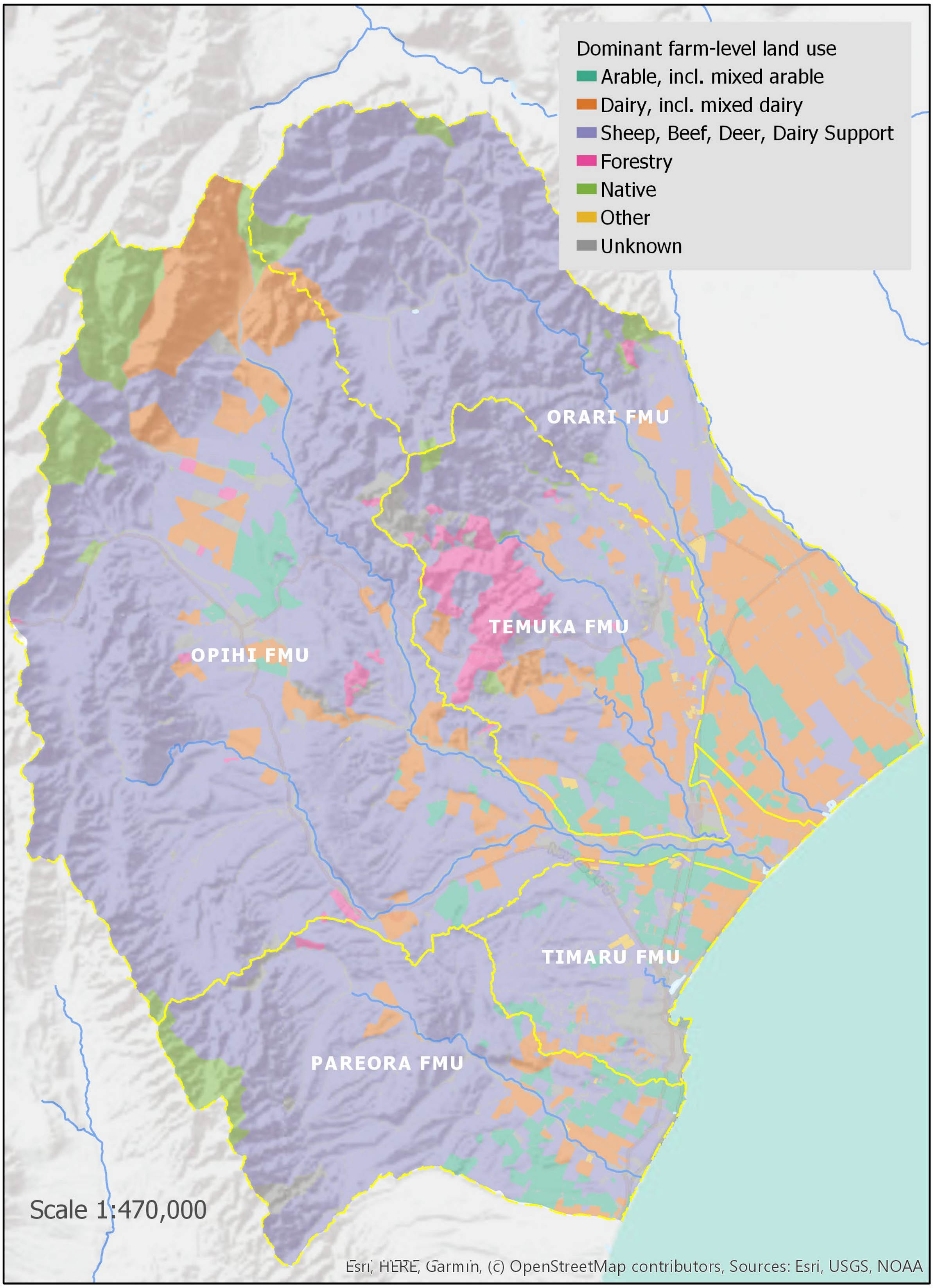

Figure 2-1: Modelled dominant farm types across the OTOP zone

2.3 Populating land use map with nutrient losses

The identification of nitrogen fluxes was determined by two ‘gate’ layers: the property mask and the land cover layers. The property mask is a simplification of the land use map and it separates parcel polygons associated with modelled farming properties from other properties, i.e. land not used for primary production. The latter includes small lifestyle blocks, golf courses, the DOC estate, roads and large water bodies.

