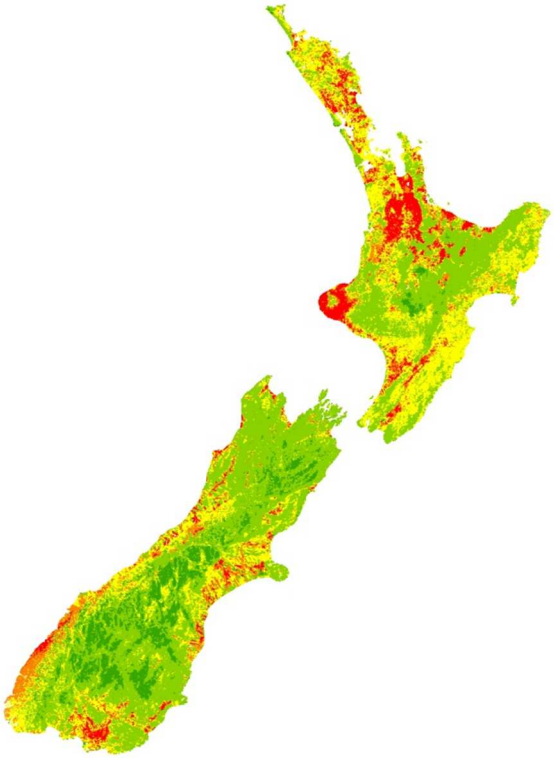
NIWA
Taihoro Nukurangi

National nutrient mapping using the CLUES model

Prepared for the Parliamentary Commissioner for the Environment

November 2013



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Contents

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Executive summary

The Parliamentary Commissioner for the Environment has commissioned Motu Economic and Public Policy Research (Motu) to conduct a study to model the effects of land use change and intensification on nutrient loads and concentrations in streams in New Zealand, over recent periods of intensification (since 1996) and into the future (until 2020). This report presents work undertaken by NIWA under contract to Motu that uses the CLUES (Catchment Land Use for Environmental Sustainability) model to predict changes in nutrients. Results are provided in the form of maps and summary statistics both regionally and nationally.

The CLUES model was run for six scenarios reflecting changes in land use and stocking rates as supplied by Motu. With regard to future (2020) land use there, there are two alternative scemarios relating to a $5 carbon price and a $25 carbon price as assumed in Motu's LURNZ (Land Use in Rural New Zealand) – Climate Land Use Change Simulations. These land use scenarios reflect short term effects of carbon prices on land use in the NZ Emissions Trading System. The stocking rates are effective stocking rates reflecting increased farming intensity for a given land use type, representing changes in numbers of animals per unit area and increased production per animal (termed S1 for the 2008 stocking rates and S2 for the 2020 stocking rates). Note that the areas farmed are not affected by S1 or S2. The scenarios and associated national increase in N and P generated load (load entering streams) are shown in the table below (Table 0-1). For example, the Y2020 $5 S1 scenario represents land use evolved by year 2020 with a $5 carbon price, and S1 signifies that losses per unit land area are kept the same as in 2008 through 'mitigation' measures.

Table 0-1: Result summary for the six land us scenarios.

Scenario	Description	Increase from 1996 (% of 1996 value)					
		N generated load	P generated load	Dairy Area	Planted Forest Area	Sheep/Beef Area	Scrub Area
Y1996	1996 land use 1996 stocking rate	0	0	0	0	0	0
Y2008	2008 land use 2008 stocking rate	8.9	0.36	22.0	10.9	-5.1	-1.4
Y2020 $5 S1	2020 land use $5 carbon price 2008 stocking rate	15.4	-0.74	49.8	23.5	-14.4	9.6
Y2020 $5 S2	2020 land use $5 carbon price 2020 stocking rate	20.2	-0.55	49.8	23.5	-14.4	9.6
Y2020 $25 S1	2020 land use $25 carbon price 2008 stocking rate	15.5	-0.93	50.9	32.1	-15.2	5.5
Y2020 $25 S2	2020 land use $25 carbon price 2020 stocking rate	20.4	-0.74	50.9	32.1	-15.2	5.5

The greatest predicted increase in the generated N load (the load entering streams) compared to the scenario Y1996 land use was by 20.2% for the Y2020 $5 S2 scenario, reflecting both an increase in dairy area (an increase of 50% from 1996 to 2020, largely as a result of replacing intensive sheep and beef) and intensification (increased stocking rates and production per unit area). P generated loads decreased by a small amount overall because increases in loads from dairying were offset by decreases in loads from land use changes such as the introduction of new forest areas. The $5 carbon prices on land use had little effect on loads compared to the $25 carbon prices on land use. The total load reaching the coast followed similar trends as the generated load.

The general increase in nutrient load is partly attributable to intensification (i.e., increased stocking rates). For the 'future' period from 2008 to 2020 with the $5 carbon price land use scenario, there was a 10.4% increase in predicted generated N load and a 0.9% decrease in generated P load. However, 43% of the predicted N increase in this future period was due to intensification. For the historical period from 1996 to 2008, we estimated that 36% of the predicted N increase and 38% of the P increase from 1996 to 2008 was due to intensification. Over the full period from 1996 to 2020, an estimated 40% of the predicted N was due to intensification, the remaining 60% of the increase being the net effect of land use change.

The predicted total N generated load increased in all regions for all periods, except for Northland, Auckland and Marlborough where the load decreased slightly from 1996 to 2008 because the area of dairying decreased. N loads in Gisborne decreases between 2008 and 2020 and between 1996 and 2020. The largest percentage increase in N loads relative to Y1996 occurred in Canterbury and Southland because there was a large percentage increase in dairying. An increase in N loads in 2020 relative to 1996 of over 20% was also predicted for Waikato, Manawatu-Wanganui, Otago, and Wellington.

Nationally, the predicted total generated loads of P entering streams did not change much over time but the change over time varied regionally. In Northland, predicted P load decreased between 1996 and 2008 because the area of dairying is expected to decrease with a corresponding increase in the area of forestry on vulnerable soils. There is also expected to be a massive increase in scrub from 2008 to 2020. Similarly, in Bay of Plenty, Gisborne, and Hawkes Bay, there is a decrease in predicted P because sheep and beef areas are predicted to be converted to forestry. Note that in Gisborne, the increase in dairy area is largely percentage-wise and only because there was so little to start off with. In contrast, in other regions such as Southland and Canterbury the predicted P load increased due to expected intensification and increased dairy areas, without afforestation.

The model probably underestimated the reduction in P load in areas where forestry was introduced, because the model currently assumes that the P contribution from mass erosion remains constant. Note that mass erosion would become less when forest or scrub is planted because the plant roots hold the soil in place and make erosion less likely. P binds to the soil and the model is likely to be underestimating P losses.

The predicted median concentration (that is, the concentration that is exceeded by half the sites) did not change over time, because the low-intensity land uses associated with low-medium concentrations remained largely unchanged. The 95-percentile concentration increased by 49% for N and 10.4% for P from 1996 to 2020. The increase in concentrations

is broadly consistent with observations in the National Rivers Water Quality Network (Ballantine and Davies-Colley 2010, Scarsbrook 2006).

The overall implication from a modelling perspective is that land use change and intensification has and will continue to result in increased nutrient loadings and concentrations in New Zealand streams. An exception is for P loads in some areas, where increased loads resulting from increased area and intensity of pastoral land use are offset by decreased loads resulting from afforestation.

Data and analysis presented in the main text of this report are based on a run of the LURNZ model conducted in mid 2013. The data from the most recent version of the LURNZ model for the Y2020 $5 S1 scenario conducted in October 2013 are presented in Appendix 6.

1 Introduction

The Parliamentary Commissioner for the Environment has commissioned Motu Economic and Public Policy Research (Motu) to conduct a study to model the effects of land use change and intensification on nutrient loads and concentrations in streams in New Zealand, over recent periods of intensification (from 1996) and into the future (to 2020).

Motu produced maps of 1996, 2008 and 2020 land use (see Anastasiadis and Kerr, 2013). These maps were used as input to the CLUES (Catchment Land Use for Environmental Sustainability) model which was applied over all of New Zealand. Motu also produced land-use intensity estimates in 1996, 2008 and 2020 for incorporation into CLUES (in the form of stocking rates).

This report outlines the methods used in the study, including a brief description of relevant aspects of the CLUES model and methods for setting up the appropriate land use and stocking rates for use in CLUES. The resulting spatial distribution of nutrient loading to streams (generated load) and changes in spatial distribution over time are presented and discussed first, to give insight into the changes. National and regional summaries of loadings are then presented. Finally, concentration results are presented.

2 Methodology

An outline of the steps in methodology of the project is illustrated in Figure 1. The components are described in sections 2.1–2.3. A $5 carbon price and a $25 carbon price relates to the two land use scenarios produced in Motu's LURNZ (Land Use in Rural New Zealand) – Climate Land Use Change Simulations (Anastasiadis and Kerr, 2013). The stocking rates are effective stocking rates reflecting increased farming intensity for a given land use type, representing changes in numbers of animals per unit area and increased production per animal. For example, the Y2020 $5 S1 scenario represents land use evolved by year 2020 with a $5 carbon price, and S1 signifies that losses per unit land area associated with stock are kept the same as in 2008 through mitigation measures.

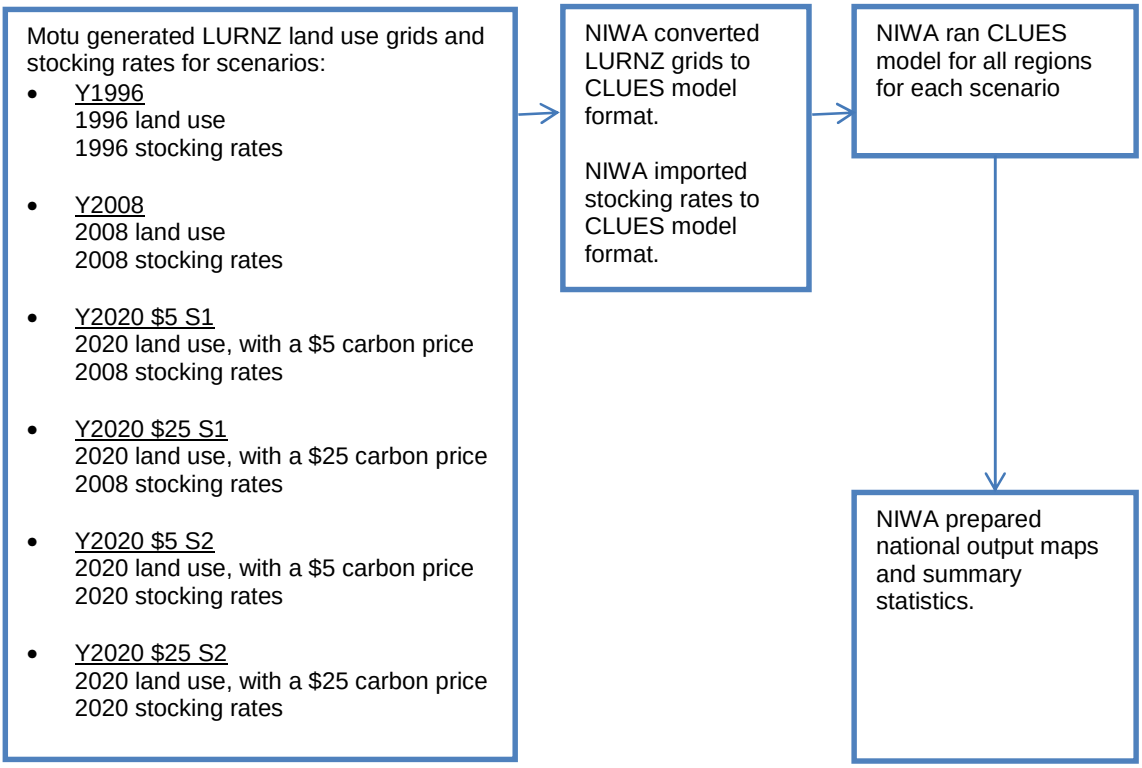

Figure 1: Outline of the methodology and components of the project.

2.1 Land Use and Stocking Rates

LURNZ (Land Use in Rural New Zealand) land use grids were supplied by Motu for the years 1996, 2008, and 2020, as described in Anastasiadis and Kerr (2013). Briefly, there are two 2020 land use scenarios relating to a $5 carbon price and a $25 carbon price as assumed in Motu's LURNZ – Climate, Land Use Change Simulations. These land use scenarios reflect short term effects of carbon prices on land use in the NZ Emissions Trading System. The grids do not cover DOC or public land, for these areas, the default CLUES land use, which is derived from the 2001–2002 Land Cover Database (LCDB2), was utilised.

Before the grids could be used in CLUES, the land use classes had to be re-classified (as summarised in Table 1). The reclassified land use grids were then converted to polygon shape files for use in CLUES. The regional boundaries used in this work are presented in Appendix 1. Note that additional areas of dairy and sheep/beef in the LURNZ other animal

and lifestyle class may be added from the CLUES default land use. Also, additional scrub, native forest, sheep/beef and dairy may be added to the DOC and public land from CLUES default classes. Note that 17% of DOC and public land is tussock, 8% is scrub, 42% is native forest, 9% is sheep/beef, and 1% is dairy. The 'other' class for the non-productive land use class may include bare soil, rivers and lakes. Appendix 2 presents maps of the CLUES land use layers of interest for dairy, sheep & beef, and planted forest land use classes created from the land use grids. Appendix 3 presents tables and figures of past and future land use areas of interest.

Table 1: Reclassification and refinement of LURNZ land use for use in CLUES.

LURNZ Land Use	CLUES Land Use
Dairy	Dairy
Sheep and beef	Split into a) intensive b) hill, and c) high based on reclassified LENZ layers (Leathwick 2002), as described in Woods et al. (2006). The reclassification of LENZ layers was provided to NIWA by Landcare Research
Plantation forest	Plantation forest
Scrub	Scrub
Horticulture	Horticulture
Non-productive	Other
Urban	Urban
Other Animal and Lifestyle	Substitute with the default land use from CLUES
Indigenous forest	Native Forest
Pasture on public land	Substitute with the default land use from CLUES
DOC and public Land	Substitute with the default land use from CLUES

CLUES allows for stocking rates to be adjusted by a percentage of the default values, which are based on conditions in 2001. In this study, changes in stocking rates to represent changes in intensification (increased stock numbers or production per unit area) were assessed by Motu (Anastasiadis and Kerr 2013). Effective stocking rates were provided for each of 1996, 2008, and 2020, relative to (as a percentage of) 2001 values. For sheep and beef farming, a single relative value was provided nationally, whereas for dairy, regional values were used. These relative stocking rates were allocated to each CLUES sub-catchment based on the region code contained within CLUES (Woods et al. 2006).The relative stocking rates and results for these are given in Table 2. To be consistent with the rest of the report, the stocking rates are expressed relative to 1996 (original data relative to 2001 is given by Anastasiadis and Kerr (2013)).

Table 2: Stocking rate adjustments (%) for each year, relative to 1996.

Land Use	Region	2008	2020
Dairy	Auckland	8.0	18.2
	Bay of Plenty	18.0	34.7
	Canterbury	57.4	95.0
	Gisborne	2.1	0.2
	Hawkes Bay	6.3	9.5
	Manawatu-Wanganui	20.9	31.4
	Marlborough	44.1	74.3
	Nelson-Tasman	44.1	74.3
	Northland	12.3	21.4
	Otago	32.3	53.7
	Southland	22.5	38.7
	Taranaki	20.4	26.6
	Waikato	22.6	40.4
	Wellington	12.1	19.7
	West Coast	27.7	54.2
Sheep and beef	All regions	8.1	18.1

2.2 The CLUES Model

CLUES (Catchment Land Use for Environmental Sustainability) is a GIS-based model for predicting the effect of land use change and intensification on various socio-economic indicators as well as on nutrient, *E. Coli*-, and sediment in surface water for each stream reach in New Zealand. The original development of CLUES was funded by MAF (now MPI) and MfE, and the model brings together various model components from NIWA, Landcare Research, AgResearch, and Plant and Food Research. The original model is described in Woods et al. (2006). References to modification to the model and various applications, along with other background material, are provided in the manual (Semadeni-Davies et al. 2011) on the MPI website[1]. The model has been set up with default input datasets and parameters, and is freely available from NIWA[2] for download and use. The base spatial unit of CLUES is the sub-catchment (~ 10 km^2 and above) which comes from the NIWA River Environment Classification (REC) of the national stream and sub-catchment network[3].

The following predicted variables for total nitrogen (TN) and total phosphorus (TP) were used in this study:

- Loads (tonnes). The mean annual load of TN or TP passing through a stream reach.
- Generated yield (kg ha^{-1} yr^{-1}). The mean annual load of nutrient generated in the catchment and entering the stream system (via surface or subsurface pathways) per unit area of land.
- Concentration (mg m^{-3}) in water. The predicted median concentration.

[1] http://www.mpi.govt.nz/environment-natural-resources/water/clues (Date of last access – 18 Oct 2013)
[2] ftp://ftp.niwa.co.nz/clues/ (Date of last access – 18 October 2013)
[3] http://www.niwa.co.nz/our-science/freshwater/tools/rec (Date of last access – 18 Oct 2013)

- Generated loads (tonnes). This is not a standard CLUES output, but was calculated from the sub-catchment generated yields and areas, summed over the area of interest.

Key assumptions or features of the model most relevant to this project are:

- TP loading for pastoral land uses is determined from a simplified version of OVERSEER, as described in Woods et al. (2006). Default stocking rates are used for each region, based on the land use type and land slope. These default stocking rates are adjusted up or down depending on user-entered relative stocking rates. The simplified OVERSEER model takes account of these stocking rates, along with the effects of slope, soil drainage class, rainfall, and soil type. Default fertiliser rates are used. The simplified OVERSEER model does not include 'farm-level' losses such as dairy effluent pond discharges.
- An additional source term for P is used for dairy areas, as described in and Wheeler and Elliott (2008) and used in Parshotam and Elliott (2009). This is a uniform value across New Zealand which is then modified by rainfall.
- An additional P source is applied to account for mass erosion, based on erosion rates from Hicks and Shankar (2003) as described in Hicks et al. (2011), which do not explicitly take account of land use effects. In this erosion model, sediment yields per area are determined as a function of geology and mean annual rainfall, but do not take land cover into account directly. In the CLUES P model, the sediment load is multiplied by a P concentration of sediment (see Woods et al. 2006) to derive the P load associated with erosion. This is a small term relative to the OVERSEER predicted P sources in pastoral areas, except where erosion rates are large.
- The assumptions for N are similar to those for P, except that there is no erosion term or additional source term for dairy. These are described in Wheeler and Elliott (2008).
- For both N and P, the loading can be adjusted up or down to take account of mitigation measures. This feature was not used in the current study. Rather, it was assumed that mitigation measures remain at the current levels implicit in the calibration of the SPARROW component of CLUES (Woods et al. 2006).
- Point sources, such as water treatment plants, freezing works and paper mills, are added, based on a survey of sources conducted around the year 2001 (Woods et al. 2006). These remained fixed for past and future scenarios in this study. Urban areas have a diffuse source contribution, so that the urban load increases as the extent of urbanisation increases.

2.3 National CLUES model output

In the standard CLUES model, the country is subdivided into 10 subs-areas to reduce datasets to a manageable size. Since this project required runs for the national scale, the CLUES model was set up and run for each region in turn and the results collated. The results of the national CLUES runs were then mapped and summarised using standard GIS (ESRI ArcMap), database (MS-Access) and spreadsheet (MS Excel) software. The results were collated by regional boundaries (not CLUES sub-areas) for reporting the results (see

Appendix 1 for the list of regions). The version of the CLUES model used was CLUES 10 for ArcGIS 10. The 28th March, 2013 version of the simplified OVERSEER model was used.

3 Results and Interpretation

3.1 CLUES Land use layers

Maps of dairy, sheep & beef, and planted forestry (pine) land use classes for scenarios Y1996, Y2008, Y2020 $5 and Y2020 $25 are presented in Appendix 2. Regional areas and absolute and relative differences in the proportion of dairy, sheep & beef, planted forest, native forest, scrub and urban are presented in Appendix 3.

Nationally, there is a projected 50% increase in the area of dairy farming to year 2020 with the $5 carbon price compared with year 1996 (i.e., a 6505 km^2 increase, with 3632 km^2 of this expected to occur between year 2008 to year 2020, with a $5 carbon price). This increase in dairy area is largely offset by a predicted decrease in intensive sheep and beef (7537 km^2 decrease from year 1996 to year 2020 with a $5 carbon price). The area of hill country sheep and beef is expected to decrease by 4632 km^2 over the period, offset by an increase in the area of planted forest. The area of scrub is predicted to decrease by 2340 km^2, high country sheep and beef is predicted to decrease by 1186 km^2 and urban area is predicted to increase by 115 km^2.

Regionally, the largest predicted percentage increases (relative to the 1996 value) in dairy area were in Gisborne (i.e., East Cape). The largest predicted increases in dairy area between 1996 and 2020 with a $5 carbon price are in Canterbury (1618 km^2), Waikato (857 km^2), Manawatu (779 km^2) and Southland (1585 km^2). Prediced increases in planted forest near or greater than 400 km^2 are expected in Manawatu, Gisborne, Waikato and Hawkes Bay. The effect of reducing the carbon price from $25 to $5 showed slight increases in areas of scrub and sheep and beef (intensive, hill, high), and slight decreases in areas of dairy and planted forest. There was no change to native forest areas.

3.2 Maps of N and P generated yields

Maps of N generated yield predicted by the model (e.g., Figure 2 and Figure A7 in the appendix) show that large generated yields occurred in big areas dominated by dairy farming (see Figures A2 to A6 in the appendix for the land use). This is particularly evident in Southland, Waikato, Taranaki and parts of Canterbury. Maps of yield increases (Figures 3 – 5) highlight the effect of the predicted new dairy areas. Some increases also occur in areas with fixed pastoral land use due to intensification. Yield decreases in some areas were due to afforestation, and because the land use model predicted that some dairy areas were converted to sheep and beef in the period from 1996 to 2008 (see Table A6). As dairying expands, the areas with high generated N yields increase (e.g., in Southland and Manawatu-Wanganui, see Figure 4). Figure 5 shows the effect of land use change on N yields.

There are some very large yields associated with point sources, but these don't show up in at the national scale because they are associated only with the local catchment. There were some unusually large N yields simulated in the Fiordland area, which were the result of very high rainfall in conjunction with imperfect soil drainage. These N loads however, are discharged into very large volumes of water.

Increases in N yields due to predicted intensification from 2008 to 2020 (scenarios Y2020 $5 S1 versus scenario Y2020 $5 S2) are shown in Figure 6. The largest increases occurred in dairying areas.

