Scenario Modelling of Nitrogen Management in Manawatū-Whanganui Region

Supporting Regional Plan Change 2

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Prepared By:

Ton Snelder

Tim Cox*

Tim Kerr

*Streamlined Environmental Ltd

For any information regarding this report please contact:

Ton Snelder

Phone: 0275758888

Email: ton@lwp.nz

LWP Ltd

PO Box 70

Lyttelton 8092

New Zealand

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Executive Summary

Horizons Regional Council (HRC) has proposed a change to its Regional Policy Statement and Regional Plan (the One Plan) known as Proposed Plan Change 2 (PPC2). PPC2 will manage the discharge of nitrogen from intensive farming land use (IFLU) across the Manawatū-Whanganui Region. This will have effects on instream loads and concentrations of nitrogen in freshwater receiving environments across the Region. This report describes an evaluation of the water quality outcome for rivers, of management of nitrogen leaching from IFLU under PPC2. The study used a water quality model to predict nitrogen loads and concentrations at 124 river assessment points under a range of nitrogen leaching management scenarios.

Region-wide predictions made using the water quality model to represent conditions prior to regulation in 2012 indicate that soluble inorganic nitrogen (SIN) concentrations exceeded the One Plan targets at most assessment points (approximately 77% of assessment points). In addition, on average, assessment points had SIN concentrations that were 31% higher than the One Plan targets.

Region-wide, most scenarios were predicted to result in only small changes to river SIN concentrations. The model predicted modest reductions in SIN concentrations have already resulted from consenting processes that reduced nitrogen leaching rates from 213 dairy farms located in the 'Target Catchments'. The impact of this consenting was predicted to reduce the mean amount by which the concentration at assessment points deviates from the target, from 31% prior to regulation in 2012 to 30%. The changes however were insufficient to reduce the number of assessment points that do not comply with the One Plan SIN concentration targets.

The model also predicts small reductions in SIN concentration if nitrogen leaching rates for all unconsented IFLU are reduced to the limits specified in the PPC2 Table 14.2. Region wide, this would reduce the mean amount by which the concentration at assessment points is greater than the target to 28%. Downstream of target catchments, this scenario would reduce the mean amount by which the concentration at assessment points is greater than the target, from 45% prior to regulation in 2012 to 40%.

The above findings apply generally; however, under some of the scenarios, the model predicted increases in nitrogen leaching in some water management sub-zones and consequently increases SIN concentrations at some assessment points. These increases occur because the model indicates that there are areas of IFLU for which current nitrogen leaching rates are less than the nitrogen leaching rates specified in PPC2 Table 14.2. Under the scenarios, it was assumed that this IFLU would increase its current leaching rate up to the leaching limits in PPC2 Table 14.2, and this leads to localised increases in SIN concentrations.

1 Introduction

Horizons Regional Council (HRC) has proposed a change to its Regional Policy Statement and Regional Plan (the One Plan) known as Proposed Plan Change 2 (PPC2). PPC2 is focused on the One Plan's provisions that manage nutrient loss from existing intensive farming land uses (dairy farming, commercial vegetable growing, cropping, and intensive sheep and beef) in target water management sub-zones. These provisions are no longer working as intended when the One Plan was developed. PPC2 seeks to update the cumulative nitrogen leaching maximums (CNLM) in the One Plan Table 14.2 to reflect improvements in the nutrient modelling software tool Overseer; reinforce good management practices as part of intensive farming land use activities; and provide a workable pathway for landowners to apply for resource consent for intensive farming land use activities that cannot achieve Table 14.2 cumulative leaching maximums.

PPC2 will have effects on instream loads and concentrations of nitrogen across the Manawatū-Whanganui Region. These effects will be spatially variable for two reasons. First, land use changes resulting from PPC2 will not be evenly distributed across the region meaning that future land use intensity will vary between the region’s catchments. Second, there is environmentally mediated variation in both potential nitrogen losses from land use and the processing of nitrogen (attenuation) as it moves through the drainage network. Because these two factors interact, the prediction of water quality outcomes of PPC2 is complex and their assessment requires catchment water quality modelling. A previous report has detailed the development and calibration of catchment water quality models for the purpose of assessing the impacts of the plan change on in-stream nitrogen loads and concentrations across the region (Snelder *et al.*, 2020).

This report describes analyses and reports results of several scenarios that have been defined to evaluate the potential outcome of PPC2 for nitrogen loads and concentrations at 124 assessment points across the region.