The land cover layer separates effective and ineffective land cover. It was derived using Land Cover Database, irrigated land layer (Brown, 2016), and the pond polygons from the NZ Topo 1:50k (Land Information New Zealand). Effective cover, and area, refers to land that is considered productive from the point of view of primary production - crops and forage - and vice versa for land mapped as ineffective.

The simplified land cover layer distinguishes different effective, or productive, land covers:

- Irrigated land: Irrigated land,
- Improved dryland: *Short-rotation crop, Orchard, Vineyard or Other Perennial Crop*, and *High Producing Exotic Grassland* covers, excluding pond polygons.
- Semi-improved and unimproved land*: Low Producing Grassland* and *Tall Tussock Grassland* covers, excluding pond polygons.

All other covers are considered ineffective. Within the farm boundaries, areas with effective cover are processed by modules that retrieve the nitrate and drainage loss rates by looking for the matching combination of land use, soil, climate and irrigation data from the lookup table. All other, ineffective, land were modelled using uniform nitrogen loss rates based on land cover. Drainage losses of ineffective land were assigned the modelled drainage rates from MGM pastural blocks, provided the land has valid soil and climate data.

Table 2-4 shows the area breakdown of simple land cover groups, for five farm types and the FMUs. The other land in the tables represents ineffective land.

Table 2-4: Area (ha) breakdown of simple land cover classes used in nutrient loss modelling for a subset of farm types in the derived base land use layer by the Freshwater Management Units (FMUs) proposed in the Orari-Temuka-Opihi-Pareora Limit zone

Dominant Land use	Simplified land cover	Opihi	Orari	Pareora	Temuka	Timaru
arable	irrigated land	900	2,200	300	900	1,200
	dryland crop and pasture	5,200	1,800	5,200	3,500	2,700
	other land	200	100	100	100	100
dairy	irrigated land	5,600	17,000	1,900	3,400	1,100
	dryland crop and pasture	10,400	4,600	1,900	5,300	1,300
	other land	9,200	600	100	700	100
sheep & beef	irrigated land	2,100	2,500	700	800	800
	dryland crop and pasture	83,900	26,300	33,800	16,400	9,100
	other land	25,400	29,700	8,900	6,900	600
dairy support & beef	irrigated land	100	1,100	0	100	100
	dryland crop and pasture	1,000	600	1,100	700	200
	other land	200	100	100	100	0
deer	irrigated land	900	700	200	200	100
	dryland crop and pasture	7,300	1,500	1,500	3,800	1,600
	other land	1,400	1,200	200	700	100