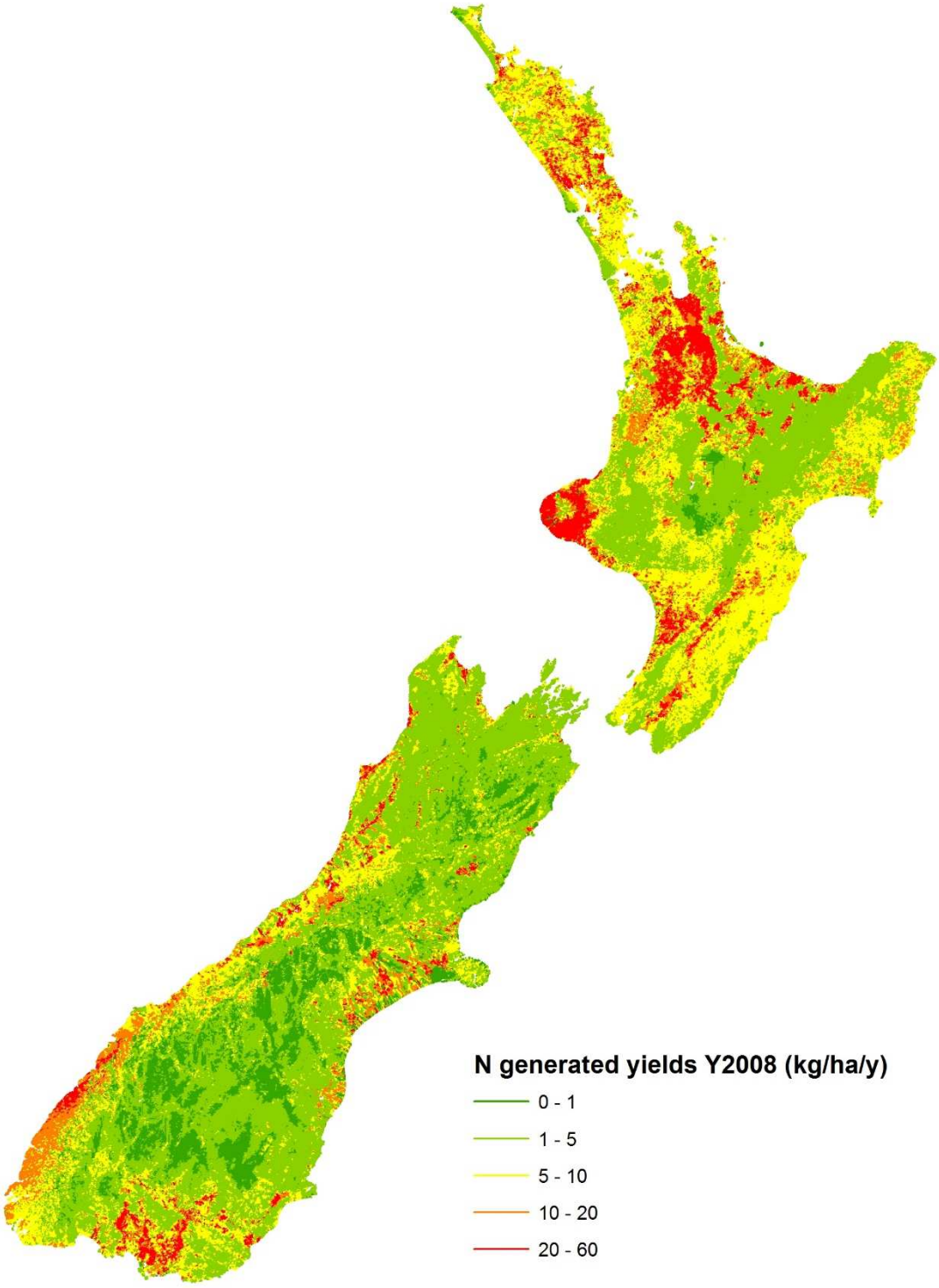

Figure 2: Map of N generated yields for scenario Y2008.

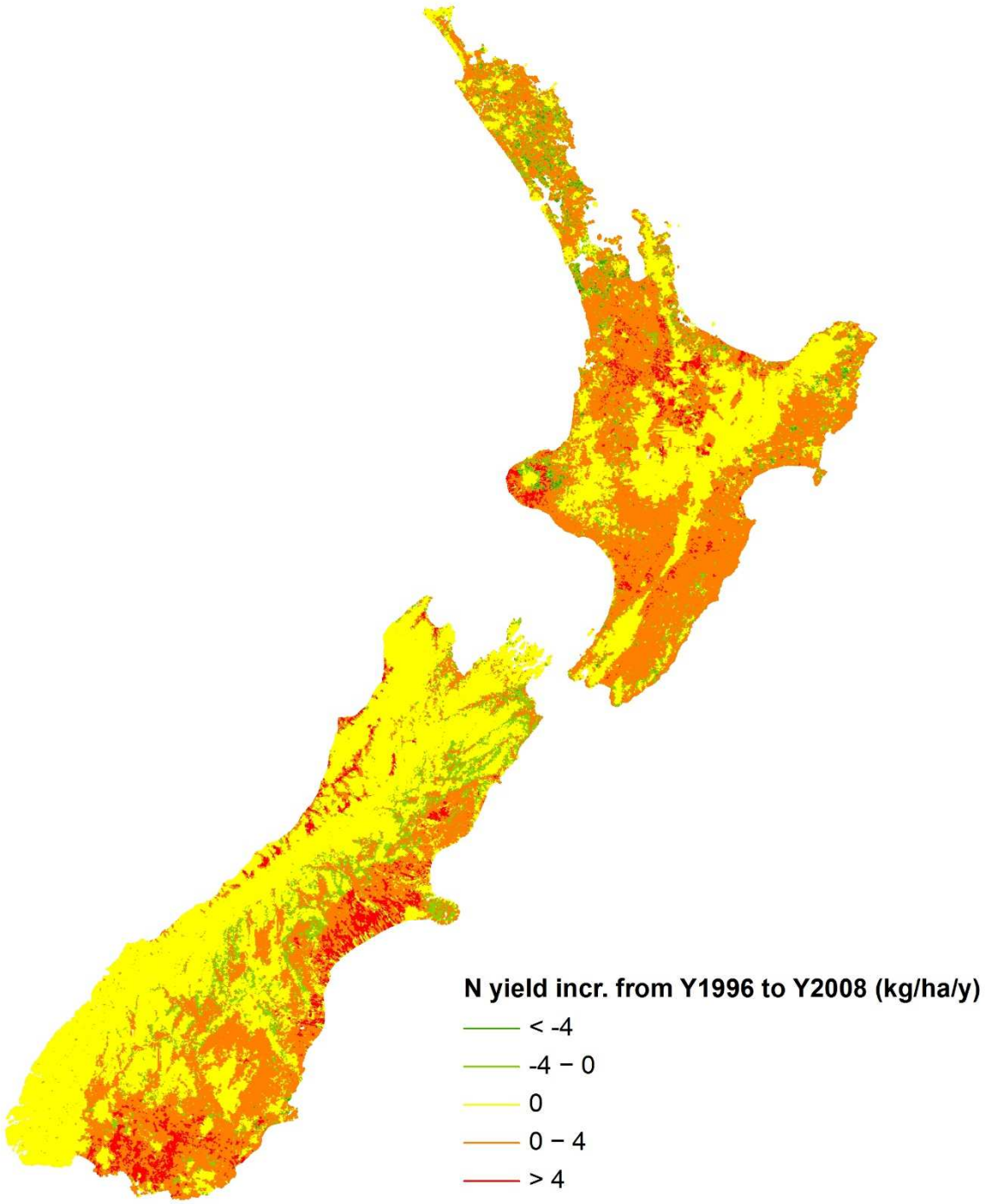

Figure 3: Change in N generated yields (kg/ha/y) from scenario Y1996 to Y2008. Positive values denote an increase in yields from 1996 to 2008.

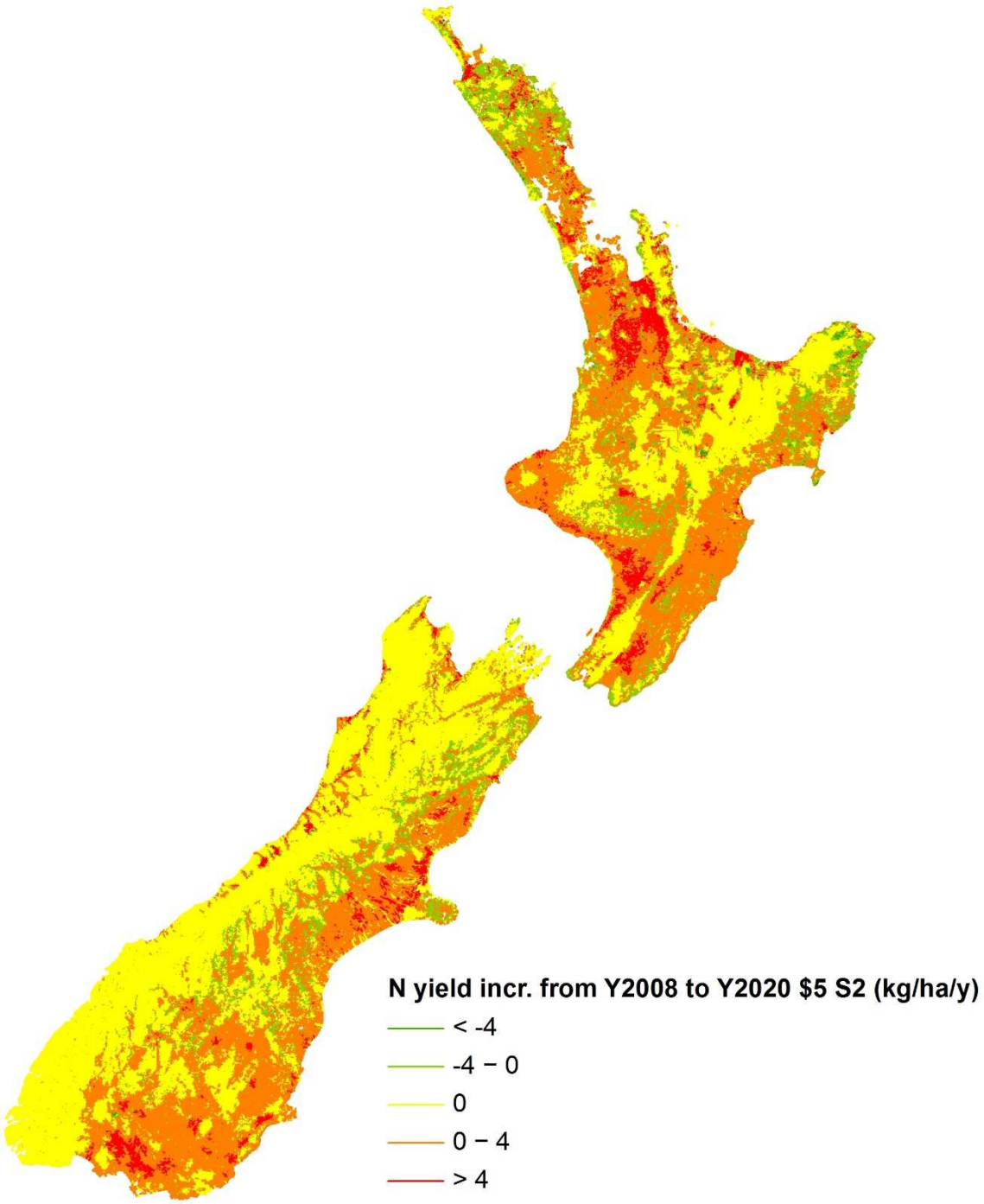

Figure 4: Change in predicted N generated yields (kg/ha/y) from scenario Y2008 to Y2020 $5 S2.

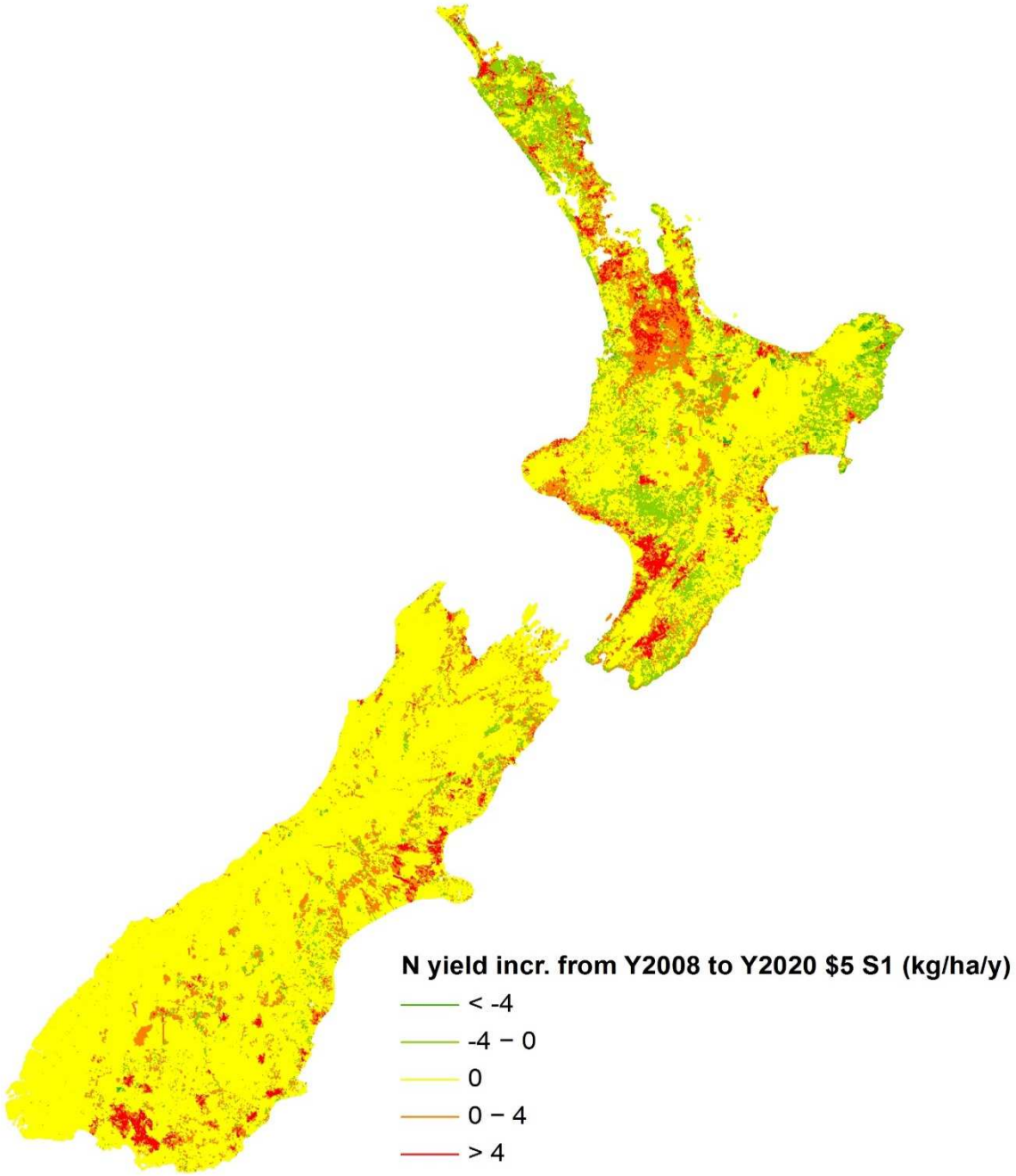

Figure 5: Change in predicted N generated yields (kg/ha/y) from scenario Y2008 to Y2020 $5 S1 showing land use change.

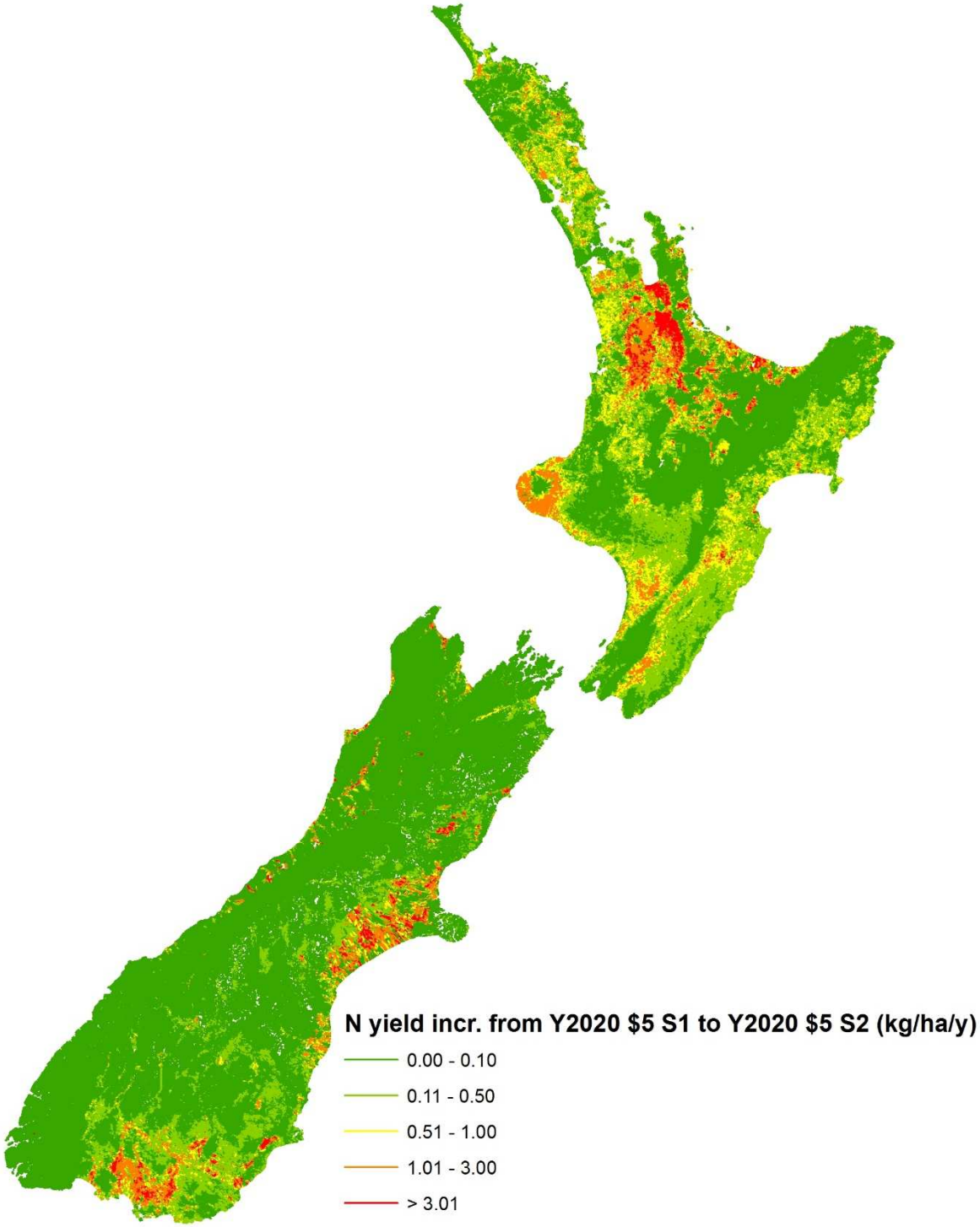

Figure 6: Change in predicted N generated yields (kg/ha/y) from scenario Y2020 $5 S1 to Y2020 $5 S2. The increases in this case are due to intensification.

The maps of P generated yield (Figure 7 and Figure A8 in the appendix) show the largest P generated yields occurred in the Southern Alps in the West Coast region. This is due to the large predicted erosion rates in that area. Large P generated yields were also predicted in other areas with high rates of erosion (e.g., East Cape, parts of Northland) and in dairying areas such as Waikato or Manawatu.

Note that it is the changes that are important, and not necessarily the baseline values that results are compared with. Increases in simulated P yield occur in areas where dairying is expected to expand, such as Southland and Canterbury (Figures 8 and 9). Figure 10 shows the effect of land use change on P yields. There are small predicted increases associated with intensification (Figure 11), reflecting the small sensitivity of the OVERSEER P model used in CLUES to stocking rate (which is consistent with the full OVERSEER model).

Decreases in predicted P yield occurred in some areas, such as parts of East Cape (i.e., Gisborne and Bay of Plenty), which are associated with new areas of forestry. This reduction in yield occurred because the P loss associated with forestry is less than the P loss OVERSEER predicted for pasture. However, these decreases were probably under-estimated because the mass erosion component of P loss in the model, which is added to other losses such as OVERSEER losses, does not change when land use is changed.

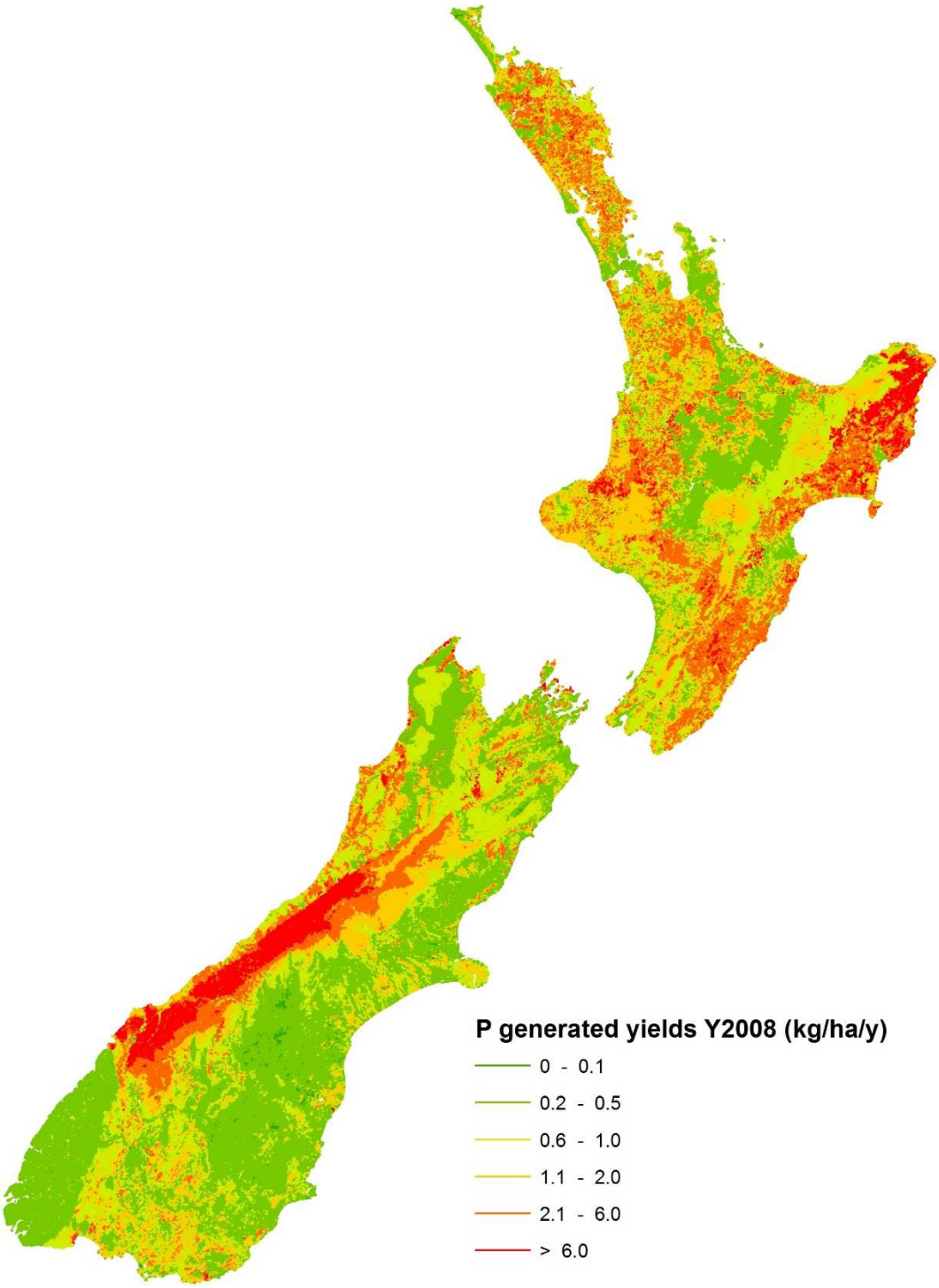

Figure 7: Map of P generated yields for scenario Y2008.