2 Water quality models

2.1 Model definition

Streamlined Environmental Limited’s (SEL) Contaminant Allocation and Simulation Model (CASM) software was used to develop water quality models for the four major river basins in the Horizons Region: the Manawatū (including the Horowhenua and Coastal Tararua catchments), the Rangitīkei, the Whanganui, and the Whangaehu (including the Turakina River catchment) (Snelder *et al.*, 2020). The entire region is encapsulated by the four CASM models. The models use sub-catchment export and attenuation coefficients to simulate the generation, transport, and downstream delivery of total nitrogen (TN) loads throughout the region.

The calibration year was 2012. This year was chosen because it was prior to implementation of the One Plan provisions for management of nitrogen discharges to land. Therefore, 2012 was prior to regulation of intensive farming land use (IFLU) in the region. The calibrated model therefore represents the historical conditions prior to regulation and enables us to model changes in water quality that have actually occurred due to changes in nitrogen discharges since 2012 (which we refer to as historical conditions) and changes resulting from possible implementation of both the operative and proposed One Plan nutrient management provisions (which we refer to as scenarios).

The models represent all land across the region as a regular 250 m by 250 m grid. Each grid cell is assigned to one of nine land use categories (i.e., including dairy, sheep and beef, horticulture; see Snelder *et al.,* 2020 for details). Each grid cell was also assigned to categories describing variation in four biophysical factors that influence nitrogen leaching rates: climate zone, plant available soil water capacity (PAW), and whether the land is irrigable and irrigated. Each grid cell was also assigned to one of eight land use capability classes (LUC; I, II, III, …, VIII), because the cumulative nitrogen leaching maximum values in Table 14.2 vary by LUC class.

The CASM models include a spatially distributed network of "assessment points" (Figure 1). Assessment points are located at the downstream end of each of the region's 124 water management subzones (WMSZ). Some of these assessment points capture drainage from a single WMSZ while others capture the aggregate drainage from multiple upstream WMSZs. The model outputs TN loads and mean concentrations for each of the 124 assessment points.