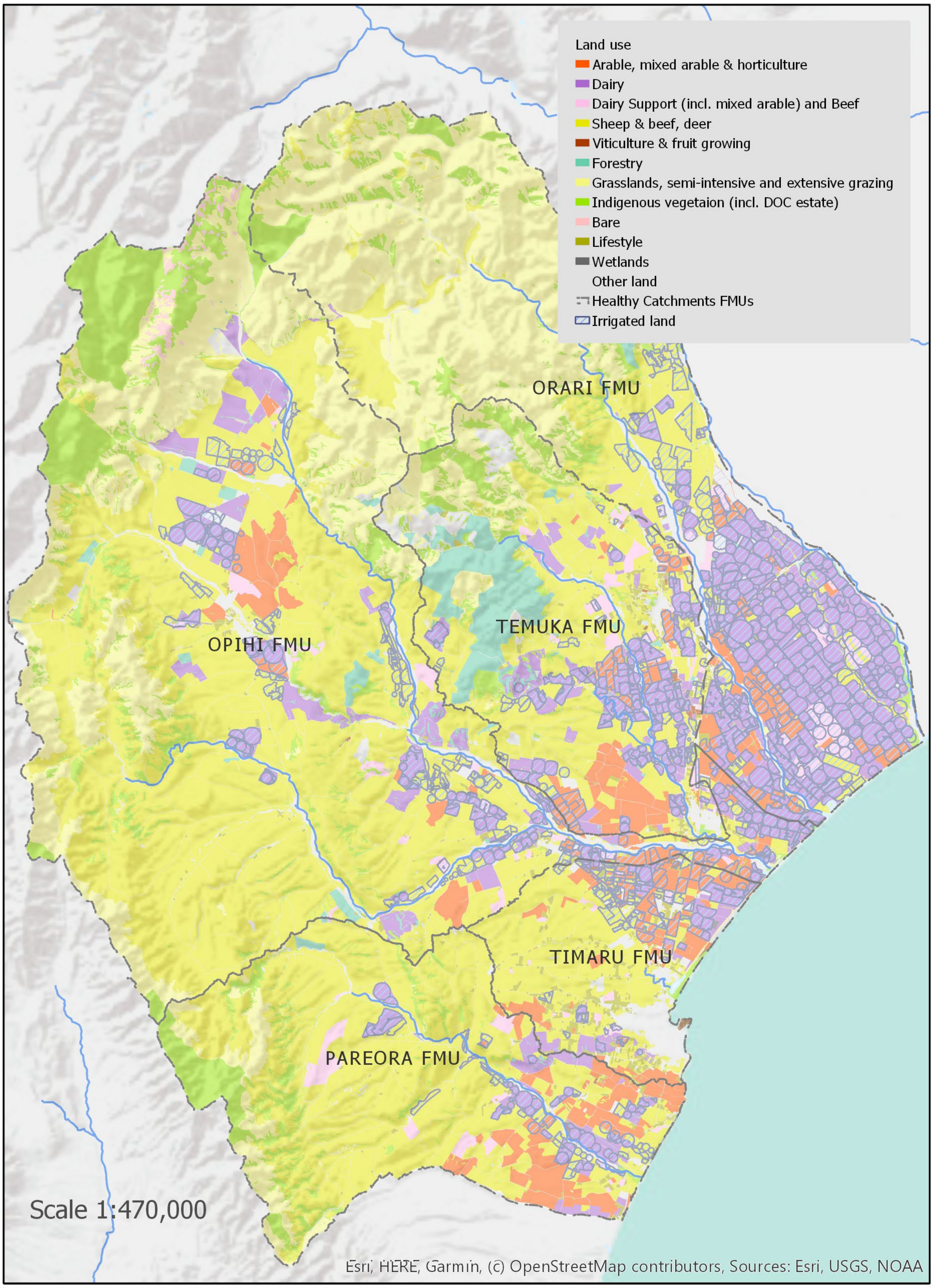

Figure 2-2: Composite map of dominant farm types and land covers applied in nutrient loss modelling. The inclusion of land cover masks constrains the scale to which the dominant farm type class is applied across the property's area

2.3.1 Climate

The climate layer was clipped from the MGM climate layer (Lilburne & Webb, 2015). The layer is produced by clustering NIWA surfaces of mean long term rainfall, temperature and potential evapotranspiration.

2.3.2 Soil

Soil data were obtained from S-map[4] and supplemented by the Improved Land Resource Inventory soil layer[5] for where S-map coverage was unavailable. The soils were classified to the nitrogen clusters created for the MGM project (Lilburne & Webb, 2015).

Where soil and nutrient loss data made it possible, nitrogen root zone losses were estimated using the set of S-map siblings associated with a soil mapping unit, weighted according to the sibling proportion.

2.3.3 Irrigated land

The distribution of c.2016 irrigated land by irrigation system type and across the proposed FMUs boundaries is shown in Table 2-5.

Table 2-5: 2016 Irrigation type by area within the different freshwater management units (FMUs). Source: Brown (2016) irrigation layer, rounded to nearest 10 ha

Irrigation system	Opihi FMU	Orari FMU	Pareora FMU	Temuka FMU	Timaru FMU	Total
Center Pivot	5,250	16,640	1,650	2,550	930	27,020
Sprayline & Long lateral	2,260	320	850	1,360	380	5,170
Unknown	1,570	4,340	670	1,550	1,230	9,360
Gun	1,340	1,690	220	2,310	530	6,090
Rotorainer	520	1,490	0	90	200	2,300
Lateral move	320	1,680	0	10	630	2,640
Borderdyke	0	0	0	0	80	80
Solid set	0	0	0	0	30	30
Total Irrigated	11,260	26,160	3,390	7,870	4,010	52,690
Dryland	156,730	71,180	58,320	50,360	21,000	357,590