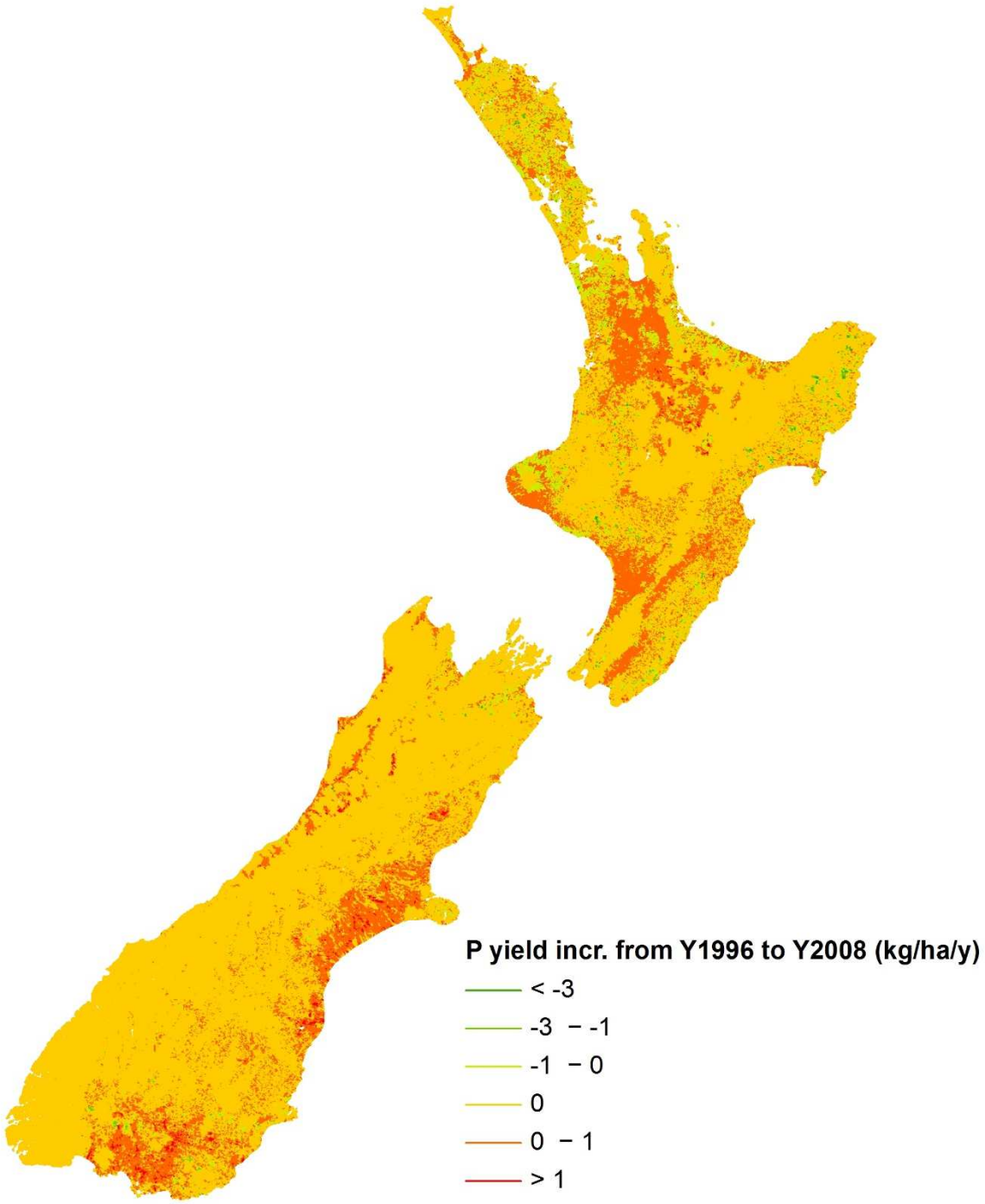

Figure 8: Change in P generated yields (kg/ha/y) from scenario Y1996 to Y2008. Positive

values denote an increase in yields from 1996 to 2008.

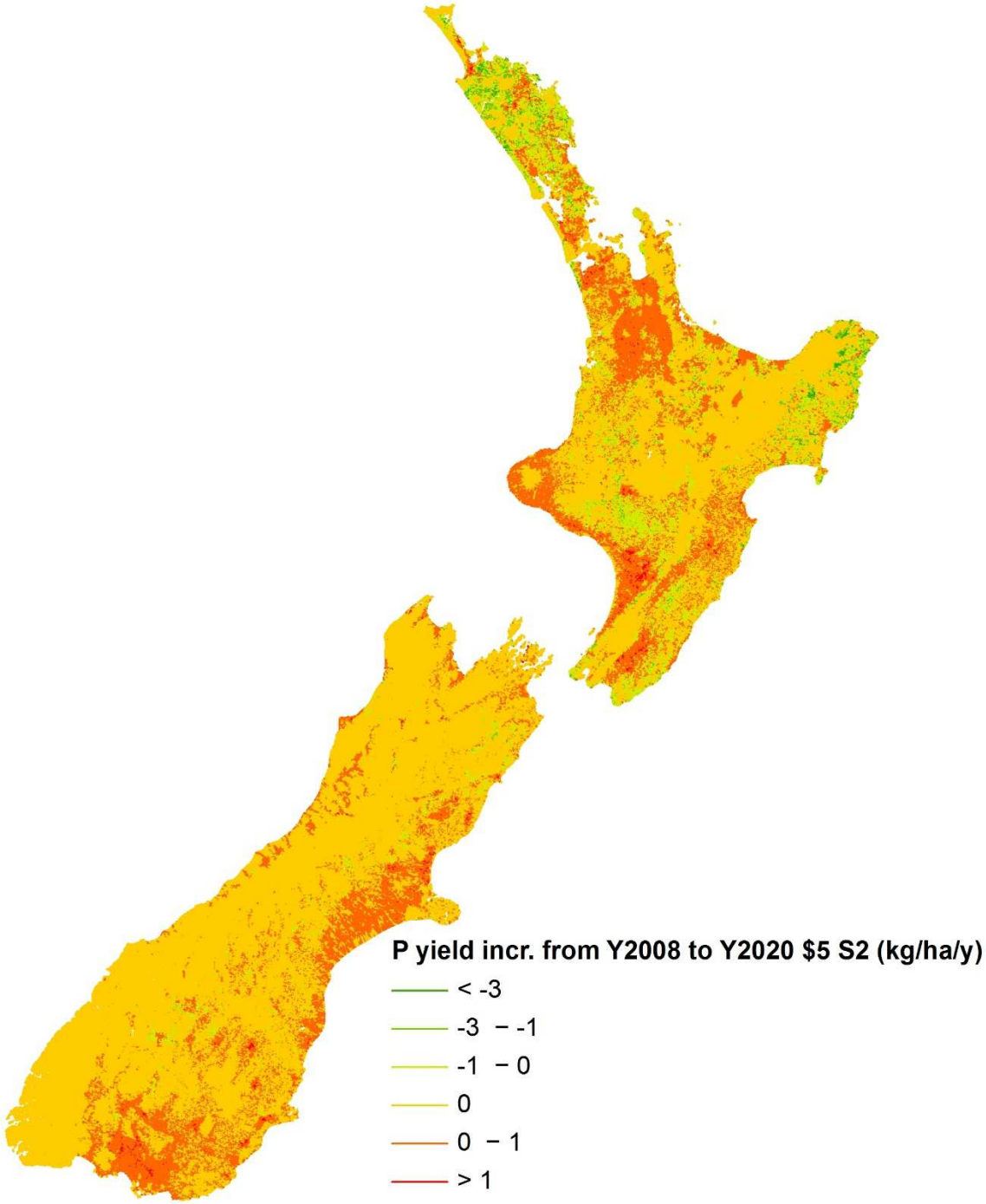

Figure 9: Change in predicted P generated yields (kg/ha/y) from scenario Y2008 to Y2020 $25 S2. Positive values denote an increase in yields from 2008 to 2020.

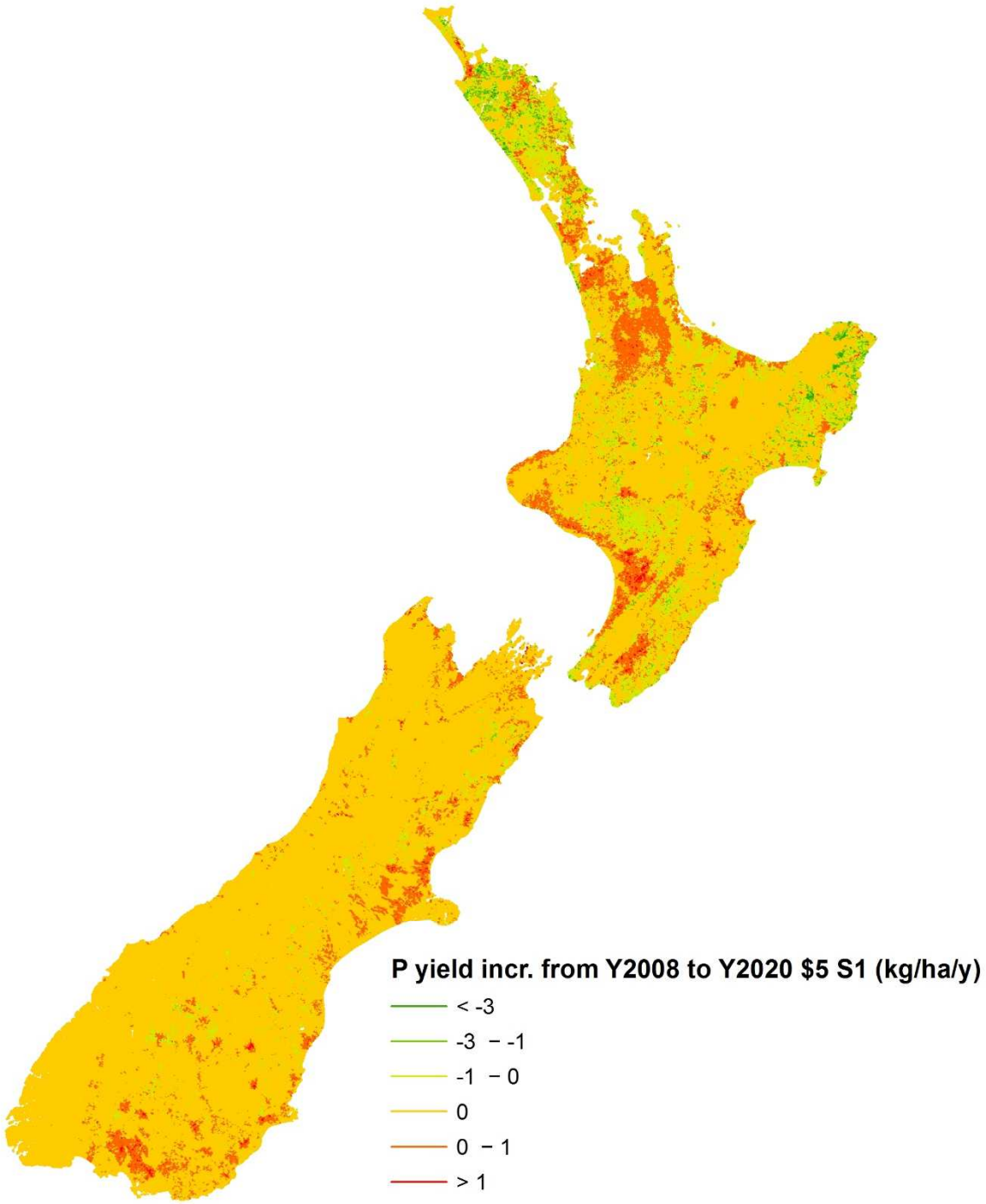

Figure 10: Change in predicted P generated yields (kg/ha/y) from scenario Y2008 to Y2020 $5 S1 showing land use change.

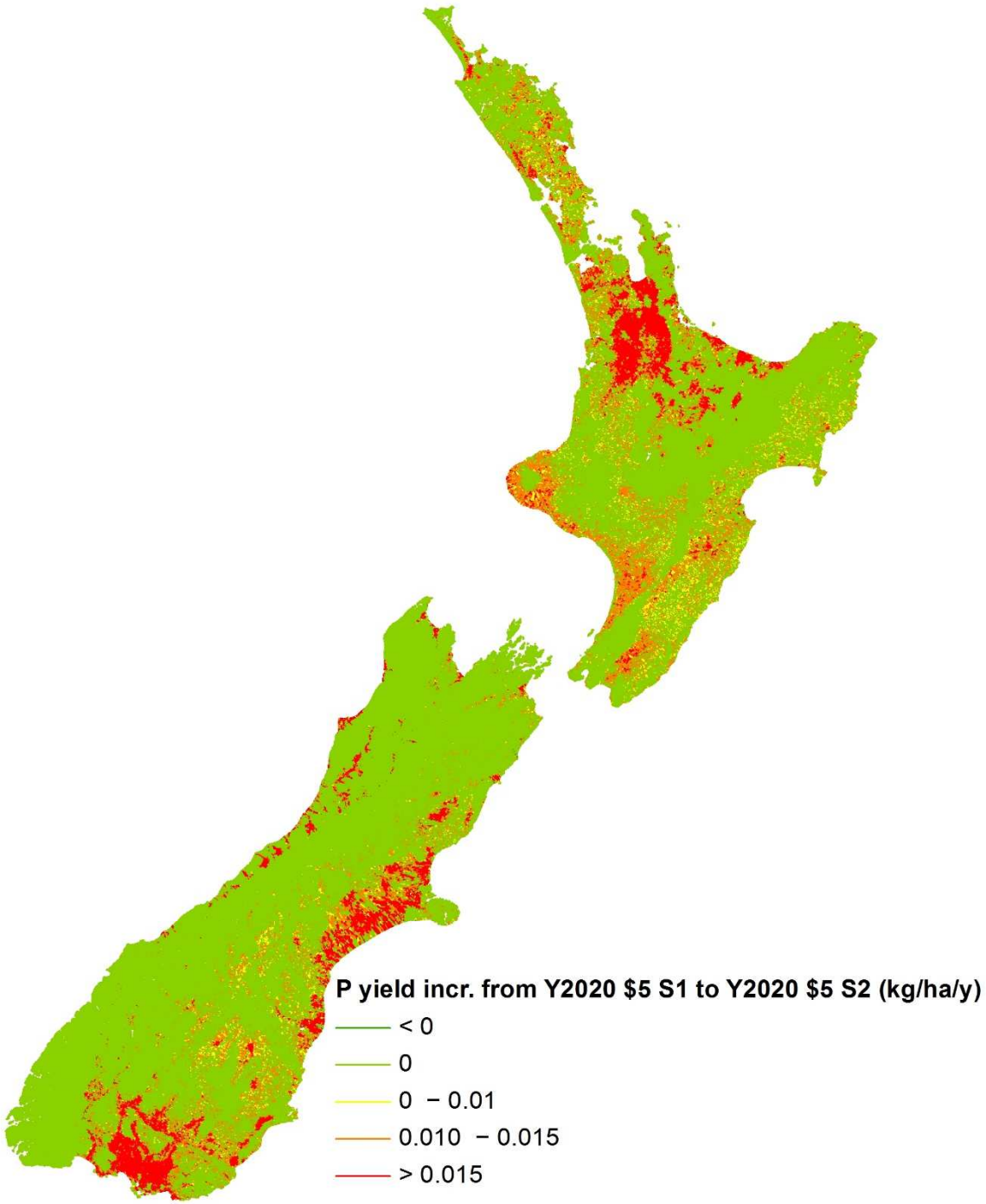

Figure 11: Change in predicted P generated yields (kg/ha/y) from scenario Y2020 $5 S1 to Y2020 $5 S2. The changes are due to intensification.

3.3 National and regional N and P generated loads

The predicted total generated loads of N entering streams across the country (Table 3, Figures 12 and 13) increased over time. Resulting N increases are generally due to projected land use changes moving away from sheep and beef into dairy. Generally, areas of sheep/beef decrease and are converted to either dairy (on flat land), forestry or scrub (on hilly land). The total load to the coast (data not given) follows the same patterns as the generated load.

Nationally, there was a slight increase between 1996 and 2008 and then a slight decrease in P load to 2020 (Figures 14 and 15 and Tables A8 and A10). This was due to the counteracting effects of changes in areas of dairying and afforestation. Generally, P decreases or stays about the same because there is less erosion of P from hilly land going to scrub or forestry, counteracting the effect of increased dairying.

The largest increases in N and P occurred between 1996 and 2008 as rates of land use change (to dairy) were higher in most regions during this period. Assumed carbon prices made little difference: almost none for N and very small for P.

Table 3: Summary of increases in the predicted national generated load.

Scenario	Increase from scenario Y1996 (%)	
	N generated load	P generated load
Y1996	0	0
Y2008	8.9	0.36
Y2020 $5 S1	15.3	-0.74
Y2020 $5 S2	20.2	-0.55
Y2020 $25 S1	15.5	-0.93
Y2020 $25 S2	20.4	-0.74

The N load increased over time in all regions (Figures 16 and 17 and Tables A7 and A9), with the exceptions of Auckland and Northland where the load decreased from 1996 to 2008 because the area of dairying decreased (Table A3). In Gisborne, simulated N loads decreased between 1996 and 2020 during which time hill country sheep and beef areas decreased considerably and planted forest and scrub areas increased.

In Auckland, there was a prominent increase in predicted N off a small baseline over time. The largest percentage increase in predicted N load occurred in Canterbury and Southland because there was a large percentage increase in dairying. An increase in predicted N loads in 2020 relative to 1996 of over 20% was also predicted for Waikato, Manawatu-Wanganui, Otago, and Wellington. In Waikato and Taranaki, the prediction is for a medium increase in N due to a medium change in farming from sheep and beef to dairy. In Otago, there was a large increase in predicted N from a low baseline and in Nelson and Tasman there was a medium increase from a low baseline. Marlborough was a good example of there being no change in simulated nutrients as a result of little land use change in general. In Gisborne, there is a decrease in the predicted N because areas of sheep and beef are predicted to be converted to forestry and scrub. In Wellington, there is a large predicted increase in N from a

low baseline, again driven by dairying. In Manawatu-Wanganui, there is a medium predicted increase in N due to a medium change in farming from sheep and beef to dairy.

Nationally, the predicted total generated loads of P entering streams did not change much over time (Figure 15) but the change over time varied regionally (Tables A8 and A10). In Northland, predicted P load decreased between 1996 and 2008 because the area of dairying is expected to decrease with a corresponding increase in the area of forestry on vulnerable soils. There is also expected to be a massive increase in scrub from 2008 to 2020. Similarly, in Bay of Plenty, Gisborne, and Hawkes Bay, there is a decrease in predicted P because sheep and beef areas are predicted to be converted to forestry. In contrast, in other regions such as Southland and Canterbury the predicted P load increased due to expected intensification and increased dairy areas, without afforestation. There is considerable regional variation in the P load changes (Figures 18 and 19, and Tables A8 and A10).

The model probably underestimated the decrease in P from afforestation, because the mass erosion source term does not take account of land cover changes. Note that mass erosion would become less when forest or scrub is planted because the plant roots hold the soil in place and make erosion less likely. P binds to the soil and the model is likely to be underestimating P losses. It would be desirable to improve this aspect of the model in future.

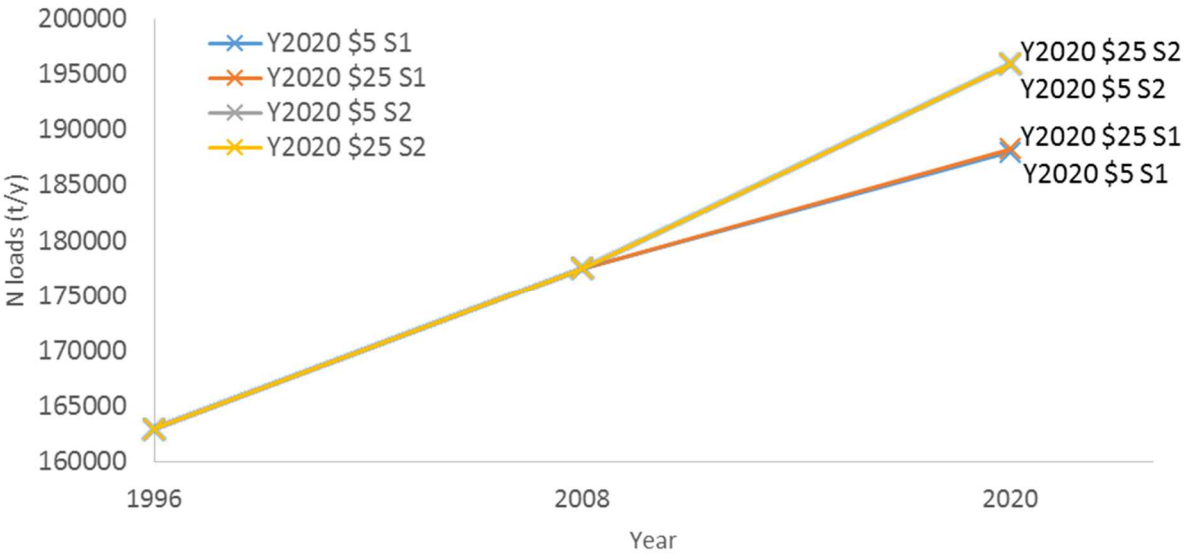

Figure 12: National N generated load for scenarios Y1996, Y2008, Y2020 $5 S1, Y2020 $5 S2, Y2020 $25 S1 and Y2020 $25 S2. The scale was started at 16 000 t/y so as to highlight changes.