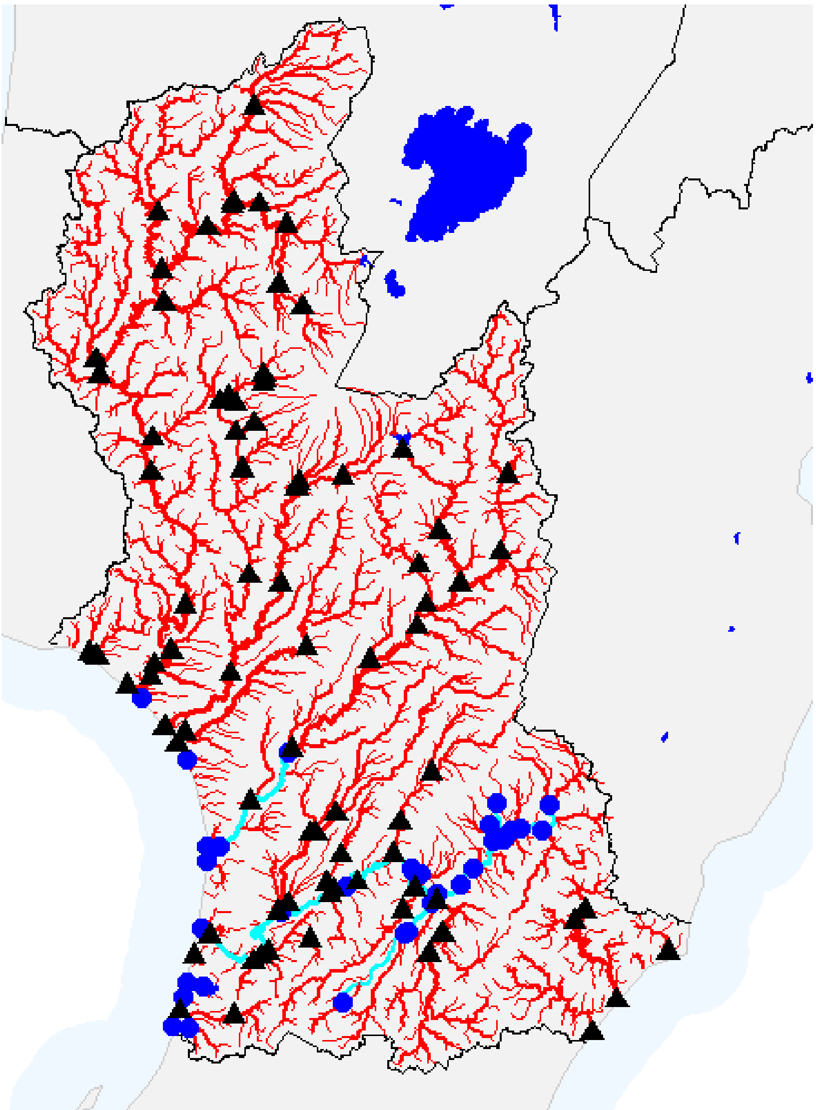

Figure 1. Map showing the location of the CASM model assessment points. Assessment points are located at the most downstream point of all WMSZs. River segments and assessment points that are located downstream of the Target Catchments are shown as light blue lines and dark blue points respectively.

The CASM models represent nitrogen sources in the region based on the widely used diffuse source "export coefficient" approach, with prescribed areal average TN mass loading rates (kg/ha/yr) linked to each model functional unit ("node"). The assigned TN export coefficients were based on Bright *et al.* (2018). Model nodes were developed for each combination of WMSZ, land use capability (LUC) category, and each of nine land use categories, as described in Snelder *et al.* (2020). Export coefficients were assigned to each model node based on values provided by Bright *et al.* (2018), which vary based on the combination of land use category and each of the four biophysical categories (i.e., climate zone, plant available soil water capacity (PAW), and whether the land is irrigable and irrigated). Some adjustments were made to Bright *et al.'s* (2018) export coefficients to account for regionally specific conditions and information and are described in Snelder *et al.* (2020). Point source loads are also represented in the models and are defined as mean annual loads of TN discharged at 38 consented discharges of greater than $20m^3\ d^{-1}$ across the region.

The CASM models were calibrated to observed TN loads at 60 water quality stations in 2012 (i.e., the calibration year), which were derived from monthly TN concentrations and observed or modelled daily flows (Snelder *et al.*, 2020). Calibration was achieved by adjusting the attenuation coefficients and, in a limited number of cases, minor adjustments to export coefficients, as outlined in Snelder *et al*., 2020.

Most of the scenarios described below were defined by adjusting the TN export coefficients for two types of agricultural land use: Intensive Farming Land Use (IFLU) and non-Intensive Farming Land Use (Non-IFLU). In the calibrated model, IFLU were defined by the following land uses types: Dairy Farming, Cropping, Horticulture and Intensive Sheep and Beef. Intensive Sheep and Beef was defined by the combination of the sheep and beef category that occurs on irrigated land. All land uses across the region, including all areas defined as IFLU, were identified using the land use and irrigated area maps described in Snelder *et al.* (2020).

IFLU land was distributed across many of the WMSZs in the Region (Figure 2). There was variation across the Region with respect to whether the TN export coefficients assigned to the IFLU land in the calibrated model were above or below the cumulative leaching maximums set under the recalibrated Table 14.2 of PPC2 (Figure 2).