The lookup table matrix only includes centre pivot and border-dyke irrigation systems. All spray irrigated land was labelled and modelled as pivot irrigated for modelling nutrient loss and drainage estimates. This will mean that irrigation systems less efficient than centre pivots, such as travelling and spray-line systems, will be represented by nitrogen losses that underestimate the real fluxes. In 2015, at least a third of irrigated land in Opihi, Temuka and Pareora FMUs was identified as being under travelling and sprayline systems (Table 2-5). It is less clear how the assumption affects nitrogen concentrations, which will depend on many aspects, including surplus mineral nitrogen and soil susceptibility for nitrogen loss.

[4] https://smap.landcareresearch.co.nz/
[5] https://apps.canterburymaps.govt.nz/lrisupport/

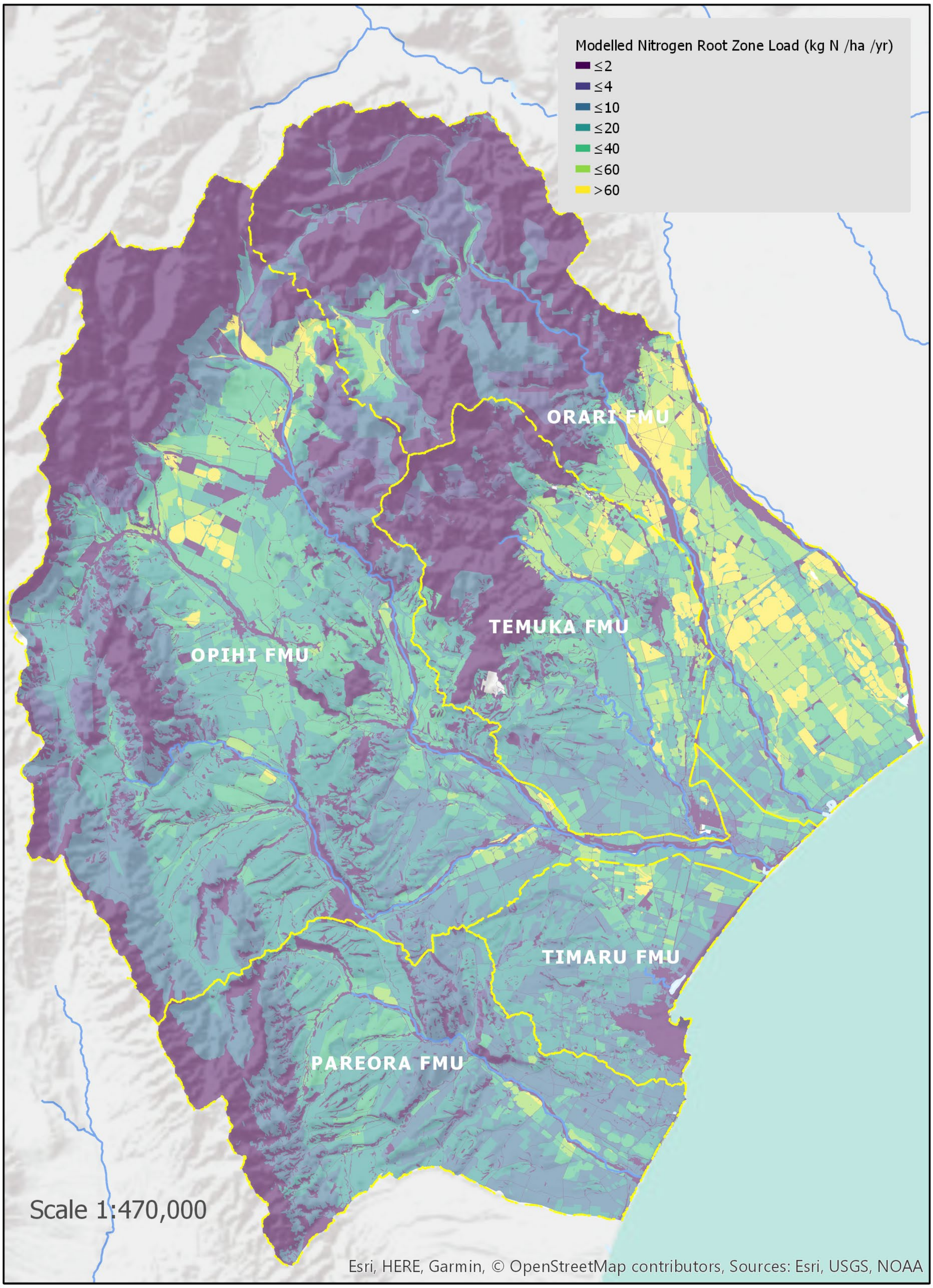

Figure 2-3: Average nitrogen loss rate lost from the root zone modelled for the base land use map and assuming good management practices (kg N /ha/yr)

2.3.4 Nutrient losses

I used a lookup table of nitrate loss and drainage rates that combines values from two sources: the catchment matrix from MGM (Robson *et al.,* 2015) and the LUT (Lilburne *et al.,* 2013) for farm types not covered by MGM. The table was created by cloning the dataset used by Farm Portal[6]. To merge the two datasets, the LUT was mapped and extrapolated onto the soil and climate dimensions used by the MGM. The MGM values are based on the latest version at the time of preparation of the Overseer Nutrient Budgets (OVERSEER®), being version 6.2.2.

Nitrogen loss from semi-improved and unimproved grazing farmland, taken as low producing grasslands and tussock grasslands LCDB land covers, were estimated using the linear regression meta-models developed for sheep/beef/deer farms from the MGM dataset (Snow *et al.,* 2016). The areas are shown as a paler yellow hue in Figure 2-2. These regression models estimate nitrogen losses by using a small number of inputs: soil, climate, stocking rate, % of beef stock, and a forage cropping area. To estimate the stocking rate input for the equations, I reduced the APSIM modelled estimates of dry matter production, from Snow *et al*. (2016), by a factor of 1/2 to reflect a lower production associated with the semi-improved and unimproved grass cover. Other inputs into the regression equations assumed 100% sheep and no winter forage cropping area.