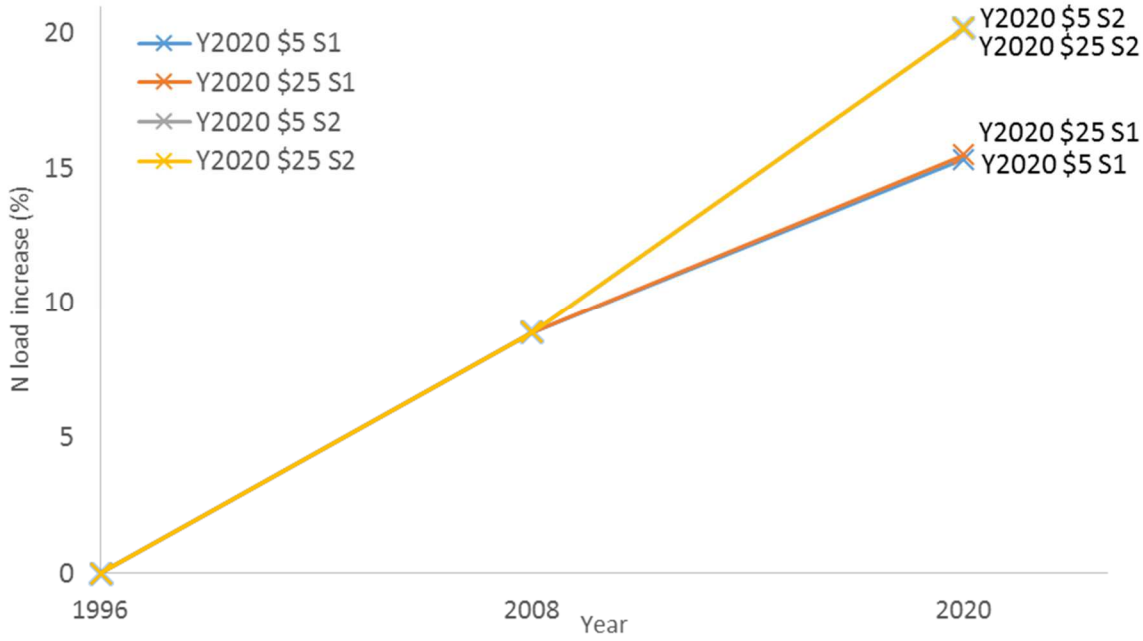

Figure 13: Percentage change in generated N loads, nationally for scenarios Y1996, Y2008, Y2020 $5 S1, Y2020 $5 S2, Y2020 $25 S1 and Y2020 $25 S2.

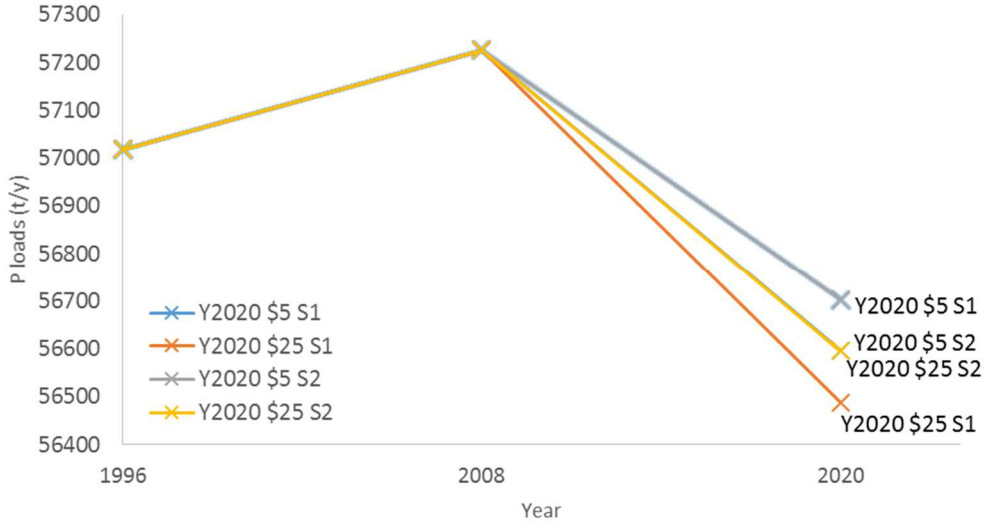

Figure 14: National P generated load for scenarios Y1996, Y2008, Y2020 $5 S1, Y2020 $5 S2, Y2020 $25 S1 and Y2020 $25 S2. The scale was started at 56400 t/y so as to highlight changes.

Figure 15: Percentage change in generated P loads, nationally for scenarios Y1996, Y2008, Y2020 $5 S1, Y2020 $5 S2, Y2020 $25 S1 and Y2020 $25 S2.

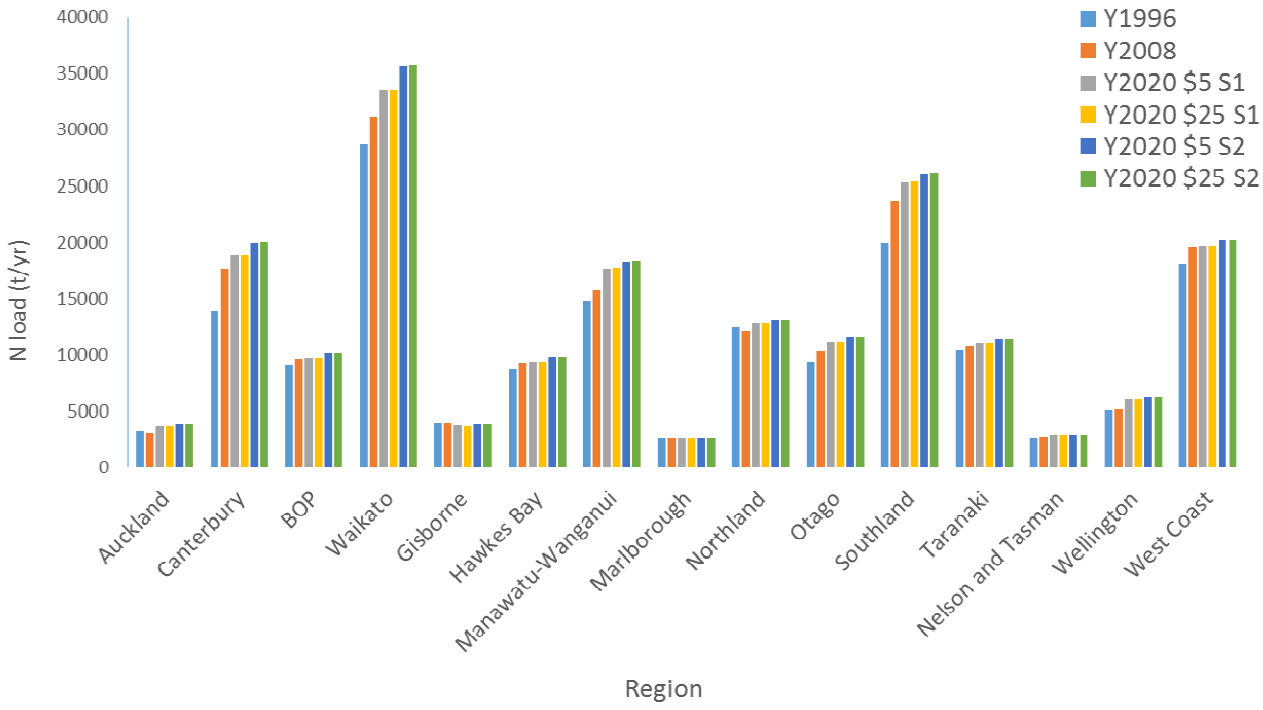

Figure 16: N generated load by region for scenarios Y1996, Y2008, Y2020 $5 S1, Y2020 $5 S2, Y2020 $25 S1 and Y2020 $25 S2.

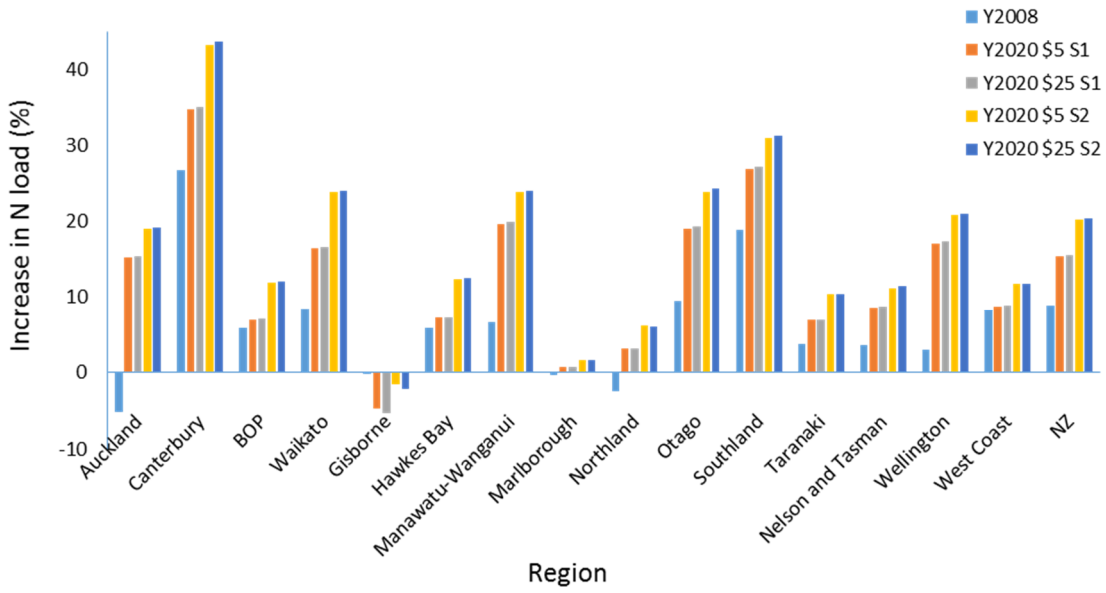

Figure 17: Percentage change in N generated load by region, relative to year 1996 for scenarios Y1996, Y2008, Y2020 $5 S1, Y2020 $5 S2, Y2020 $25 S1 and Y2020 $25 S2.

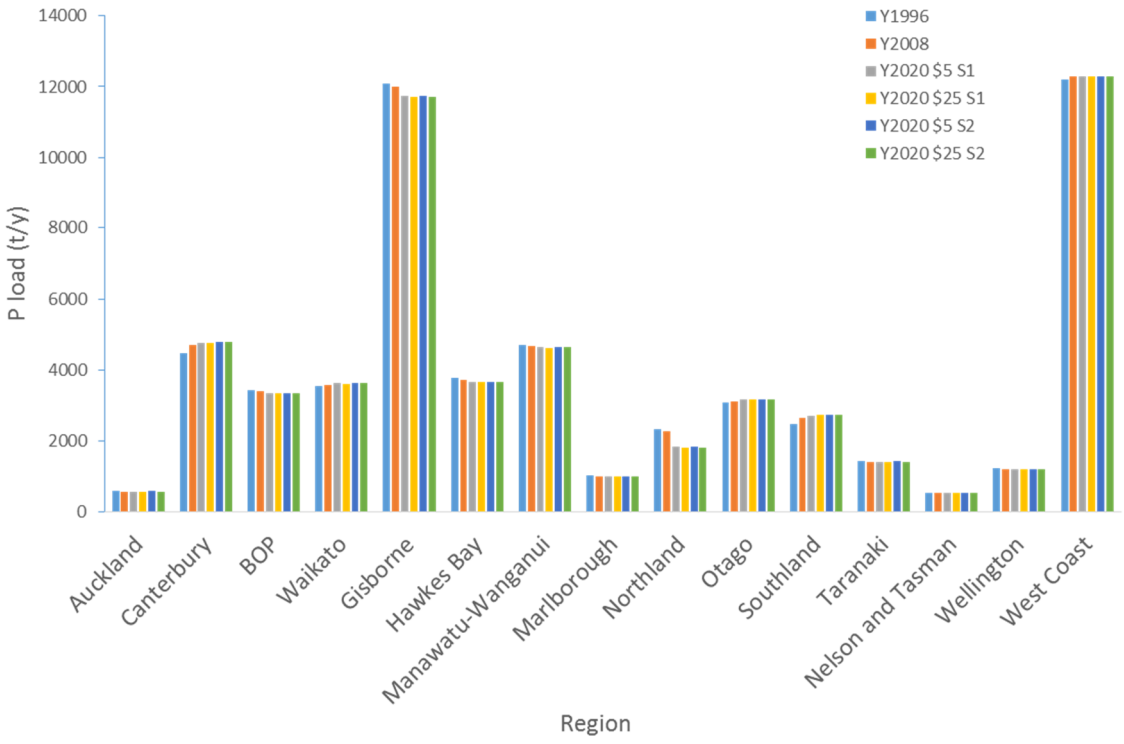

Figure 18: P generated load by region for scenarios Y1996, Y2008, Y2020 $5 S1, Y2020 $5 S2, Y2020 $25 S1 and Y2020 $25 S2.

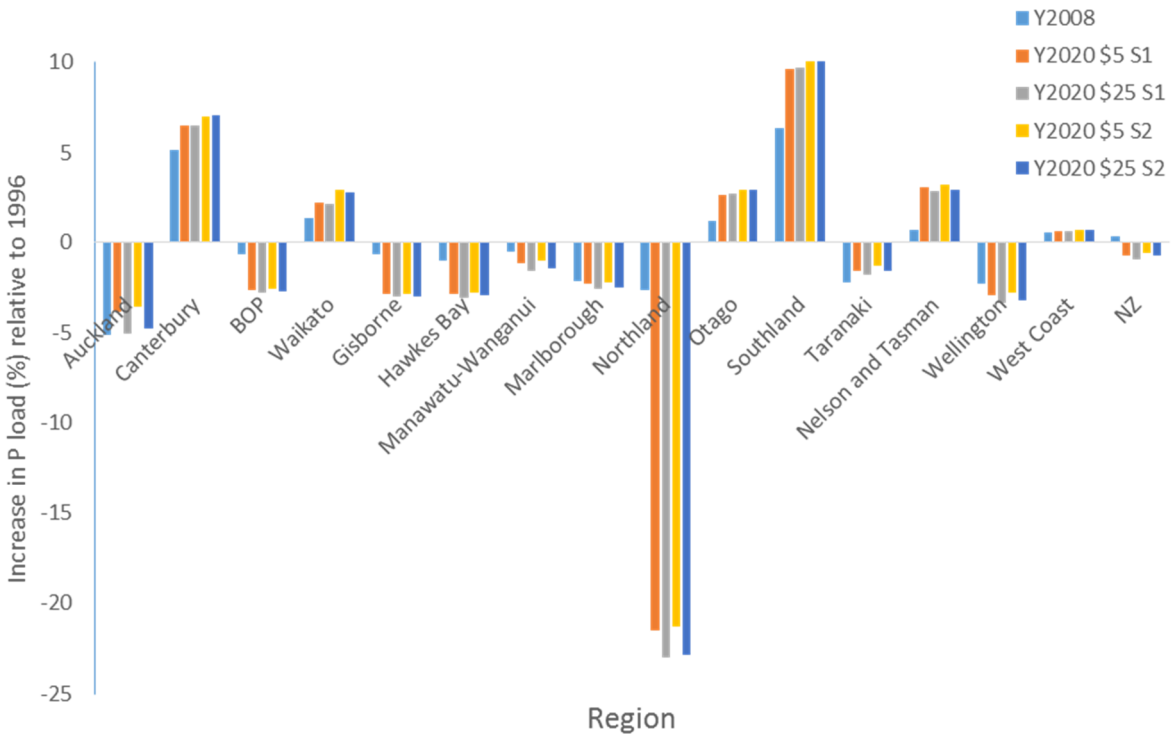

Figure 19: Percentage change in generated P load by region, relative to year 1996 for scenarios Y1996, Y2008, Y2020 $5 S1, Y2020 $5 S2, Y2020 $25 S1 and Y2020 $25 S2.

The increase in nutrient load is partly attributable to land use intensification (i.e., increased stocking rates). For the 'future' period from scenario Y2008 to Y2020 $5 S2, there is a 10.4% increase in predicted generated N load and a 0.9% decrease in generated P load. The difference in nutrient load between scenarios Y2020 $5 S1 and Y2020 $5 S2 is a measure of the effect of intensification over this period and 43% of the predicted N increase in this future period was due to intensification (see Table 4).

For the historical period from scenario Y1996 to Y2008, we did not have model runs with and without intensification. However, from subcatchments where the land use was unchanged, we were able to estimate the percentage increase in yield due to intensification for each land use. By taking these yield increases and the relevant land areas into account, we were able to derive an approximate estimate of the effect of intensification. Hence we estimated that 36% of the predicted N increase and 38% of the P increase from 1996 to 2008 was due to intensification. Over the full period from 1996 to 2020, an estimated 40% of the predicted N increase was due to intensification, the remaining 60% of the increase being the net effect of land use change.

The regional breakdown of the percentage increase in N load due to intensification for the period 2008 to 2020 is shown in Table 4. Results are not shown for P because the overall change was negative in many cases. Results are not shown for other periods because the relevant model runs were not conducted. The percentages are largest where there is relatively stable pastoral land use.

Table 4: Changes in regional N loads between Y2008 and Y2020 $5, due to intensification as approximated by increased stocking rates.

Region	Percentage of total N load changes predicted from scenario Y2008 to Y2020 $5, due to intensification
Auckland	15.4
Canterbury	51.7
BOP	82.8
Waikato	48.0
Gisborne	–
Hawkes Bay	79.0
Manawatu-Wanganui	24.5
Marlborough	45.4
Northland	33.7
Otago	34.2
Southland	34.0
Taranaki	52.6
Nelson-Tasman	34.0
Wellington	20.8
West coast	86.4
NZ	43.0

3.4 Concentrations

The predicted concentration increases are shown in Tables 5 and 6 and Figures 20 and 21. Concentration values from the model of Unwin et al. (2010), which relate to the period from 2003 to 2007, are shown for reference. The absolute concentrations from Unwin et al. (2010) are probably more reliable than the absolute values from CLUES, because the Unwin et al. model was determined by calibration to concentrations and 601 sites were used, whereas CLUES concentrations are derived indirectly from load estimates and used only 77 calibration sites. Hence we use the Unwin et al. (2010) concentrations to approximate the current conditions. Percentage increases from CLUES may be also used, for the same reasons, to give future concentrations by adjusting Unwin et al. (2010) concentrations appropriately. In all cases, the concentrations are predictions for the median concentration at a location, and we examine the distribution (percentiles) of this concentration across all the REC stream reaches. For example, the 10-percentile of the distribution is the median concentration that is exceeded by 90% of the REC stream reaches.

The lower percentiles of the distribution, such as the 10-percentile and 50-percentile, change only slightly over time. This is because low-intensity land uses (such as native forest and high country), which are associated with the lower and medium concentrations, remain in the same or similar state over time.

The higher percentiles, such as the 95-percentile concentrations increase significantly over time. This is partly due to increases in the area and intensity of intensive pastoral land use in catchments where there is already intensive land use, and partly due to the introduction of dairying into some catchments where there was previously low-intensity land use (but it

would be difficult to provide this breakdown). The 50-percentile increased by 0.94% for N and -0.65% for P from scenario Y1996 to Y2020 $5 S2, and the 95-percentile increased by 49% for N and 10.4% for P, from scenario Y1996 to Y2020 $5 S2.

The significant increase at higher percentiles predicted here is consistent with trends in the National Rivers Water Quality Network (NRWQN) which show a steady increase of N in rivers where this nutrient is already high (Scarsbrook, 2006). Ballatine and Davies-Colley (2010) showed an overall increase in N and P concentrations over 1989-2007 for sites in the NRWQN. However, their analysis showed that the median increased was positive (0.98% per year for N and 0.47% per year for P). It is hard to know whether this discrepancy for the median increase is due to site bias in Ballantine and Davies-Colley (2010) or inaccuracy in our work. Overall though, our results are broadly consistent with the trends observed nationally.

Table 5: N concentration change relative to concentrations from scenarios Y1996 and Y2008.

Percentile	Unwin et al. (2010) conc. (g/m^3)	Increase (%)								
		Y1996 to Y2008	Y1996 to Y2020 $5 S1	Y1996 to Y2020 $25 S1	Y1996 to Y2020 $5 S2	Y1996 to Y2020 $25 S2	Y2008 to Y2020 $5 S1	Y2008 to Y2020 $25 S1	Y2008 to Y2020 $5 S2	Y2008 to Y2020 $25 S2
1	0.10	0.07	0.08	0.08	0.09	0.09	0.01	0.01	0.02	0.02
2	0.12	0.04	0.15	0.17	0.15	0.17	0.12	0.13	0.12	0.13
3	0.13	0.07	0.22	0.22	0.24	0.24	0.15	0.15	0.16	0.16
4	0.14	0.17	0.60	0.60	0.68	0.68	0.43	0.43	0.51	0.51
5	0.16	0.10	0.82	0.83	0.84	0.85	0.72	0.72	0.74	0.75
10	0.21	0.20	1.94	1.99	1.99	2.02	1.74	1.79	1.79	1.82
15	0.25	0.29	1.95	1.98	1.99	2.06	1.65	1.69	1.69	1.76
20	0.30	0.36	1.61	1.64	1.71	1.73	1.25	1.27	1.34	1.36
25	0.35	0.36	1.22	1.22	1.32	1.32	0.86	0.86	0.96	0.96
30	0.41	0.47	0.72	0.71	0.93	0.92	0.25	0.24	0.46	0.45
35	0.47	0.37	0.32	0.30	0.57	0.56	-0.05	-0.07	0.20	0.19
40	0.54	0.43	0.18	0.14	0.63	0.59	-0.25	-0.29	0.19	0.16
45	0.62	0.65	0.13	0.08	0.71	0.64	-0.51	-0.57	0.06	-0.01
50	0.71	0.83	0.04	-0.05	0.94	0.84	-0.79	-0.87	0.11	0.01
55	0.79	1.31	0.20	0.06	1.46	1.31	-1.09	-1.23	0.15	0.00
60	0.91	1.76	0.78	0.59	2.52	2.32	-0.97	-1.15	0.74	0.55
65	1.08	2.46	1.56	1.38	3.73	3.53	-0.88	-1.06	1.24	1.05
70	1.31	3.36	2.79	2.64	5.49	5.34	-0.56	-0.70	2.05	1.91
75	1.57	4.45	4.58	4.47	8.04	7.93	0.12	0.01	3.43	3.33
80	1.79	5.74	7.10	7.06	11.19	11.17	1.29	1.25	5.15	5.13
85	2.02	7.93	11.30	11.43	16.13	16.32	3.12	3.24	7.59	7.77
90	2.40	12.09	19.88	20.19	26.01	26.42	6.95	7.22	12.42	12.78
95	2.99	21.15	39.53	40.25	48.66	49.37	15.17	15.77	22.71	23.29
96	3.16	23.52	43.76	44.48	53.81	54.62	16.38	16.97	24.52	25.17
97	3.42	23.69	44.09	44.54	54.78	55.47	16.49	16.85	25.13	25.69
98	3.79	22.77	42.88	43.30	54.08	54.62	16.38	16.72	25.50	25.95
99	4.27	22.60	43.21	43.88	54.32	54.99	16.81	17.36	25.87	26.42

Table 6: P concentration change relative to concentrations from scenarios Y1996 and Y2008.