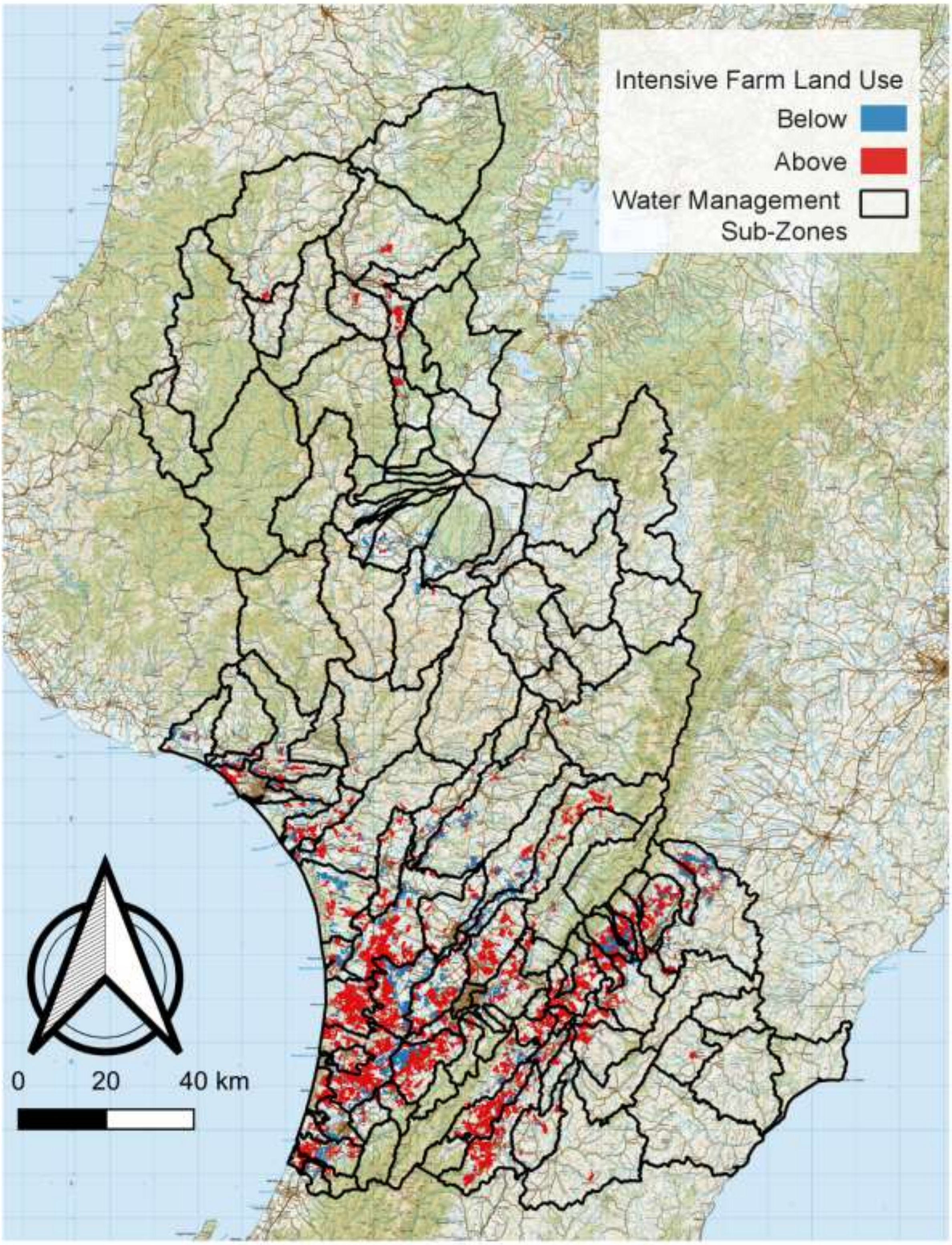

Figure 2. Map showing the location of all intensive farming land use (IFLU) in the region. IFLU with export coefficients in the calibrated model that are above and below the limits specified in Table 14.2 of PPC2 are shown in red and blue respectively.

2.2 Use of models to simulate scenarios

The CASM models were used to simulate water quality under historical conditions and in response to scenarios associated with the management of nitrogen discharges from diffuse sources (i.e., leached from land) and point sources. There are four groups of simulations: Historical Simulations, Operative Plan Scenarios, Proposed Plan Scenarios and Additional Scenarios. In the simulations that are reported here, changes in the management of nitrogen are simulated by changing the TN export coefficients from land (represented in the models by nodes) and/or by changing point source TN loading rates. The models allow for significant control of the assumed TN export coefficients from land. Export coefficients can be adjusted directly in the model for each combination of WMSZ, land use category, and LUC class. Additionally, they can be adjusted outside of the model (pre-processing) in consideration of the four biophysical factors.

The CASM models predict the annual TN load and mean TN concentrations at each assessment point for several scenarios described in detail below. Concentrations at each assessment point were estimated by dividing the load by the estimated mean discharge at that location (Snelder *et al.*, 2020).

2.3 Comparison of model predictions with One Plan water quality targets

The One Plan sets targets that pertain to river nitrogen concentrations for all WMSZ in the region. The first target is the soluble inorganic nitrogen (SIN) concentration. The One Plan SIN compliance statistic is specified as the annual average SIN concentration (g/m^3) when the river flow is at or below the 20th flow exceedance percentile. The One Plan also sets targets for periphyton: two region-wide targets for filamentous cover and diatoms and cyanobacteria (both measured as percentage cover) and WMSZ specific targets for maximum periphyton biomass (measured as chlorophyll-*a* in mg/m^2). The periphyton biomass target can be linked to a nitrogen concentration target using regional relationships between periphyton biomass and river water column nutrient concentrations. In this study, we have only reported against the One Plan SIN concentrations.