The above exception for semi-improved and unimproved grazing is applied due to a high level of uncertainty associated with the conditions where OVERSEER® is poorly calibrated. The motivation for using the MGM regression approach for the low production land was the assessment that, at the very low stocking rates, the OVERSEER® block-level nitrate loss estimates are insensitive to stocking rate, but highly sensitive to the boundary conditions, particularly the initial soil mineral nitrogen pool.

Further exceptions were implemented for the following conditions:

- Irrigated land on very low intensity sheep and beef farms was modelled as a more intensive variant (*VeryLowIntensity* to *LowIntensity* / *Med Pasture* MGM base farm codes).
- Dryland dairy was modelled as a high dairy sheep & beef farm system in cases (soils and climates) where the dairy matrix does not cater for the combination (*HiDairy* MGM base farm codes),
- Likewise, because the MGM cropping table is also sparse for certain soil and climate combinations, e.g. hilly ground, the model switched to map the land use to a sheep & beef proxy (*LowIntensity* MGM base farm codes).

2.4 Scenario modelling

Two scenarios were modelled in addition to the base land use at good management practices:

- Base land use at current management practices,
- Zone Implementation Plan (ZIP A), combining further permitted activity uptake and loss reductions for consented activities in nitrogen hot spots.

This section describes the modelling steps I applied to estimate the changes to nitrogen losses for these scenarios.

2.4.1 Permitted activity status

The modelled farms were labelled as being permitted or requiring a land use consent according to the narrative thresholds of the Plan Change 5 to the Land and Water Regional Plan (LWRP). This classification requires data on the area of irrigated land and winter grazing[7] within each farm. The rule for permitted winter grazing is up to 10 ha for farms < 100 ha, up to 10% of the farm for farms > 100 ha and < 1000 ha, and up to 100 ha for farms > 1000 ha. If the area of winter grazing fits this permitted winter grazing rule and the irrigated area is less than 50 ha, then the farm was classified as “permitted”, otherwise “consented”.

[6] https://farmportal.ecan.govt.nz

[7] The LWRP defines winter grazing as "grazing of cattle within the period of 1 May to 30 September, where the cattle are contained for break-feeding of in-situ brassica and root vegetable forage crops or for consuming supplementary feed that has been brought onto the property”.