Percentile	Unwin et al. (2010) conc. (g/m^3)	Increase (%)								
		Y1996 to Y2008	Y1996 to Y2020 $5 S1	Y1996 to Y2020 $25 S1	Y1996 to Y2020 $5 S2	Y1996 to Y2020 $25 S2	Y2008 to Y2020 $5 S1	Y2008 to Y2020 $25 S1	Y2008 to Y2020 $5 S2	Y2008 to Y2020 $25 S2
1	0.01	-0.03	-0.03	-0.03	-0.02	-0.03	0.00	0.00	0.02	0.00
2	0.01	0.04	0.05	0.04	0.07	0.06	0.00	0.00	0.02	0.02
3	0.01	0.09	-0.02	-0.06	0.00	-0.04	-0.11	-0.15	-0.09	-0.13
4	0.01	0.06	-0.11	-0.13	-0.06	-0.11	-0.17	-0.19	-0.12	-0.16
5	0.01	0.23	-0.05	-0.05	-0.03	-0.04	-0.28	-0.28	-0.26	-0.27
10	0.01	0.18	-0.31	-0.37	-0.29	-0.34	-0.49	-0.54	-0.47	-0.51
15	0.02	0.19	-0.32	-0.36	-0.27	-0.31	-0.51	-0.55	-0.47	-0.50
20	0.02	0.23	-0.35	-0.41	-0.27	-0.35	-0.58	-0.64	-0.50	-0.58
25	0.02	0.25	-0.47	-0.56	-0.38	-0.46	-0.72	-0.82	-0.63	-0.72
30	0.02	0.26	-0.66	-0.83	-0.51	-0.68	-0.92	-1.09	-0.77	-0.94
35	0.02	0.22	-0.83	-0.98	-0.65	-0.82	-1.05	-1.20	-0.87	-1.04
40	0.02	0.36	-0.95	-1.11	-0.73	-0.89	-1.30	-1.46	-1.08	-1.25
45	0.03	0.25	-1.09	-1.25	-0.78	-0.96	-1.33	-1.49	-1.03	-1.21
50	0.03	0.48	-0.97	-1.18	-0.65	-0.85	-1.44	-1.65	-1.12	-1.32
55	0.03	0.69	-0.79	-1.03	-0.41	-0.62	-1.47	-1.70	-1.10	-1.30
60	0.04	1.08	-0.45	-0.70	0.04	-0.21	-1.51	-1.76	-1.02	-1.27
65	0.04	1.48	0.09	-0.21	0.63	0.35	-1.37	-1.66	-0.84	-1.11
70	0.05	1.96	0.69	0.42	1.33	1.01	-1.24	-1.51	-0.62	-0.93
75	0.05	2.49	1.51	1.21	2.14	1.84	-0.96	-1.25	-0.34	-0.63
80	0.06	3.01	2.37	2.03	2.98	2.63	-0.62	-0.95	-0.03	-0.37
85	0.07	3.40	3.44	3.07	4.07	3.68	0.04	-0.33	0.64	0.27
90	0.09	3.89	5.14	4.87	5.82	5.56	1.21	0.95	1.86	1.61
95	0.10	5.30	9.46	9.39	10.40	10.35	3.95	3.89	4.84	4.79
96	0.11	5.94	10.89	10.78	11.86	11.68	4.67	4.57	5.59	5.43
97	0.11	6.97	12.76	12.70	13.90	13.77	5.41	5.36	6.48	6.36
98	0.12	8.19	15.65	15.70	16.85	16.90	6.89	6.94	8.00	8.05
99	0.14	10.42	17.87	18.08	19.25	19.46	6.74	6.94	7.99	8.18

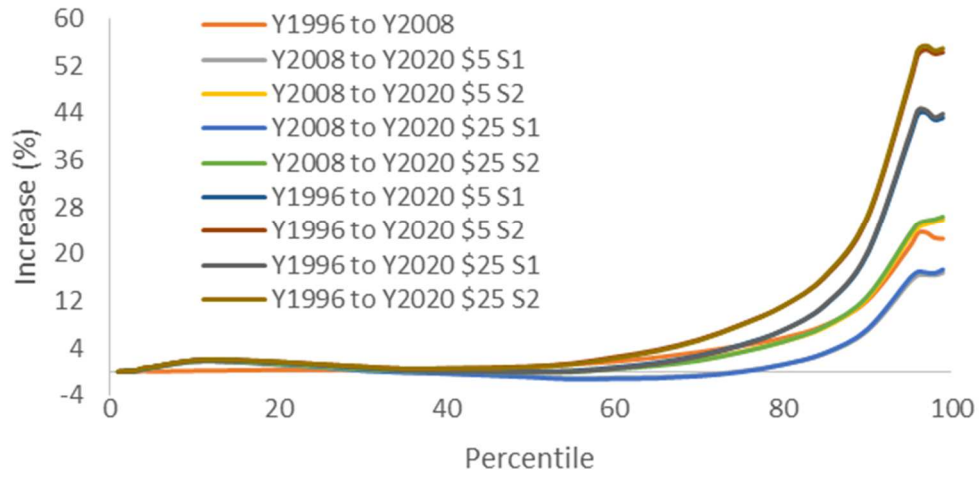

Figure 20: Relative change (%) in the nth percentile of the distribution of N concentrations over REC reaches relative to concentrations from scenarios Y1996 and Y2008.

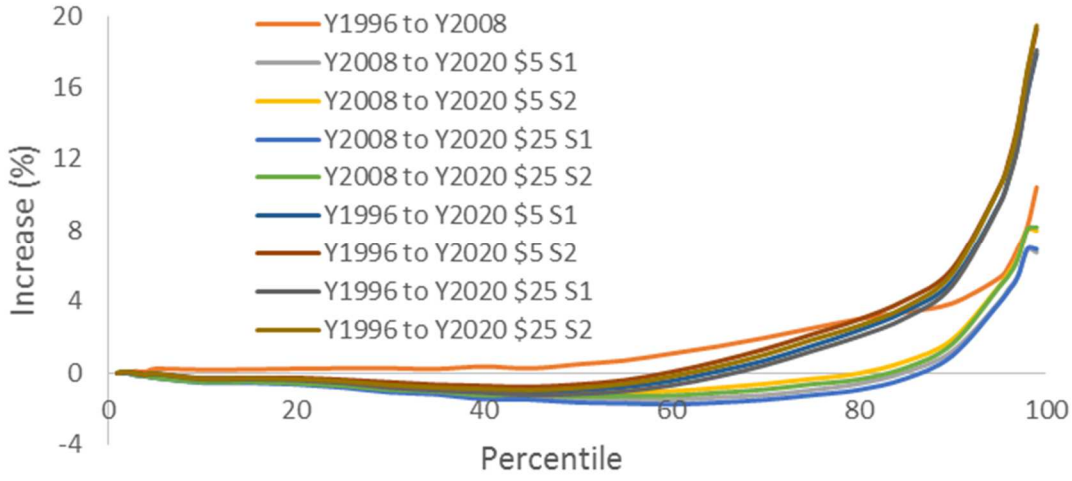

Figure 21: Relative change (%) in the nth percentile of the distribution of P concentrations over REC reaches relative to concentrations from scenarios Y1996 and Y2008.

4 Summary of key results

Predicted national N loads increased significantly over time, as a result of both intensification and land use change. P increased initially between 1996 and 2008 but is predicted to decrease by a relatively small amount overall due to counteracting effects of changes in areas of dairying and changes in afforestation.

Predicted N loads increased over time in all regions with the exception of Auckland and Northland, where the load decreased slightly from 1996 to 2008 because the area of dairying decreased. In Gisborne, predicred N loads decreased from 1996 to 2020, due to a projected considerable decrease in hill country sheep and beef areas and a corresponding increase in planted forest and scrub areas. The largest percentage increase in predicted N loads in 2008 and 2020, relative to 1996, occurred in the Canterbury and Southland region, associated with the large increases in dairying expected in these regions.

Predicted P loads decreased slightly overall nationally, with increases in some regions and decreases in others. In Northland, the predicted P load decreases because the modelled area of dairying decreases with a corresponding increase in the area of forestry on vulnerable soils. In Northland, there is also a decrease in predicted P because sheep and beef areas are reverting to scrub. In Bay of Plenty, there is a decrease in predicted P because sheep and beef areas being planted for forestry. In other regions, such as Gisborne and Hawkes Bay, there is an overall decrease because the effect of increased dairy is outweighed by the effect of afforestation. In areas such as Southland, though, there is an overall increase in P predicted due to increased dairying without afforestation, while in other regions, such as Canterbury, the predicted P load increased due to intensification and increased dairy areas.

The increase in predicted nutrient load is partly attributable to intensification simulated here as increased stock rates. For the historical period from 1996 to 2008, we estimated that 36% of the predicted N increase and 38% of the P increase from 1996 to 2008 was due to intensification. For the ‘future’ period from scenario Y2008 to Y2020 $5 there was a 10.4% increase in predicted generated N load and a 0.9% decrease in generated P load. Also, 43% of the predicted N increase in this future period was due to intensification. Over the full period from 1996 to 2020, an estimated 39% of the predicted N increase was due to intensification, the remaining 60% of the increase being the net effect of land use change.

The $5 carbon prices on land use had little effect on N and P loads compared to the $25 carbon prices on land use.

The lower percentiles of the distribution of predicted nurtrient concentration, such as the 10-percentile and 50 percentile, changed only slightly over time, because the low-intensity land uses associated with low-medium concentrations remained largely unchanged. Higher percentiles such as the 95-percentile concentrations increased by 49 % for N and 10.4 % for P from 1996 to 2020 (Scenario Y2020 $5 S2).

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Appendix 1. Regional boundaries and regional codes

The regional boundaries and codes used to summarise results data is given in Figure A1 and Table A1, respectively. Note that these boundaries are not the same as the CLUES model regional boundaries.

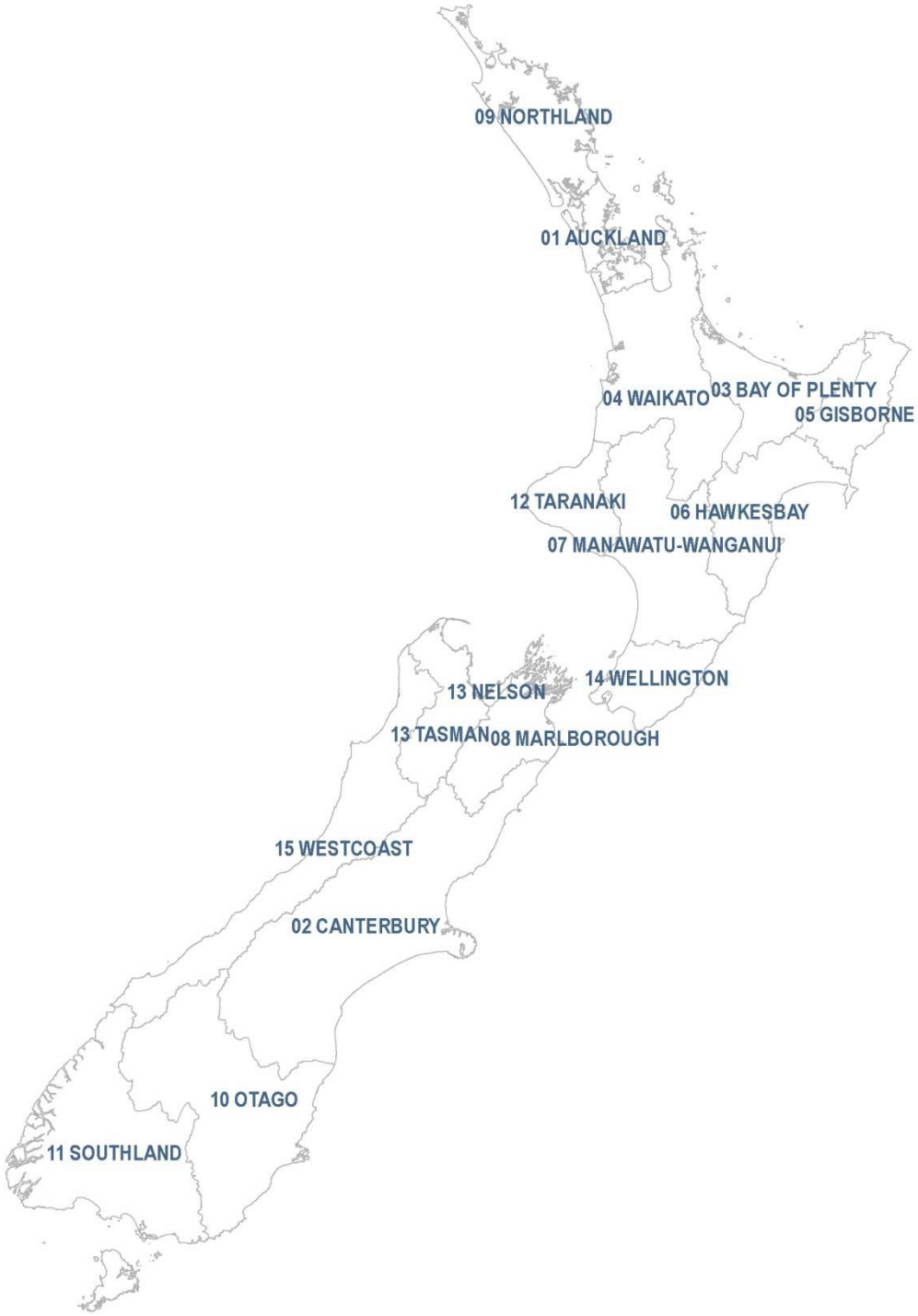


Figure A1: CLUES regional boundaries.

Table A1: Regional codes.

Region	Code
Auckland	1
Canterbury	2
Bay of Plenty	3
Waikato	4
Gisborne	5
Hawkes Bay	6
Manawatu-Wanganui	7
Marlborough	8
Northland	9
Otago	10
Southland	11
Taranaki	12
Nelson and Tasman	13
Wellington	14
West Coast	15

Appendix 2. Maps of CLUES dairy, sheep & beef, planted forest, native forest, scrub and urban classes

The following maps show the land use scenarios developed by Motu after reclassification into CLUES format. White areas denote other land uses such as urban areas, bare soil, rivers and lakes. The land use maps were created by combining the LURNZ land use maps provided by Motu with CLUES land use layers. This involved reclassifying some of the LURNZ land use classes to equivalent CLUES land use classes. Details are given in Section 2.1.

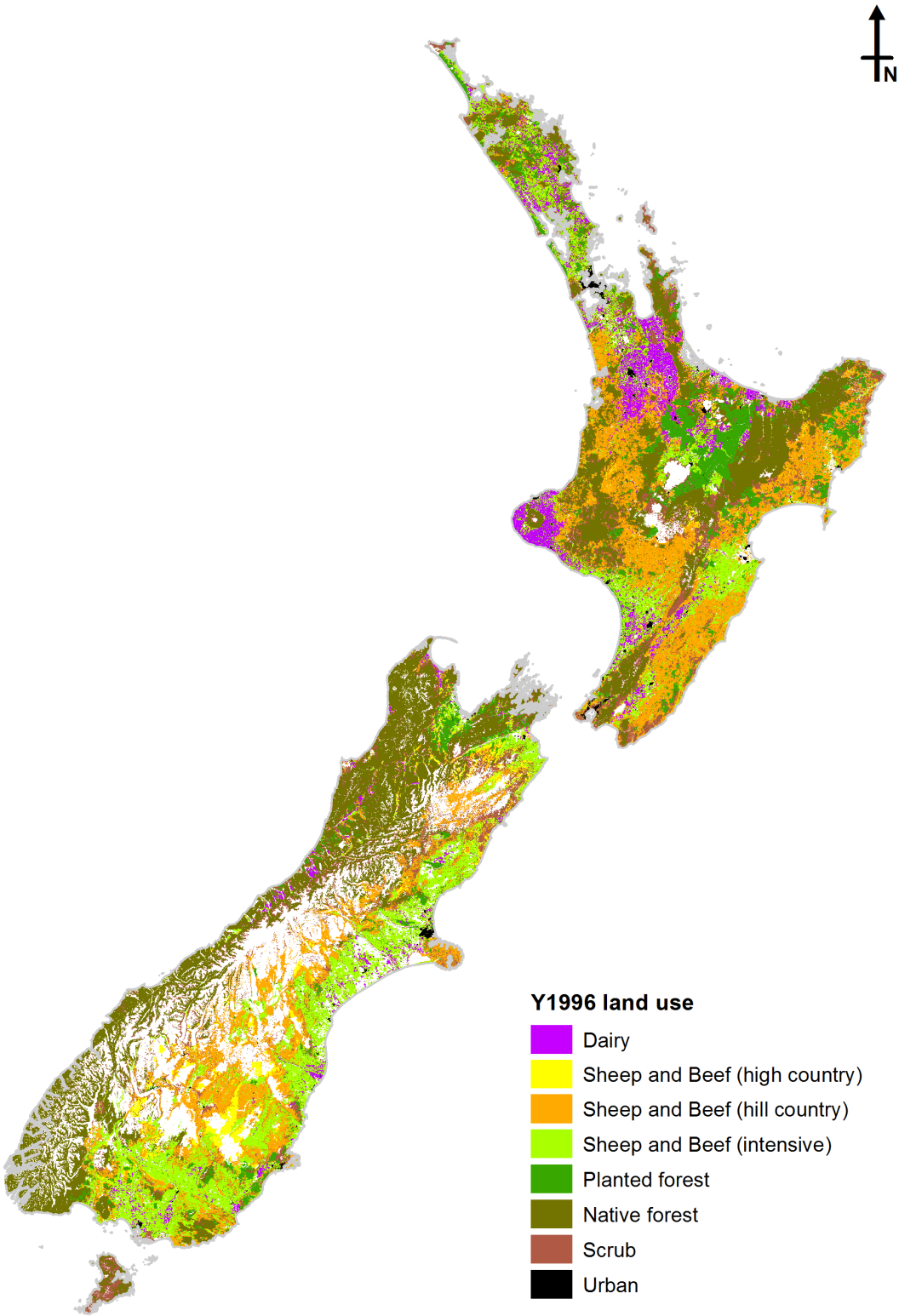


Figure A2: Map of CLUES land use layers for dairy, sheep & beef, planted forest, native forest, scrub and urban classes for scenario Y1996.

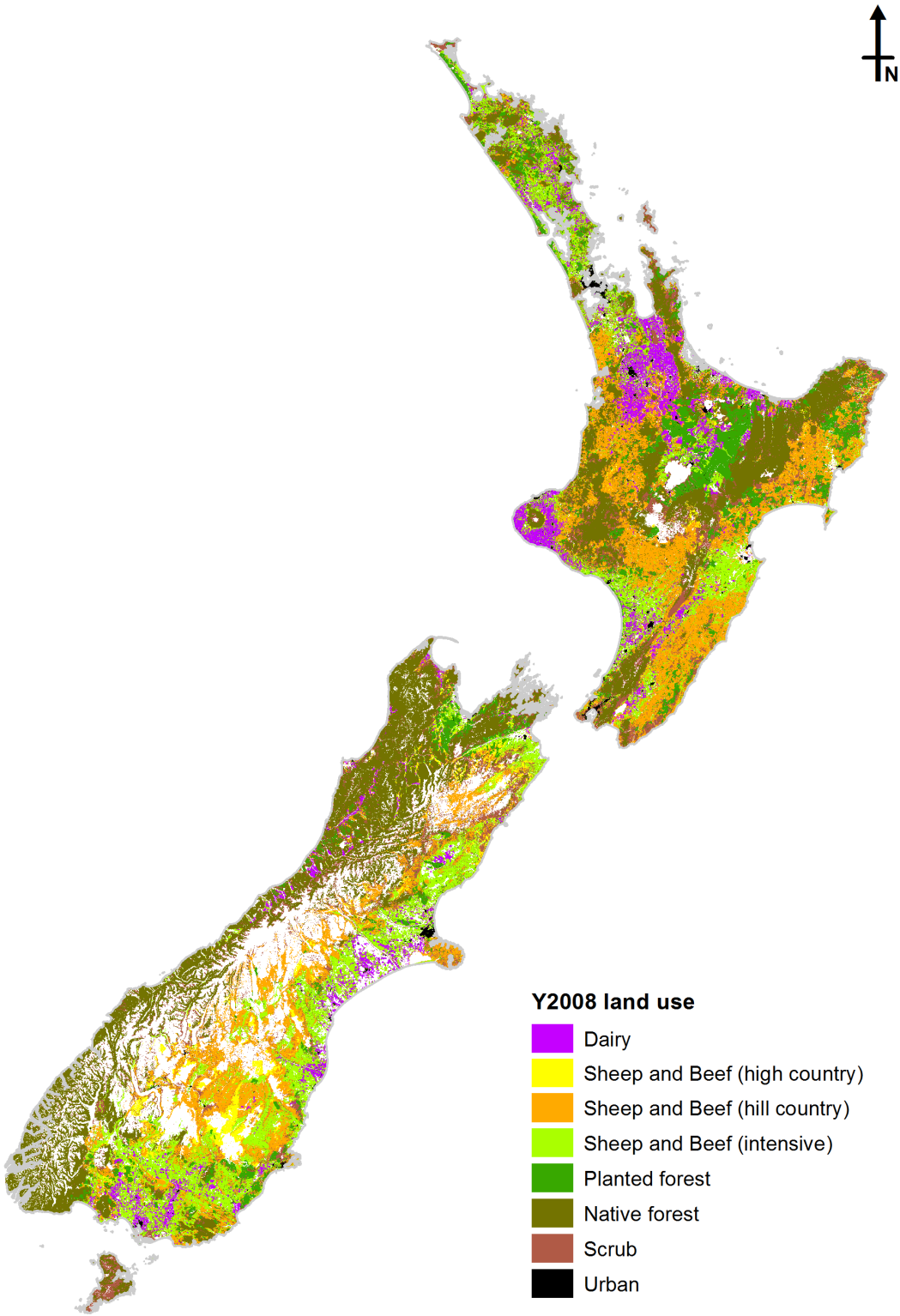


Figure A3: Map of CLUES land use layers for dairy, sheep & beef, planted forest, native forest, scrub and urban classes for scenario Y2008.

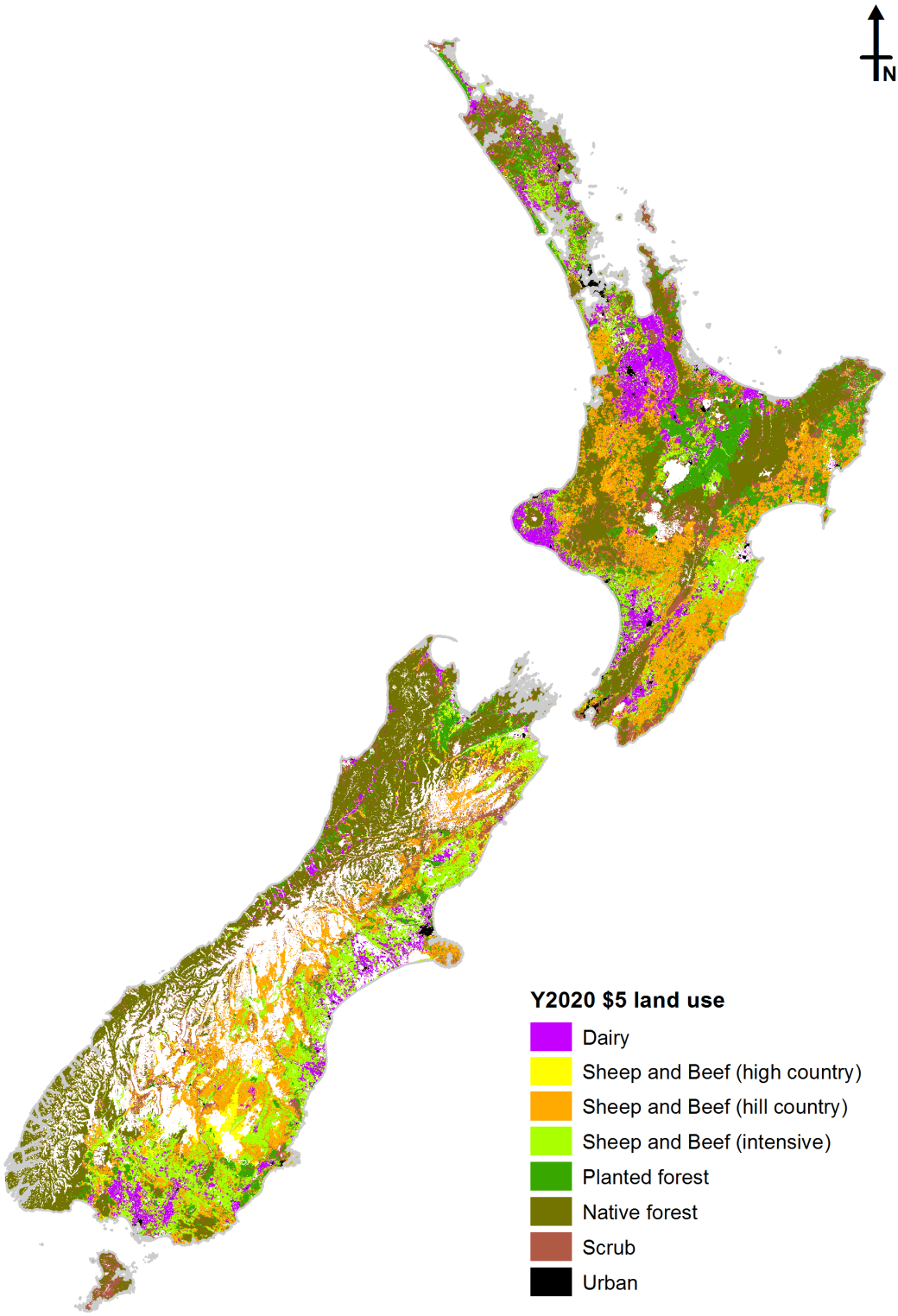


Figure A4: Map of CLUES land use layers for dairy, sheep & beef, planted forest, native forest, scrub and urban classes for scenario Y2020 $5.

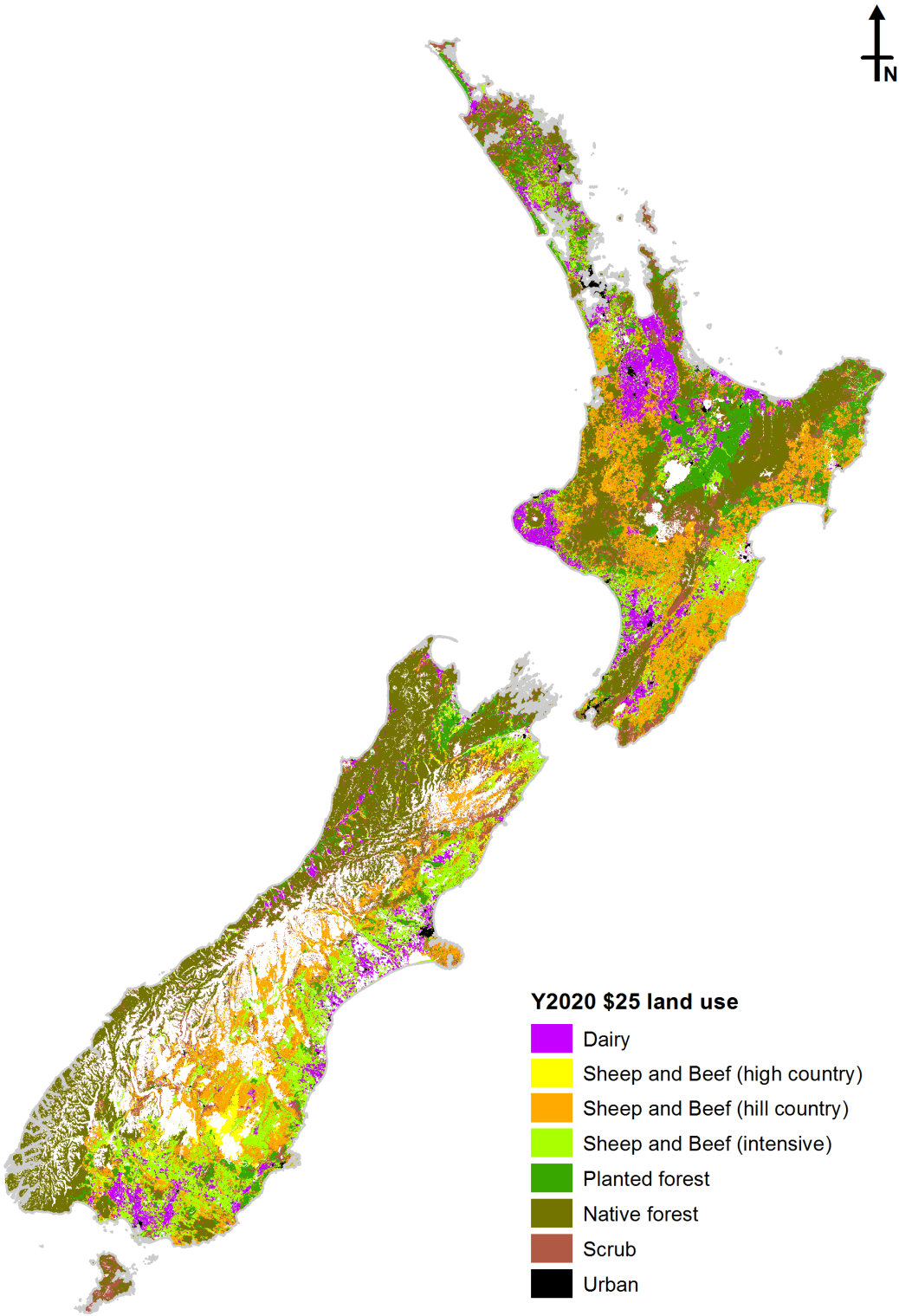


Figure A5: Map of CLUES land use layers for dairy, sheep & beef, planted forest, native forest, scrub and urban classes for scenario Y2020 $25.

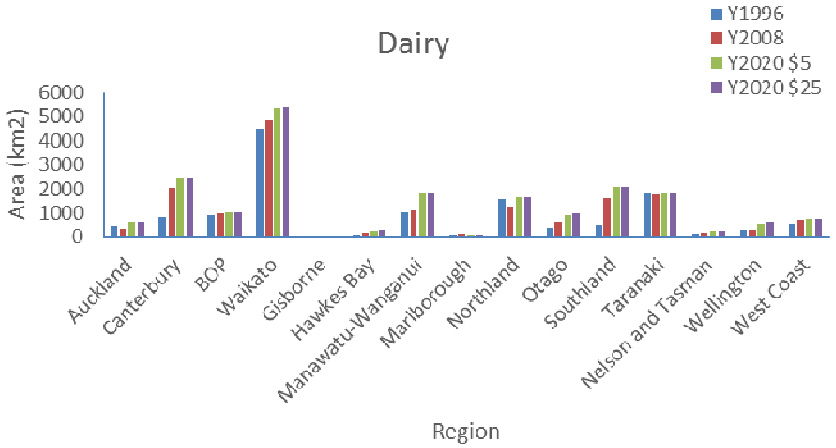
Appendix 3. Landuse areas used for the CLUES input data

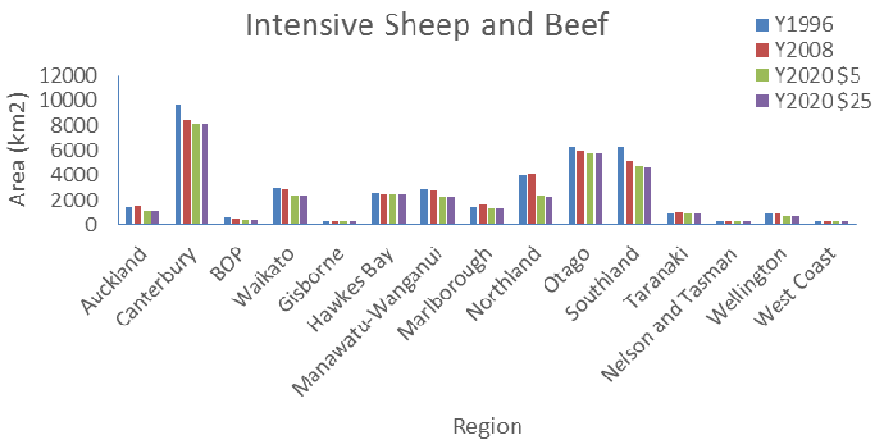
The following tables and figures present the regional and national areas of dairy, sheep and beef, planted forest, native forest, scrub, and urban areas and the changes in these areas over time.

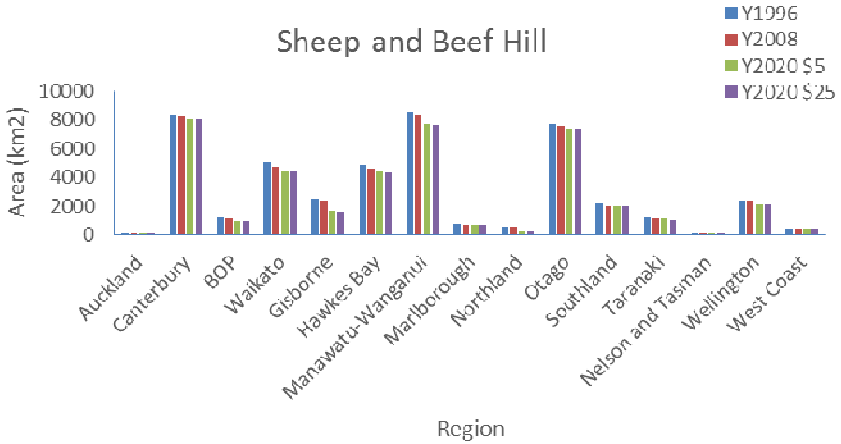
Table A2: Areas (km^2).

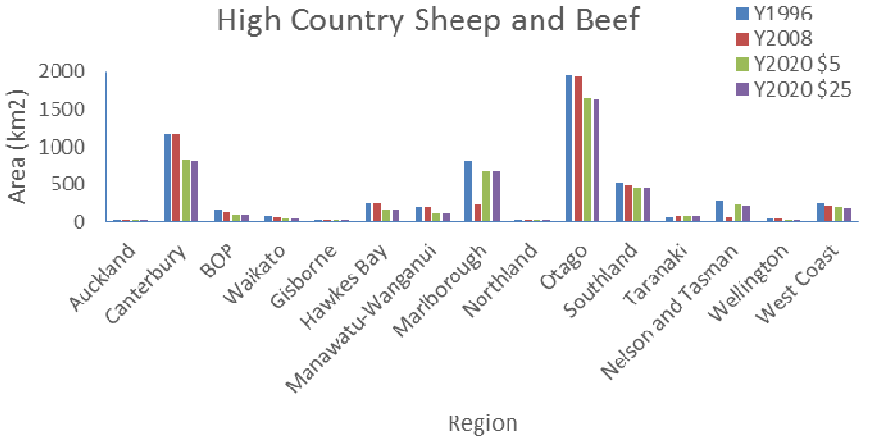
Region	Dairy				Intensive Sheep and Beef				Sheep and Beef Hill Country				Sheep and Beef High Country			
	Y1996	Y2008	2020 $5	2020 $25	Y1996	Y2008	2020 $5	2020 $25	Y1996	Y2008	2020 $5	2020 $25	Y1996	Y2008	2020 $5	2020 $25
Auckland	440	313	585	588	1457	1530	1186	1164	87	84	63	61	0	0	0	0
Canterbury	806	2042	2423	2443	9663	8408	8138	8103	8337	8245	8083	8052	1165	1162	828	803
BOP	904	958	1008	1018	620	577	474	468	1171	1101	945	928	162	136	104	102
Waikato	4486	4834	5343	5371	3037	2952	2376	2347	5002	4690	4448	4414	78	70	53	51
Gisborne	5	7	49	50	360	350	305	302	2514	2320	1680	1632	14	12	4	4
Hawkes_Bay	105	192	254	260	2598	2540	2492	2485	4850	4628	4356	4331	248	241	161	157
Manawatu_Wanganui	1011	1134	1790	1808	2945	2843	2260	2244	8570	8311	7730	7633	198	193	121	119
Marlborough	92	91	108	109	1455	1367	1363	1356	777	740	694	689	798	749	680	672
Northland	1536	1241	1635	1642	3936	4124	2344	2213	528	524	202	190	0	0	0	0
Otago	370	597	929	945	6254	5932	5754	5730	7703	7556	7344	7313	1961	1941	1660	1643
Southland	488	1605	2073	2098	6247	5184	4745	4716	2143	1971	1988	1980	526	493	466	462
Taranaki	1851	1734	1857	1859	953	1031	913	909	1149	1113	1070	1058	62	77	77	77
Nelson_Tasman	147	155	213	214	383	372	325	322	97	95	99	98	279	257	227	221
Wellington	300	290	547	553	950	953	746	739	2446	2323	2094	2066	43	40	23	22
West_Coast	522	743	753	756	392	289	293	289	391	330	337	331	251	223	193	188
NZ	13062	15935	19567	19715	41251	38452	33713	33389	45765	44032	41133	40776	5784	5594	4598	4522

Region	Planted Forest				Native Forest				Scrub				Urban			
	Y1996	Y2008	2020 $5	2020 $25	Y1996	Y2008	2020 $5	2020 $25	Y1996	Y2008	2020 $5	2020 $25	Y1996	Y2008	2020 $5	2020 $25
Auckland	436	472	511	610	452	453	451	451	343	341	395	317	394	416	418	418
Canterbury	1291	1445	1471	1502	2963	2962	2962	2962	4431	4381	4736	4781	290	303	303	303
BOP	2798	2849	3062	3133	5914	5910	5910	5910	767	787	814	761	131	141	141	141
Waikato	3368	3398	3837	4020	4788	4783	4783	4783	1768	1767	1657	1512	232	259	259	259
Gisborne	1242	1458	1837	2015	537	537	537	537	1041	1030	1302	1175	26	27	27	27
Hawkes_Bay	1579	1807	2099	2203	3106	3105	3105	3105	1842	1803	1851	1776	72	74	74	74
Manawatu_Wanganui	1201	1448	1799	2017	4366	4361	4361	4361	2316	2311	2541	2421	139	143	143	143
Marlborough	617	764	807	834	2140	2141	2141	2141	1593	1528	1588	1578	27	29	29	29
Northland	1685	1829	1925	2248	2434	2423	2416	2416	1386	1353	2976	2790	66	73	74	74
Otago	1212	1495	1550	1602	1874	1872	1872	1872	2414	2382	2673	2677	119	127	127	127
Southland	790	961	984	989	10707	10705	10705	10705	1346	1329	1287	1299	67	68	68	68
Taranaki	288	357	462	558	2271	2267	2267	2267	730	723	656	574	64	66	66	66
Nelson_Tasman	1029	1065	1122	1168	2879	2876	2876	2876	712	698	657	619	37	43	43	43
Wellington	607	746	828	968	1616	1615	1615	1615	1411	1400	1527	1415	184	190	191	191
West_Coast	487	558	714	750	16770	16747	16747	16747	2335	2261	2115	2089	29	31	31	31
NZ	18629	20652	23008	24617	62815	62757	62747	62746	24435	24093	26775	25783	1877	1989	1992	1992


Dairy
Y1996
Y2008
Y2020 $5
Y2020 $25
Area (km2)
6000
5000
4000
3000
2000
1000
0
Auckland
Canterbury
BOP
Waikato
Gisborne
Hawkes Bay
Manawatu-Wanganui
Marlborough
Northland
Otago
Southland
Taranaki
Nelson and Tasman
Wellington
West Coast
Region


Intensive Sheep and Beef
Y1996
Y2008
Y2020 $5
Y2020 $25
Area (km2)
12000
10000
8000
6000
4000
2000
0
Auckland
Canterbury
BOP
Waikato
Gisborne
Hawkes Bay
Manawatu-Wanganui
Marlborough
Northland
Otago
Southland
Taranaki
Nelson and Tasman
Wellington
West Coast
Region


Sheep and Beef Hill
Y1996
Y2008
Y2020 $5
Y2020 $25
Area (km2)
10000
8000
6000
4000
2000
0
Auckland
Canterbury
BOP
Waikato
Gisborne
Hawkes Bay
Manawatu-Wanganui
Marlborough
Northland
Otago
Southland
Taranaki
Nelson and Tasman
Wellington
West Coast
Region


High Country Sheep and Beef
Y1996
Y2008
Y2020 $5
Y2020 $25
Area (km2)
2000
1500
1000
500
0
Auckland
Canterbury
BOP
Waikato
Gisborne
Hawkes Bay
Manawatu-Wanganui
Marlborough
Northland
Otago
Southland
Taranaki
Nelson and Tasman
Wellington
West Coast
Region

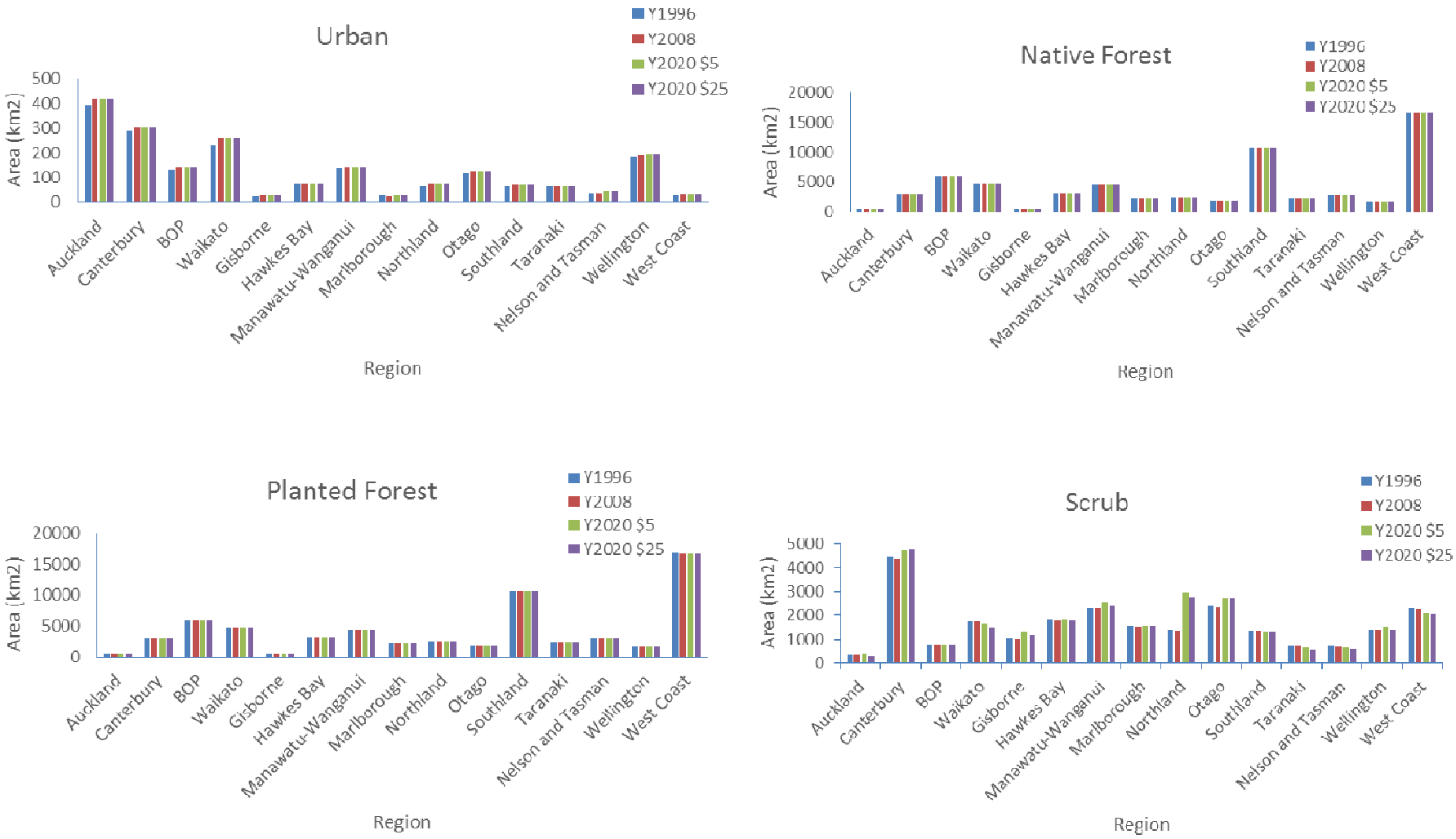


Figure A6: Figures of CLUES land use areas used for scenarios Y1996, Y2008, Y2020 $5 and Y2020 $25.

Table A3: Change in area (km^2).