To estimate the base area of winter grazing on each farm, I summed the area of kale, swede and fodder beet crops classified as being winter forage by North *et al.* (2017) in her region-wide paddock-scale classification of 2016 winter crops. While the data does not include stock type, I assumed that cattle will be dominant stock fed on the above subset of winter forage crops. Irrigated land areas were captured by the irrigated land layer used in the land use map (Brown, 2016).

The presence and the average area of winter forage cover on modelled farms varied considerably in 2016, although both increase with the property size, as illustrated in Table 2-6.

Table 2-6: Summary of 2016 winter forage brassica areas by property. Properties grouped according to their size. Source: North *et al.* (2017)

Farm area bins	Property Area (ha)			Properties with >1 ha in winter forage brassicas (2016)			
	Number of properties	median property area	total area	Number of properties	percent of all properties	median area in winter forage brassicas	median percent of the property area in winter forage brassicas (%)
< 5 ha	1,052	2	2,339	16	2%	1.4	46%
5-10 ha	274	8	2,074	23	8%	1.9	26%
10-20 ha	367	14	5,675	65	18%	2.8	17%
20-50 ha	188	37	6,899	90	48%	3.9	11%
50-100 ha	166	69	11,666	90	54%	6.0	8.2%
100-300 ha	396	180	73,144	305	77%	14	7.3%
300-500 ha	133	374	51,118	118	89%	25	6.5%
500-1000 ha	88	689	61,731	84	95%	43	6.1%
>1000 ha	69	1,634	179,837	61	88%	41	2.2%

2.4.2 Current land use practices

A scenario was created to simulate an assumption that modelled activities are currently not operating at good management practices. To reflect the difference, I also assumed that the farms classified as requiring consent would have higher losses relative to the GMP expectations. On average, the scenario assumes that the good management practice losses are 15 % lower than losses under current practices. This value is close to the average effect estimated by the Farm Portal GMP proxies for a set of industry survey files (Robson *et al.,* 2015). Drainage rates were not adjusted. The prevalence of spray irrigation, the high security of water supply, and presence of on-farm storage facilities are factors suggesting that the irrigation scheduling will be close to the good management practice expectations.

2.4.3 Permitted activity development

The permitted activity development scenarios simulated changes to the winter grazing areas as a hypothetical pathway of intensification. To estimate the effect of winter forage development, we assumed that the North *et al.* (2017) region-wide paddock-scale classification of 2016 winter forage crops represents the base conditions on the modelled farms.

I modelled the effect of increasing the existing area of winter grazing activity in terms of a change to the root zone nitrogen losses. Variants to the narrative thresholds of permitted winter grazing areas were explored for comparison against the thresholds in the Land and Water Plan regime. No subdivision of large properties was modelled. Winter forage areas were not increased on farms modelled as requiring consent, or on exotic forestry blocks.

A forage crop suitability layer was created to identify and constrain the additional development of winter forage cropping:

- Land lower than 800 m,
- Land less than 20 degrees in slope, and
- The study excluded Department of Conservation estate, urban and impervious surfaces, land under bare, sparse or native vegetation cover, or water bodies (including a 10 m buffer).

All land captured by the crop suitability layer was considered equally likely to be used for the hypothetical increase in the winter forage area

A constraint was applied on modelling the maximum percentage of a property in winter grazing, by assuming that the long-term average winter grazing area is unlikely to exceed 15 % of the property area. This value stems from the soil management issues posed by the grazing of heavy stock at high densities. The constraint limits the area of winter forage areas permitted by the rule on properties smaller than 66 ha. I also assumed that the winter forage activity is unlikely to cover all available land area on a property, and introduce a small, arbitrary buffer of 1 ha.

The scenario assumes a partial utilisation of the winter forage development rule by all eligible properties, implemented at a level of 50% uptake. It was applied by reducing the additional modelled winter forage area by 50% for each candidate farm. This simple method was compared to the average effect of randomly sampling 50% of the properties, and the difference in the additional area was small, justifying the simpler, non-random approach.

In summary, if an increase to the winter forage activity was modelled as permitted for a farm, its area was limited to the following constraints:

- Lesser of the crop suitability area or 15 % of the effective farm area, and
- Occurring at 50 % uptake.