Region	Dairy			Intensive Sheep and Beef			Sheep and Beef Hill			Sheep and Beef High		
	Y1996 to Y2008	Y2008 to Y2020 $5	Y1996 to Y2020 $5	Y1996 to Y2008	Y2008 to Y2020 $5	Y1996 to Y2020 $5	Y1996 to Y2008	Y2008 to Y2020 $5	Y1996 to Y2020 $5	Y1996 to Y2008	Y2008 to Y2020 $5	Y1996 to Y2020 $5
Auckland	-127	272	145	73	-344	-271	-3	-21	-24	0	0	0
Canterbury	1236	382	1618	-1255	-270	-1526	-92	-162	-254	-4	-333	-337
BOP	54	50	104	-43	-103	-146	-70	-156	-226	-26	-31	-57
Waikato	349	508	857	-84	-576	-661	-312	-242	-555	-8	-17	-25
Gisborne	3	42	44	-10	-45	-55	-194	-640	-834	-1	-8	-10
Hawkes_Bay	87	62	149	-57	-49	-106	-222	-272	-494	-7	-80	-87
Manawatu_Wanganui	123	656	779	-101	-583	-684	-259	-581	-840	-5	-71	-76
Marlborough	-1	17	16	-87	-5	-92	-37	-46	-83	-49	-69	-118
Northland	-295	394	100	187	-1779	-1592	-4	-322	-326	0	0	0
Otago	227	332	559	-322	-178	-500	-147	-212	-359	-20	-281	-301
Southland	1117	469	1585	-1064	-439	-1502	-171	17	-155	-33	-26	-59
Taranaki	-117	123	6	78	-118	-40	-36	-43	-79	15	0	15
Nelson_Tasman	7	58	65	-11	-47	-58	-1	4	2	-22	-31	-52
Wellington	-10	257	248	2	-207	-205	-123	-229	-352	-2	-18	-20
West_Coast	221	10	230	-104	4	-99	-61	7	-54	-28	-30	-58
NZ	2873	3632	6505	-2799	-4739	-7537	-1733	-2899	-4632	-190	-996	-1186

Region	Planted Forest			Native Forest			Scrub			Urban		
	Y1996 to Y2008	Y2008 to Y2020 $5	Y1996 to Y2020 $5	Y1996 to Y2008	Y2008 to Y2020 $5	Y1996 to Y2020 $5	Y1996 to Y2008	Y2008 to Y2020 $5	Y1996 to Y2020 $5	Y1996 to Y2008	Y2008 to Y2020 $5	Y1996 to Y2020 $5
Auckland	36	39	76	1	-2	-1	-2	54	52	22	2	24
Canterbury	154	26	180	0	0	0	-50	355	305	13	0	13
BOP	52	213	265	-4	0	-4	19	28	47	10	0	10
Waikato	30	440	470	-5	0	-5	0	-110	-110	27	0	27
Gisborne	215	380	595	0	0	0	-11	272	261	1	0	1
Hawkes_Bay	228	292	520	-1	0	-1	-39	48	9	2	0	2
Manawatu_Wanganui	247	351	598	-5	0	-5	-6	230	225	4	0	4
Marlborough	147	43	190	1	0	1	-65	59	-5	2	0	2
Northland	144	96	240	-10	-8	-18	-32	1622	1590	7	0	8
Otago	283	55	338	-2	0	-2	-32	290	258	8	0	8
Southland	171	23	194	-3	0	-3	-17	-42	-59	1	0	1
Taranaki	70	105	174	-3	0	-3	-8	-67	-74	2	0	2
Nelson_Tasman	36	57	93	-3	0	-3	-14	-41	-55	5	0	5
Wellington	140	81	221	-1	1	-1	-12	128	116	6	1	7
West_Coast	71	155	226	-23	0	-23	-75	-146	-220	1	0	1
NZ	2023	2356	4380	-59	-9	-68	-342	2683	2340	111	3	115

Table A4: Percentage change in area relative to the 1996 area.

Region	Dairy			Intensive Sheep and Beef			Sheep and Beef Hill			Sheep and Beef High		
	Y1996 to Y2008	Y2008 to Y2020 $5	Y1996 to Y2020 $5	Y1996 to Y2008	Y2008 to Y2020 $5	Y1996 to Y2020 $5	Y1996 to Y2008	Y2008 to Y2020 $5	Y1996 to Y2020 $5	Y1996 to Y2008	Y2008 to Y2020 $5	Y1996 to Y2020 $5
Auckland	-28.9	61.8	32.9	5.0	-23.6	-18.6	-3.4	-23.8	-27.2	-1.8	-8.8	-10.5
Canterbury	153.4	47.4	200.8	-13.0	-2.8	-15.8	-1.1	-1.9	-3.0	-0.3	-28.6	-28.9
BOP	6.0	5.5	11.5	-6.9	-16.6	-23.5	-6.0	-13.3	-19.3	-16.2	-19.3	-35.5
Waikato	7.8	11.3	19.1	-2.8	-19.0	-21.8	-6.2	-4.8	-11.1	-10.5	-21.9	-32.4
Gisborne	64.6	919.9	984.5	-2.9	-12.4	-15.3	-7.7	-25.5	-33.2	-10.1	-60.8	-70.9
Hawkes_Bay	83.2	58.9	142.1	-2.2	-1.9	-4.1	-4.6	-5.6	-10.2	-2.8	-32.2	-34.9
Manawatu_Wanganui	12.2	64.9	77.1	-3.4	-19.8	-23.2	-3.0	-6.8	-9.8	-2.4	-36.2	-38.5
Marlborough	-1.0	18.9	17.9	-6.0	-0.3	-6.3	-4.8	-6.0	-10.7	-6.2	-8.7	-14.8
Northland	-19.2	25.7	6.5	4.8	-45.2	-40.4	-0.8	-60.9	-61.7	-7.1	-46.9	-54.0
Otago	61.2	89.8	150.9	-5.1	-2.8	-8.0	-1.9	-2.8	-4.7	-1.0	-14.3	-15.3
Southland	228.7	96.0	324.7	-17.0	-7.0	-24.0	-8.0	0.8	-7.2	-6.3	-5.0	-11.3
Taranaki	-6.3	6.6	0.3	8.1	-12.3	-4.2	-3.1	-3.8	-6.9	24.3	0.3	24.7
Nelson_Tasman	4.9	39.3	44.2	-2.8	-12.4	-15.2	-1.2	3.7	2.5	-7.7	-11.0	-18.7
Wellington	-3.2	85.9	82.6	0.2	-21.8	-21.6	-5.0	-9.4	-14.4	-5.6	-41.2	-46.8
West_Coast	42.3	1.9	44.1	-26.4	1.1	-25.3	-15.5	1.7	-13.8	-11.1	-12.0	-23.2
NZ	22.0	27.8	49.8	-6.8	-11.5	-18.3	-3.8	-6.3	-10.1	-3.3	-17.2	-20.5

Region	Planted Forest			Native Forest			Scrub			Urban		
	Y1996 to Y2008	Y2008 to Y2020 $5	Y1996 to Y2020 $5	Y1996 to Y2008	Y2008 to Y2020 $5	Y1996 to Y2020 $5	Y1996 to Y2008	Y2008 to Y2020 $5	Y1996 to Y2020 $5	Y1996 to Y2008	Y2008 to Y2020 $5	Y1996 to Y2020 $5
Auckland	8.3	9.0	17.3	0.2	-0.5	-0.3	-0.6	15.8	15.2	5.5	0.5	6.0
Canterbury	11.9	2.0	14.0	0.0	0.0	0.0	-1.1	8.0	6.9	4.5	0.0	4.5
BOP	1.8	7.6	9.5	-0.1	0.0	-0.1	2.5	3.6	6.1	7.6	0.0	7.6
Waikato	0.9	13.1	13.9	-0.1	0.0	-0.1	0.0	-6.2	-6.2	11.8	0.0	11.8
Gisborne	17.3	30.6	47.9	0.0	0.0	0.0	-1.1	26.1	25.1	2.6	0.0	2.6
Hawkes_Bay	14.4	18.5	32.9	0.0	0.0	0.0	-2.1	2.6	0.5	2.8	0.0	2.8
Manawatu_Wanganui	20.6	29.3	49.8	-0.1	0.0	-0.1	-0.2	10.0	9.7	2.6	0.0	2.6
Marlborough	23.8	7.0	30.7	0.0	0.0	0.0	-4.1	3.7	-0.3	8.4	0.0	8.4
Northland	8.6	5.7	14.3	-0.4	-0.3	-0.7	-2.3	117.1	114.8	10.9	0.7	11.6
Otago	23.4	4.5	27.9	-0.1	0.0	-0.1	-1.3	12.0	10.7	6.8	0.0	6.8
Southland	21.6	2.9	24.5	0.0	0.0	0.0	-1.2	-3.1	-4.4	1.5	0.0	1.5
Taranaki	24.2	36.4	60.6	-0.1	0.0	-0.1	-1.0	-9.1	-10.2	2.6	0.0	2.6
Nelson_Tasman	3.5	5.6	9.1	-0.1	0.0	-0.1	-2.0	-5.7	-7.7	14.2	0.0	14.2
Wellington	23.0	13.4	36.4	-0.1	0.0	0.0	-0.8	9.1	8.2	3.2	0.5	3.8
West_Coast	14.6	31.8	46.4	-0.1	0.0	-0.1	-3.2	-6.2	-9.4	5.0	0.0	5.0
NZ	10.9	12.6	23.5	-0.1	0.0	-0.1	-1.4	11.0	9.6	5.9	0.2	6.1

Table A5: Percentage of total regional area.

Region	Dairy				Intensive Sheep and Beef				Sheep and Beef Hill				Sheep and Beef High			
	Y1996	Y2008	Y2020 $5	Y2020 $25	Y1996	Y2008	Y2020 $5	Y2020 $25	Y1996	Y2008	Y2020 $5	Y2020 $25	Y1996	Y2008	Y2020 $5	Y2020 $25
Auckland	11.5	8.2	15.3	15.4	38.2	40.1	31.1	30.5	2.3	2.2	1.7	1.6	0.0	0.0	0.0	0.0
Canterbury	1.7	4.4	5.2	5.2	20.7	18.0	17.5	17.4	17.9	17.7	17.3	17.3	2.5	2.5	1.8	1.7
BOP	6.8	7.3	7.6	7.7	4.7	4.4	3.6	3.5	8.9	8.3	7.2	7.0	1.2	1.0	0.8	0.8
Waikato	18.4	19.9	21.9	22.1	12.5	12.1	9.8	9.6	20.5	19.3	18.3	18.1	0.3	0.3	0.2	0.2
Gisborne	0.1	0.1	0.8	0.8	5.9	5.8	5.0	5.0	41.5	38.3	27.7	26.9	0.2	0.2	0.1	0.1
Hawkes_Bay	0.7	1.3	1.7	1.7	17.1	16.7	16.4	16.4	32.0	30.5	28.7	28.6	1.6	1.6	1.1	1.0
Manawatu_Wanganui	4.6	5.2	8.2	8.3	13.4	13.0	10.3	10.2	39.1	37.9	35.3	34.8	0.9	0.9	0.6	0.5
Marlborough	1.0	1.0	1.2	1.2	16.4	15.4	15.4	15.3	8.8	8.4	7.8	7.8	9.0	8.5	7.7	7.6
Northland	12.8	10.3	13.6	13.7	32.8	34.4	19.5	18.4	4.4	4.4	1.7	1.6	0.0	0.0	0.0	0.0
Otago	1.2	1.9	2.9	3.0	19.8	18.8	18.2	18.1	24.4	23.9	23.3	23.2	6.2	6.1	5.3	5.2
Southland	1.7	5.5	7.0	7.1	21.2	17.6	16.1	16.0	7.3	6.7	6.8	6.7	1.8	1.7	1.6	1.6
Taranaki	24.6	23.1	24.7	24.7	12.7	13.7	12.1	12.1	15.3	14.8	14.2	14.1	0.8	1.0	1.0	1.0
Nelson_Tasman	2.4	2.5	3.5	3.5	6.3	6.1	5.3	5.3	1.6	1.6	1.6	1.6	4.6	4.2	3.7	3.6
Wellington	3.8	3.7	6.9	7.0	12.1	12.1	9.5	9.4	31.0	29.5	26.6	26.2	0.5	0.5	0.3	0.3
West_Coast	1.9	2.8	2.8	2.8	1.5	1.1	1.1	1.1	1.5	1.2	1.3	1.2	0.9	0.8	0.7	0.7
NZ	5.0	6.1	7.5	7.5	15.8	14.7	12.9	12.8	17.5	16.9	15.7	15.6	2.2	2.1	1.8	1.7

Region	Planted Forest				Native Forest				Scrub				Urban			
	Y1996	Y2008	Y2020 $5	Y2020 $25	Y1996	Y2008	Y2020 $5	Y2020 $25	Y1996	Y2008	Y2020 $5	Y2020 $25	Y1996	Y2008	Y2020 $5	Y2020 $25
Auckland	11.4	12.4	13.4	16.0	11.9	11.9	11.8	11.8	9.0	8.9	10.4	8.3	10.3	10.9	11.0	11.0
Canterbury	2.8	3.1	3.2	3.2	6.4	6.4	6.4	6.4	9.5	9.4	10.2	10.3	0.6	0.6	0.6	0.7
BOP	21.2	21.6	23.2	23.7	44.8	44.7	44.7	44.7	5.8	6.0	6.2	5.8	1.0	1.1	1.1	1.1
Waikato	13.8	14.0	15.8	16.5	19.7	19.6	19.6	19.6	7.3	7.3	6.8	6.2	1.0	1.1	1.1	1.1
Gisborne	20.5	24.0	30.3	33.2	8.9	8.9	8.9	8.9	17.2	17.0	21.5	19.4	0.4	0.4	0.4	0.4
Hawkes_Bay	10.4	11.9	13.8	14.5	20.5	20.5	20.5	20.5	12.1	11.9	12.2	11.7	0.5	0.5	0.5	0.5
Manawatu_Wanganui	5.5	6.6	8.2	9.2	19.9	19.9	19.9	19.9	10.6	10.5	11.6	11.1	0.6	0.7	0.7	0.7
Marlborough	7.0	8.6	9.1	9.4	24.2	24.2	24.2	24.2	18.0	17.3	17.9	17.8	0.3	0.3	0.3	0.3
Northland	14.0	15.2	16.0	18.7	20.3	20.2	20.1	20.1	11.5	11.3	24.8	23.3	0.6	0.6	0.6	0.6
Otago	3.8	4.7	4.9	5.1	5.9	5.9	5.9	5.9	7.6	7.5	8.5	8.5	0.4	0.4	0.4	0.4
Southland	2.7	3.3	3.3	3.4	36.4	36.4	36.4	36.4	4.6	4.5	4.4	4.4	0.2	0.2	0.2	0.2
Taranaki	3.8	4.8	6.1	7.4	30.2	30.2	30.2	30.2	9.7	9.6	8.7	7.6	0.9	0.9	0.9	0.9
Nelson_Tasman	16.9	17.4	18.4	19.1	47.2	47.1	47.1	47.1	11.7	11.4	10.8	10.1	0.6	0.7	0.7	0.7
Wellington	7.7	9.5	10.5	12.3	20.5	20.5	20.5	20.5	17.9	17.8	19.4	18.0	2.3	2.4	2.4	2.4
West_Coast	1.8	2.1	2.7	2.8	62.6	62.5	62.5	62.5	8.7	8.4	7.9	7.8	0.1	0.1	0.1	0.1
NZ	7.1	7.9	8.8	9.4	24.0	24.0	24.0	24.0	9.4	9.2	10.2	9.9	0.7	0.8	0.8	0.8

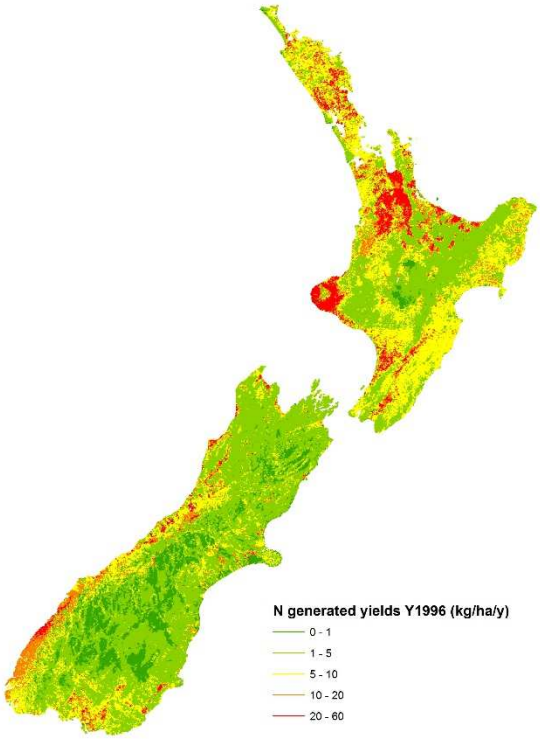
Table A6: Change in area as percent of regional area.

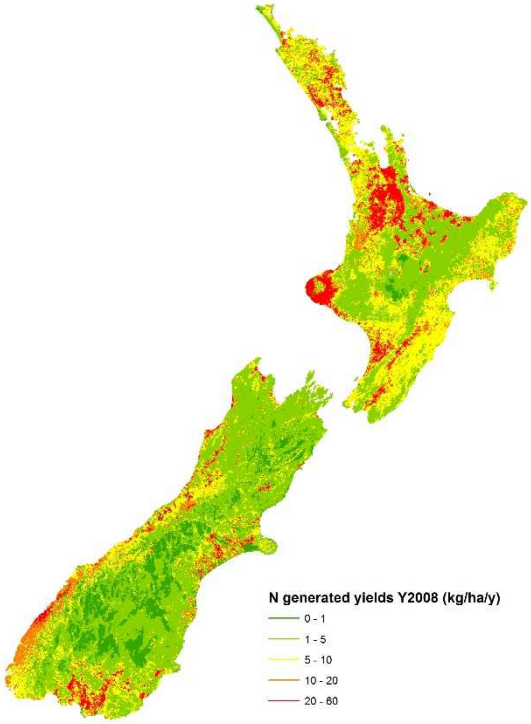
Region	Dairy			Intensive Sheep and Beef			Sheep and Beef Hill			Sheep and Beef High		
	Y1996 to Y2008	Y2008 to Y2020 $5	Y1996 to Y2020 $5	Y1996 to Y2008	Y2008 to Y2020 $5	Y1996 to Y2020 $5	Y1996 to Y2008	Y2008 to Y2020 $5	Y1996 to Y2020 $5	Y1996 to Y2008	Y2008 to Y2020 $5	Y1996 to Y2020 $5
Auckland	-3.33	7.13	3.80	1.92	-9.03	-7.10	-0.08	-0.54	-0.62	0.00	0.00	0.00
Canterbury	2.65	0.82	3.47	-2.69	-0.58	-3.27	-0.20	-0.35	-0.54	-0.01	-0.71	-0.72
BOP	0.41	0.38	0.79	-0.33	-0.78	-1.10	-0.53	-1.18	-1.71	-0.20	-0.24	-0.43
Waikato	1.43	2.09	3.52	-0.35	-2.37	-2.71	-1.28	-0.99	-2.28	-0.03	-0.07	-0.10
Gisborne	0.05	0.68	0.73	-0.17	-0.74	-0.91	-3.21	-10.56	-13.77	-0.02	-0.14	-0.16
Hawkes_Bay	0.57	0.41	0.98	-0.38	-0.32	-0.70	-1.46	-1.80	-3.26	-0.05	-0.53	-0.57
Manawatu_Wanganui	0.56	2.99	3.56	-0.46	-2.66	-3.12	-1.18	-2.65	-3.83	-0.02	-0.33	-0.35
Marlborough	-0.01	0.20	0.19	-0.99	-0.05	-1.04	-0.42	-0.52	-0.94	-0.56	-0.78	-1.34
Northland	-2.46	3.29	0.83	1.56	-14.83	-13.27	-0.03	-2.68	-2.71	0.00	0.00	0.00
Otago	0.72	1.05	1.77	-1.02	-0.56	-1.58	-0.47	-0.67	-1.14	-0.06	-0.89	-0.95
Southland	3.79	1.59	5.39	-3.61	-1.49	-5.10	-0.58	0.06	-0.53	-0.11	-0.09	-0.20
Taranaki	-1.56	1.63	0.07	1.03	-1.56	-0.53	-0.48	-0.58	-1.06	0.20	0.00	0.20
Nelson_Tasman	0.12	0.95	1.07	-0.18	-0.78	-0.95	-0.02	0.06	0.04	-0.35	-0.50	-0.85
Wellington	-0.12	3.26	3.14	0.03	-2.63	-2.60	-1.56	-2.90	-4.46	-0.03	-0.22	-0.25
West_Coast	0.82	0.04	0.86	-0.39	0.02	-0.37	-0.23	0.02	-0.20	-0.10	-0.11	-0.22
NZ	1.10	1.39	2.49	-1.07	-1.81	-2.88	-0.66	-1.11	-1.77	-0.07	-0.38	-0.45

Region	Planted Forest			Native Forest			Scrub			Urban		
	Y1996 to Y2008	Y2008 to Y2020 $5	Y1996 to Y2020 $5	Y1996 to Y2008	Y2008 to Y2020 $5	Y1996 to Y2020 $5	Y1996 to Y2008	Y2008 to Y2020 $5	Y1996 to Y2020 $5	Y1996 to Y2008	Y2008 to Y2020 $5	Y1996 to Y2020 $5
Auckland	0.95	3.62	4.57	0.03	-0.06	-0.03	-0.06	1.43	1.37	0.57	0.05	0.62
Canterbury	0.33	0.12	0.45	0.00	0.00	0.00	-0.11	0.76	0.65	0.03	0.00	0.03
BOP	0.39	2.15	2.54	-0.03	0.00	-0.03	0.15	0.21	0.36	0.08	0.00	0.08
Waikato	0.12	2.55	2.68	-0.02	0.00	-0.02	0.00	-0.45	-0.45	0.11	0.00	0.11
Gisborne	3.55	9.19	12.75	0.00	0.00	0.00	-0.19	4.49	4.30	0.01	0.00	0.01
Hawkes_Bay	1.50	2.61	4.12	-0.01	0.00	-0.01	-0.26	0.32	0.06	0.01	0.00	0.01
Manawatu_Wanganui	1.13	2.60	3.73	-0.02	0.00	-0.02	-0.03	1.05	1.03	0.02	0.00	0.02
Marlborough	1.66	0.79	2.45	0.01	0.00	0.01	-0.73	0.67	-0.06	0.03	0.00	0.03
Northland	1.20	3.49	4.69	-0.09	-0.06	-0.15	-0.27	13.52	13.25	0.06	0.00	0.06
Otago	0.90	0.34	1.24	-0.01	0.00	-0.01	-0.10	0.92	0.82	0.03	0.00	0.03
Southland	0.58	0.10	0.68	-0.01	0.00	-0.01	-0.06	-0.14	-0.20	0.00	0.00	0.00
Taranaki	0.92	2.66	3.59	-0.04	0.00	-0.04	-0.10	-0.89	-0.99	0.02	0.00	0.02
Nelson_Tasman	0.59	1.69	2.28	-0.05	0.00	-0.05	-0.23	-0.67	-0.90	0.09	0.00	0.09
Wellington	1.77	2.82	4.59	-0.02	0.01	-0.01	-0.15	1.62	1.48	0.07	0.01	0.09
West_Coast	0.26	0.72	0.98	-0.08	0.00	-0.08	-0.28	-0.54	-0.82	0.01	0.00	0.01
NZ	0.77	1.52	2.29	-0.02	0.00	-0.03	-0.13	1.03	0.90	0.04	0.00	0.04

Appendix 4. Maps of N and P generated yields for the various scenarios

The following maps show N and P generated yields for the various scenarios.





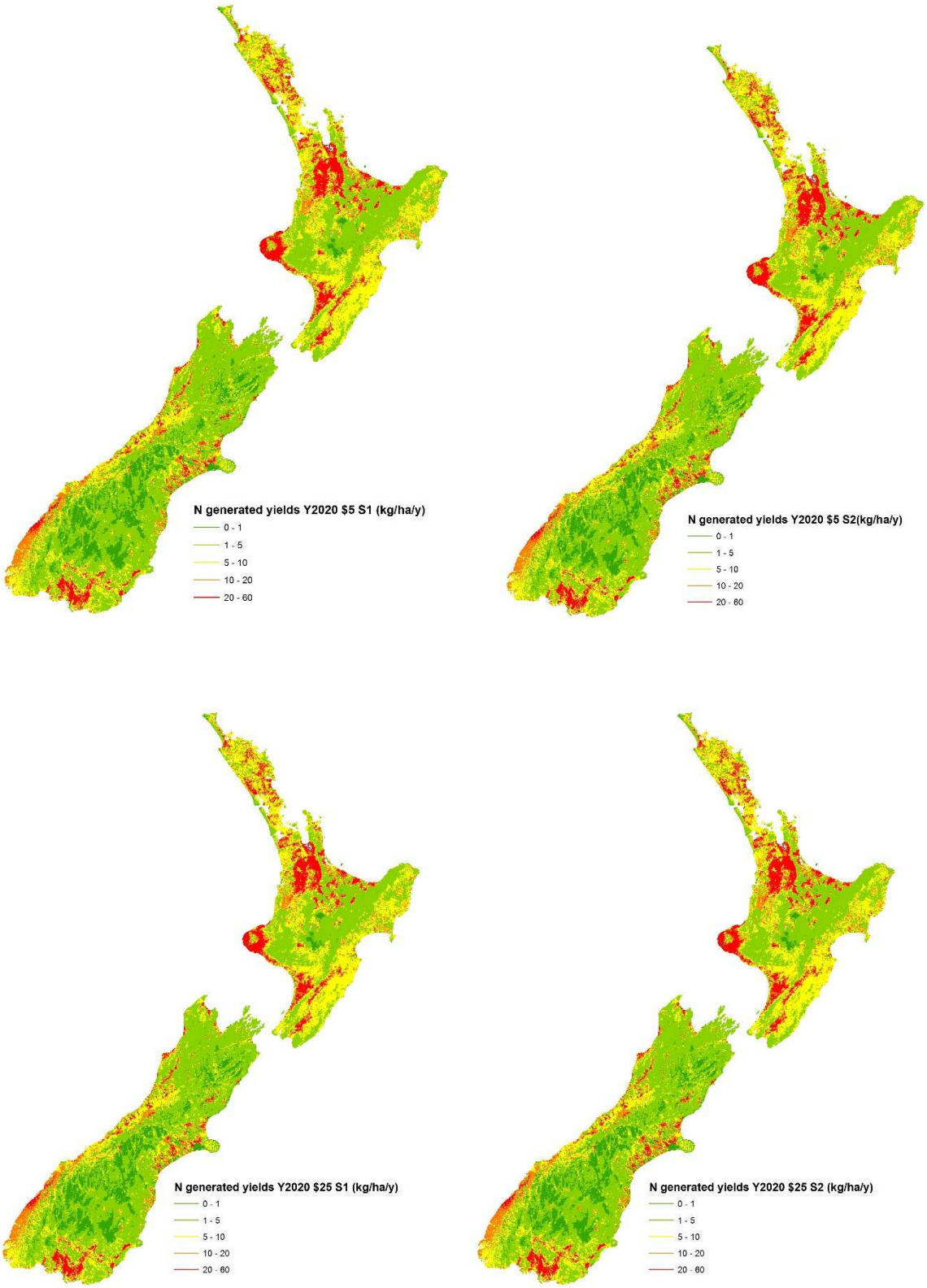
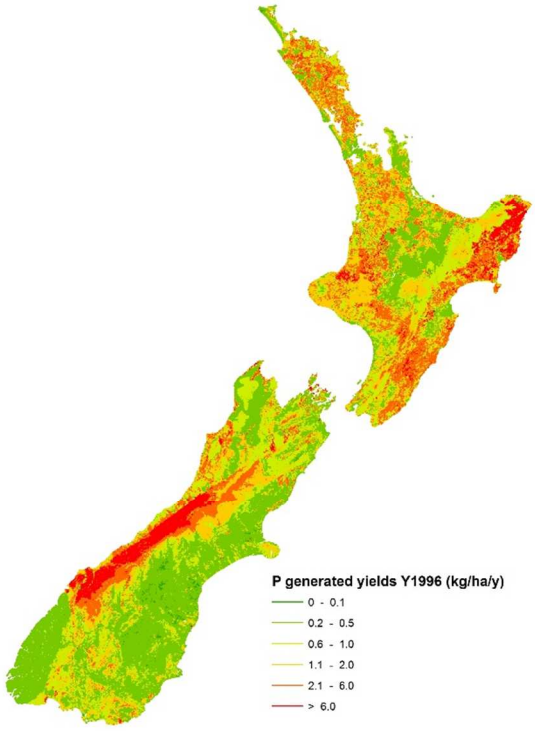
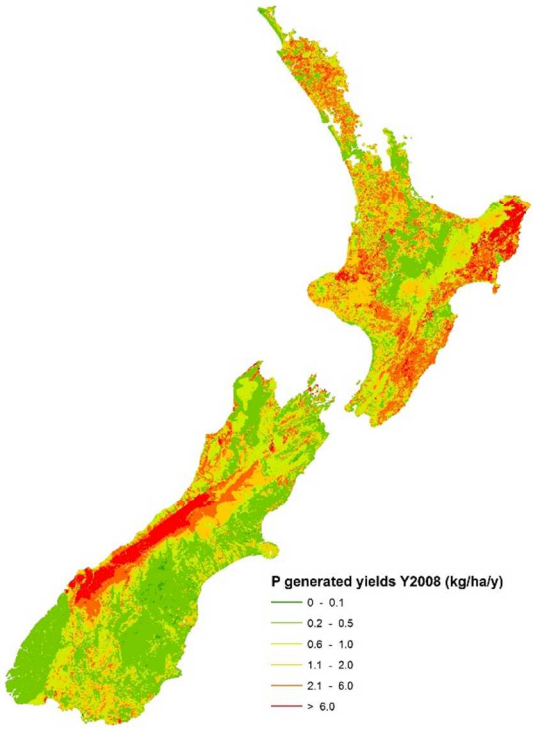
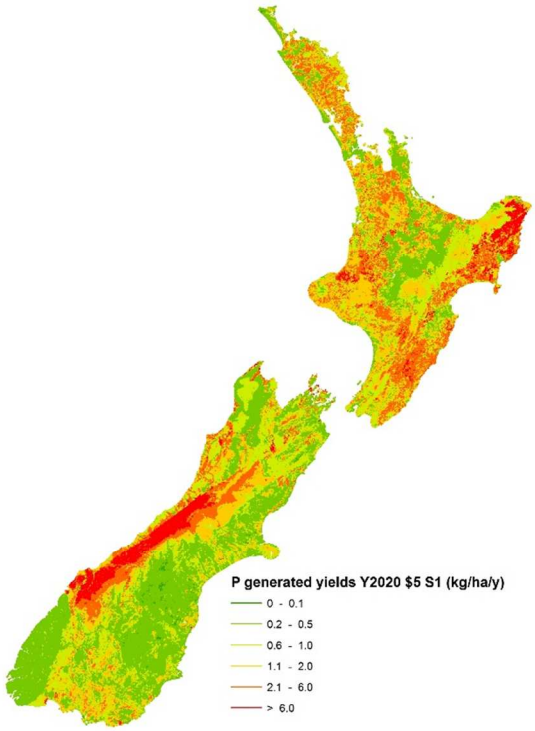
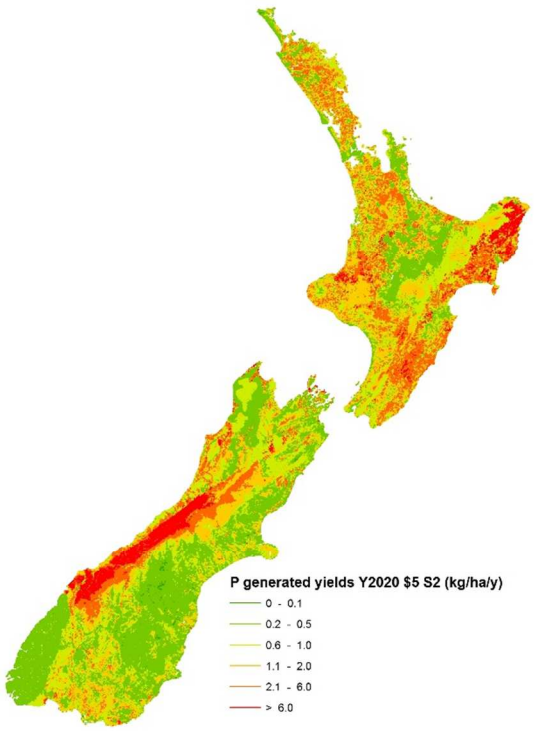


Figure A7: **Map of N generated yields for the various scenarios**.


P generated yields Y1996 (kg/ha/y)
0 - 0.1
0.2 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 6.0
> 6.0


P generated yields Y2008 (kg/ha/y)
0 - 0.1
0.2 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 6.0
> 6.0


P generated yields Y2020 $5 S1 (kg/ha/y)
0 - 0.1
0.2 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 6.0
> 6.0


P generated yields Y2020 $5 S2 (kg/ha/y)
0 - 0.1
0.2 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 6.0
> 6.0

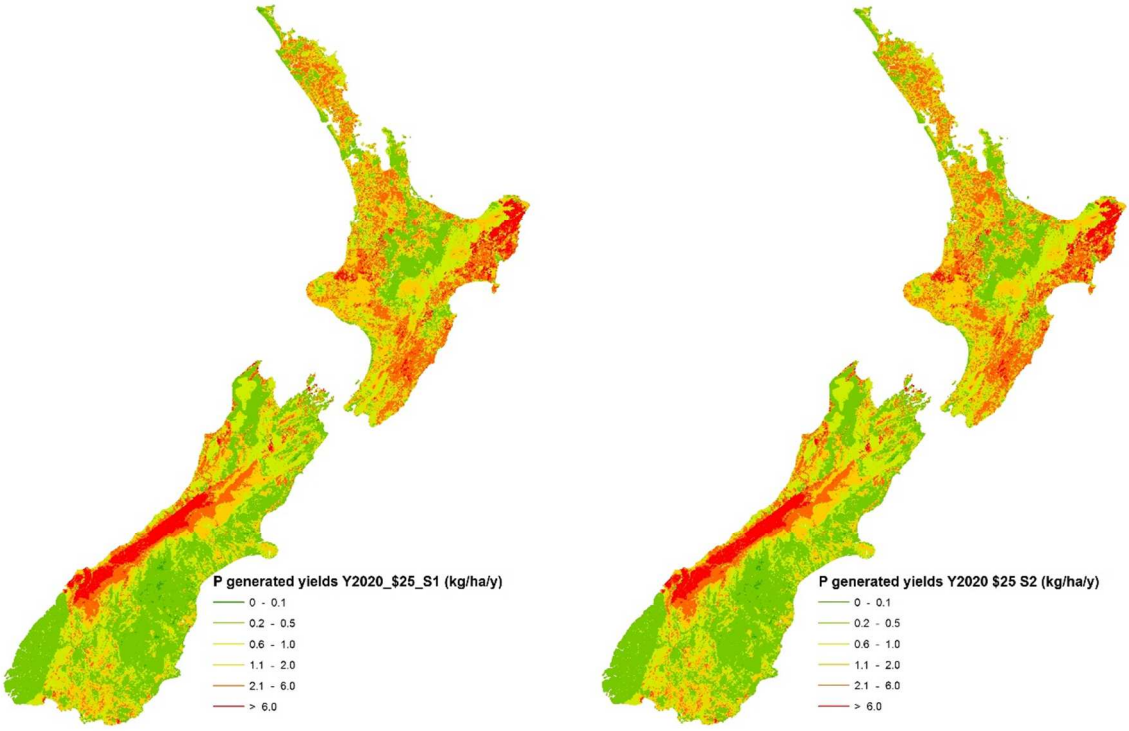


Figure A8: **Map of P generated yields for the various scenarios**.

Appendix 5. Tables of regional changes in N and P loads

The following tables show the regional changes in N and P generated loads and their changes, relative to 1996, predicted using the CLUES model.

Table A7: Total N loads (t/y) by region.

Region	Y1996	Y2008	Y2020 $5 S1	Y2020 $5 S2	Y2020 $25 S1	Y2020 $25 S2
Auckland	3198	3032	3686	3805	3693	3812
Canterbury	13951	17684	18793	19980	18838	20040
BOP	9072	9601	9697	10157	9711	10172
Waikato	28752	31179	33485	35614	33541	35674
Gisborne	3910	3910	3724	3848	3702	3824
Hawkes_Bay	8743	9254	9375	9830	9382	9838
Manawatu_Wanganui	14790	15777	17705	18332	17729	18354
Marlborough	2598	2588	2617	2641	2616	2640
Northland	12386	12084	12786	13143	12777	13127
Otago	9393	10286	11178	11641	11215	11681
Southland	19939	23718	25294	26106	25370	26188
Taranaki	10419	10810	11137	11500	11141	11504
Nelson_Tasman	2618	2711	2844	2912	2849	2917
Wellington	5119	5274	5996	6186	6008	6197
West_Coast	18087	19594	19679	20217	19686	20224
NZ	162975	177501	187996	195911	188256	196192

Table A8: Total P loads (t/y) by region.

Region	Y1996	Y2008	Y2020 $5 S1	Y2020 $5 S2	Y2020 $25 S1	Y2020 $25 S2
Auckland	591	560	568	570	561	562
Canterbury	4481	4712	4771	4794	4774	4797
BOP	3434	3413	3342	3346	3337	3342
Waikato	3545	3595	3625	3650	3622	3647
Gisborne	12078	11996	11736	11737	11718	11719
Hawkes_Bay	3776	3738	3667	3672	3661	3665
Manawatu_Wanganui	4707	4682	4653	4660	4631	4638
Marlborough	1033	1011	1009	1010	1007	1007
Northland	2356	2294	1850	1854	1814	1818
Otago	3086	3121	3169	3177	3170	3178
Southland	2490	2649	2730	2745	2732	2748
Taranaki	1454	1422	1431	1435	1428	1431
Nelson_Tasman	516	519	532	532	530	531
Wellington	1261	1232	1224	1226	1218	1220
West_Coast	12211	12282	12289	12295	12287	12293
NZ	57018	57226	56597	56703	56489	56596

Table A9: Change in N loads (%) by region relative to 1996.

Region	Y2008	Y2020 $5 S1	Y2020 $5 S2	Y2020 $25 S1	Y2020 $25 S2
Auckland	-5.18	15.25	18.98	15.47	19.19
Canterbury	26.76	34.71	43.22	35.03	43.65
BOP	5.83	6.88	11.95	7.03	12.12
Waikato	8.44	16.46	23.87	16.66	24.07
Gisborne	0.00	-4.74	-1.57	-5.31	-2.19
Hawkes_Bay	5.85	7.23	12.44	7.31	12.52
Manawatu_Wanganui	6.67	19.71	23.95	19.87	24.10
Marlborough	-0.39	0.72	1.65	0.71	1.63
Northland	-2.43	3.23	6.12	3.16	5.99
Otago	9.50	19.00	23.92	19.39	24.35
Southland	18.95	26.86	30.93	27.24	31.34
Taranaki	3.75	6.89	10.37	6.93	10.41
Nelson_Tasman	3.55	8.61	11.22	8.80	11.43
Wellington	3.02	17.14	20.84	17.36	21.06
West_Coast	8.33	8.80	11.77	8.84	11.81
NZ	8.91	15.35	20.21	15.51	20.38

Table A10: Change in P loads (%) by region relative to 1996.

Region	Y2008	Y2020 $5 S1	Y2020 $5 S2	Y2020 $25 S1	Y2020 $25 S2
Auckland	-5.13	-3.85	-3.56	-5.08	-4.79
Canterbury	5.17	6.48	7.00	6.54	7.06
BOP	-0.62	-2.67	-2.55	-2.81	-2.68
Waikato	1.38	2.25	2.95	2.15	2.85
Gisborne	-0.68	-2.83	-2.82	-2.98	-2.97
Hawkes_Bay	-1.02	-2.88	-2.77	-3.06	-2.95
Manawatu_Wanganui	-0.52	-1.14	-0.99	-1.61	-1.46
Marlborough	-2.11	-2.29	-2.24	-2.54	-2.49
Northland	-2.67	-21.51	-21.33	-23.03	-22.85
Otago	1.16	2.69	2.97	2.72	3.00
Southland	6.39	9.62	10.24	9.70	10.33
Taranaki	-2.22	-1.55	-1.32	-1.80	-1.57
Nelson_Tasman	0.67	3.12	3.25	2.87	3.00
Wellington	-2.30	-2.94	-2.75	-3.36	-3.18
West_Coast	0.58	0.64	0.68	0.62	0.67
NZ	0.36	-0.74	-0.55	-0.93	-0.74

Appendix 6. Tables of regional changes in N and P loads – October 2013 LURNZ run

The following tables show the regional changes in N and P generated loads and their changes, relative to 1996. The data from the most recent run of the LURNZ model for the Y2020 $5 S1 scenario conducted in October 2013 are presented.

Table A11: Total N loads (t/y) by region.

Region	Y1996	Y2008	Y2020 $5 S1
Auckland	3198	3032	3213
Canterbury	13951	17684	20254
BOP	9072	9601	9593
Waikato	28752	31179	32586
Gisborne	3910	3910	3773
Hawkes_Bay	8743	9254	9655
Manawatu_Wanganui	14790	15777	16516
Marlborough	2598	2588	2636
Northland	12386	12084	12566
Otago	9393	10286	11577
Southland	19939	23718	25554
Taranaki	10419	10810	11354
Nelson_Tasman	2618	2711	2903
Wellington	5119	5274	6012
West_Coast	18087	19594	19495
NZ	162975	177501	187688

Table A12: Total P loads (t/y) by region.

Region	Y1996	Y2008	Y2020 $5 S1
Auckland	591	560	568
Canterbury	4481	4712	4866
BOP	3434	3413	3358
Waikato	3545	3595	3591
Gisborne	12078	11996	11784
Hawkes_Bay	3776	3738	3631
Manawatu_Wanganui	4707	4682	4476
Marlborough	1033	1011	978
Northland	2356	2294	2291
Otago	3086	3121	3185
Southland	2490	2649	2738
Taranaki	1454	1422	1405
Nelson_Tasman	516	519	537
Wellington	1261	1232	1240
West_Coast	12211	12282	12286
NZ	57018	57226	56935

Table A13: Change in N loads (%) by region relative to 1996.

Region	Y2008	Y2020 $5 S1
Auckland	-5.18	0.46
Canterbury	26.76	45.19
BOP	5.83	5.74
Waikato	8.44	13.33
Gisborne	0.00	-3.49
Hawkes_Bay	5.85	10.43
Manawatu_Wanganui	6.67	11.67
Marlborough	-0.39	1.48
Northland	-2.43	1.46
Otago	9.50	23.25
Southland	18.95	28.16
Taranaki	3.75	8.97
Nelson_Tasman	3.55	10.89
Wellington	3.02	17.44
West_Coast	8.33	7.79
NZ	8.91	15.16

Table A14: Change in P loads (%) by region relative to 1996.

Region	Y2008	Y2020 $5 S1
Auckland	-5.13	-3.85
Canterbury	5.17	8.60
BOP	-0.62	-2.22
Waikato	1.38	1.29
Gisborne	-0.68	-2.44
Hawkes_Bay	-1.02	-3.84
Manawatu_Wanganui	-0.52	-4.90
Marlborough	-2.11	-5.34
Northland	-2.67	-2.77
Otago	1.16	3.23
Southland	6.39	9.94
Taranaki	-2.22	-3.37
Nelson_Tasman	0.67	4.17
Wellington	-2.30	-1.63
West_Coast	0.58	0.62
NZ	0.36	-0.15

Table A15: Areas (km^2).

Region	Dairy			Intensive Sheep and Beef			Sheep and Beef Hill Country			Sheep and Beef High Country		
	Y1996	Y2008	Y2020 $5	Y1996	Y2008	Y2020 $5	Y1996	Y2008	Y2020 $5	Y1996	Y2008	Y2020 $5
Auckland	440	313	380	1457	1530	1461	87	84	81	0	0	0
Canterbury	806	2042	3019	9663	8408	7512	8337	8245	7713	1165	1162	572
BOP	904	958	1004	620	577	480	1171	1101	989	162	136	109
Waikato	4486	4834	5098	3037	2952	2618	5002	4690	4487	78	70	54
Gisborne	5	7	50	360	350	309	2514	2320	1776	14	12	5
Hawkes_Bay	105	192	400	2598	2540	2377	4850	4628	4135	248	241	131
Manawatu_Wanganui	1011	1134	1449	2945	2843	2536	8570	8311	7345	198	193	106
Marlborough	92	91	142	1455	1367	1292	777	740	603	798	749	572
Northland	1536	1241	1406	3936	4124	3905	528	524	496	0	0	0
Otago	370	597	1090	6254	5932	5551	7703	7556	7165	1961	1941	1508
Southland	488	1605	2133	6247	5184	4680	2143	1971	1984	526	493	437
Taranaki	1851	1734	1911	953	1031	851	1149	1113	974	62	77	71
Nelson_Tasman	147	155	250	383	372	289	97	95	98	279	257	225
Wellington	300	290	550	950	953	740	2446	2323	2157	43	40	24
West_Coast	522	743	721	392	289	326	391	330	342	251	223	203
NZ	13062	15935	19602	41251	38452	34928	45765	44032	40347	5784	5594	4015

Region	Planted Forest			Native Forest			Scrub			Urban		
	Y1996	Y2008	Y2020 $5	Y1996	Y2008	Y2020 $5	Y1996	Y2008	Y2020 $5	Y1996	Y2008	Y2020 $5
Auckland	436	472	474	452	453	450	343	341	345	394	416	418
Canterbury	1291	1445	1497	2963	2962	2962	4431	4381	5320	290	303	303
BOP	2798	2849	3040	5914	5910	5910	767	787	785	131	141	141
Waikato	3368	3398	3572	4788	4783	4783	1768	1767	1883	232	259	259
Gisborne	1242	1458	2001	537	537	537	1041	1030	1035	26	27	27
Hawkes_Bay	1579	1807	2267	3106	3105	3105	1842	1803	1903	72	74	74
Manawatu_Wanganui	1201	1448	1546	4366	4361	4361	2316	2311	3259	139	143	143
Marlborough	617	764	883	2140	2141	2141	1593	1528	1736	27	29	29
Northland	1685	1829	2061	2434	2423	2416	1386	1353	1212	66	73	74
Otago	1212	1495	1563	1874	1872	1872	2414	2382	3025	119	127	127
Southland	790	961	989	10707	10705	10705	1346	1329	1316	67	68	68
Taranaki	288	357	505	2271	2267	2267	730	723	724	64	66	66
Nelson_Tasman	1029	1065	1163	2879	2876	2876	712	698	617	37	43	43
Wellington	607	746	903	1616	1615	1615	1411	1400	1390	184	190	191
West_Coast	487	558	569	16770	16747	16747	2335	2261	2234	29	31	31
NZ	18629	20652	23032	62815	62757	62747	24435	24093	26785	1877	1989	1992