No subdivision of large properties was modelled. Winter forage areas were not increased on farms modelled as requiring consent, or on exotic forestry blocks.

I sourced the winter forage nutrient loss rates from the block-level MGM OVERSEER® dataset, meaning they reflect good management practices according to the proxy rules (notably fertiliser and irrigation management). No changes to drainage rates were modelled as part of the scenarios.

2.4.4 Nitrogen hotspot reductions

The effect of load reductions proposed for three nitrogen hotspot areas (not shown in the report) in the Zone Implementation Plans (ZIP) was applied to the modelled nitrogen root zone losses of farms with a consented status. The reduction targets were not applied to ineffective land. Two different implementations of reductions were requested for scenario assessments. They were initially as uniform rates, and finally as rates that are conditional on farm type. The latter is described in Table 2-7. The reduction factors in Table 2-7 were weighted for the modelled dairy farms to account for the fact that they include support blocks. Based on the district-level data on effective milking platform areas, I estimated that 25% of the modelled dairy farm areas are likely to be support blocks.

Table 2-7: Farm-type based reductions applied to nitrogen loads in the three nitrogen hotspot zones, expressed as factors

Name of nitrogen hotspot	Dairy	Other land
Levels Plains	0.20	0.10
Orari	0.20	0.10
Ashwick Flat	0.10	0.05

3 Uncertainty

Using a modelling approach to understand the impact of land use on catchment nitrogen loads introduces a number of uncertainties. While no formal assessment of errors or parameter uncertainty was done, it is valuable to understand the sources of error and their potential magnitude.

Data uncertainty include errors in the input soil, climate, irrigation, land use and landcover layers as well as the effect of simplification of the spatial variability in these layers. Farms are simplified to the dominant land use activity as defined by the limited set of MGM farm types. Similarly, the range in irrigation systems was simplified and represented by the more efficient pivot irrigation. Farm system nutrient modelling in OVERSEER® introduces additional sources of error, including those associated with their assumptions of long-term equilibria in nutrient cycling and the use of long-term climate conditions.

These errors and simplifications mean that root zone losses at the block or farm scale are likely to be inaccurate. However, the risks associated with these potentially high levels of uncertainty can be mitigated by aggregating data at the scale of catchments, thereby cancelling out individual errors (e.g. over estimates are balanced by underestimates). Another risk mitigation is to focus on relative differences in catchment loads rather than relying on the absolute numerical estimates of loads.

Note that any attenuation of loads beyond the root zone is beyond the scope of this report so the estimates cannot be verified through a comparison of the root zone estimates of losses with measured downstream water quality data.

4 Summary

The estimated nitrogen loads for the principal scenarios and the zone FMUs I assessed using the land use and nutrient model are summarised in Table 4-1.

Table 4-1: Catchment sums of root zone nitrogen loads for the three scenarios modelled in support of Orari-Temuka-Opihi-Pareora limit setting process, broken down across modelled Land and Water Plan activity statuses

Name	Modelled activity status	Base land use at good management practice (GMP)	Base land use at current management practice (CMP	ZIP A simulation (permitted development, hot spot reduction, and good management practice loss rates)	Area (ha)
Opihi FMU	consent	920	1,040	900	63,220
	permitted	810	810	910	102,590
	other	50	50	50	12,960
	total	1,780	1,900	1,850	178,770
Orari FMU	consent	1,190	1,370	1,080	55,190
	permitted	250	250	270	38,300
	other	60	60	60	7,810
	total	1,500	1,680	1,410	101,300
Pareora FMU	consent	210	230	210	19,240
	permitted	300	300	340	39,770
	other	20	20	20	4,870
	total	530	550	570	63,870
Temuka FMU	consent	370	420	370	32,580
	permitted	220	220	250	18,660
	other	30	30	30	7,370
	total	630	680	660	58,610
Timaru FMU	consent	120	140	110	7,860
	permitted	100	100	120	11,710
	other	20	20	20	5,900
	total	240	260	250	25,470
All other land in the sub-regional boundary	consent	170	190	170	57,110
	permitted	90	90	110	12,410
	other	10	10	10	7,730
	total	280	290	290	77,250

5 Acknowledgements

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