The CASM water quality model predictions were compared with the One Plan SIN targets by converting the model outputs to an equivalent One Plan SIN compliance statistic in four steps. First, we used existing regional water quality predictions made by Fraser and Snelder (2020) to estimate the calibration (i.e., 2012) SIN concentration (mg/m^3) for each assessment point. These SIN predictions were consistent with the One Plan compliance statistic (i.e., annual average SIN concentration (g/m^3) when the river flow is at or below the 20th flow exceedance percentile). The SIN concentration predictions were used as estimates of the One Plan SIN compliance statistic at each assessment point.

At the second step, we compared the One Plan SIN targets for each assessment point with SIN concentration predictions made by Fraser and Snelder (2020) to evaluate the pre-regulation (2012) water quality state. Water quality state was summarised as achieving or not achieving the One Plan targets depending on whether the predicted SIN concentration was less than or greater than the target.

At the third step we converted the CASM predictions for TN concentrations for each assessment point, and for each modelled scenario, to an equivalent SIN concentration. This conversion was made based on assumption that SIN concentration changes in proportion to the change in TN concentration changes, i.e., the following relationship applies:

$$\frac{SIN_{Scenario}}{TN_{Scenario}} = \frac{SIN_{Calibration}}{TN_{Calibration}} \qquad \text{(Equation 1)}$$

Therefore, the scenario SIN concentration for each assessment point was derived as:

$$SIN_{Scenario} = SIN_{Calibration} \times \frac{TN_{Scenario}}{TN_{\ Calibration}} \qquad \textit{(Equation 2)}$$

where $TN_{Calibration}$ is the model calibration TN concentration (g/m^3) estimated by the CASM model for each assessment point , $TN_{Scenario}$ is the TN concentration (g/m^3) predicted by the CASM model for the scenario and $SIN_{Calibration}$ is the SIN concentration estimated by Fraser and Snelder (2020). At the fourth step, we evaluated the water quality state for each assessment point and scenario based on comparing $SIN_{Scenario}$ to its associated One Plan SIN target.

2.4 Presentation of scenario simulations and results

Most scenarios are summarised by three maps. The first map shows the spatial distribution of differences in the export coefficients at the level of the WMSZ relative to an appropriate comparison simulation (the comparator). The second map shows the difference in the predicted SIN concentrations at the assessment points compared to the same comparator.

The appropriate comparator varies by scenario as described in detail in the following section. For example, some scenarios are appropriately compared to the 'calibrated model', which is the pre-regulation situation in 2012. For other scenarios, the appropriate comparator is another scenario. In this report, each scenario is compared with at least one comparator (some scenarios are compared with one or two additional comparators). We note that the choice of the appropriate comparator is subjective. Some discussions may benefit from comparisons with alternative comparator scenarios. If this is necessary, maps and summaries of comparisons between any pair of simulations can be prepared.

The third map shows the predicted water quality 'state' (i.e., the $SIN_{Scenario}$) at all assessment points for the scenario. These maps show state in relative terms by expressing how much lower or higher the predicted SIN concentration is relative to the One Plan SIN target (as a percentage). When discussing the predicted water quality state, we use the terms 'achieve' to mean a predicted concentration is less than the target and 'not achieve' to mean the predicted concentration is greater than the target.

Results are also summarised numerically in three ways. First, we quantify the number of positive and negative differences in SIN values at assessment points compared to the comparator simulation. Second, we quantify the number of assessment points at which SIN does not comply with One Plan SIN target are quantified. Third, we quantify the mean relative difference for each simulation. The mean relative difference indicates the mean amount (as a percentage) by which the predicted SIN concentration at assessment points deviate from the target SIN concentration. Positive values indicate the predicted SIN concentration exceeds the target (i.e., the objective is not achieved).

3 Model Simulations

3.1 General definition of scenarios

In this section the general approach to definition of scenarios is described. Multiple and different types of scenarios are then described in more detail in section 3.2 to 3.5. A summary of all the different types of scenarios is provided in section 3.6.

For the purpose of defining scenarios, we identify two types of IFLU: Consented-IFLU and Unconsented-IFLU. We further subdivide the Unconsented-IFLU into Known and Unknown Unconsented IFLU and subdivide again the Known Unconsented IFLU into Compliant-IFLU and Noncompliant-IFLU (Figure 3). Compliant means the nitrogen leaching rate is up to but not exceeding the Table 14.2 limits and non-compliant means the rate exceeds the Table 14.2 limits.

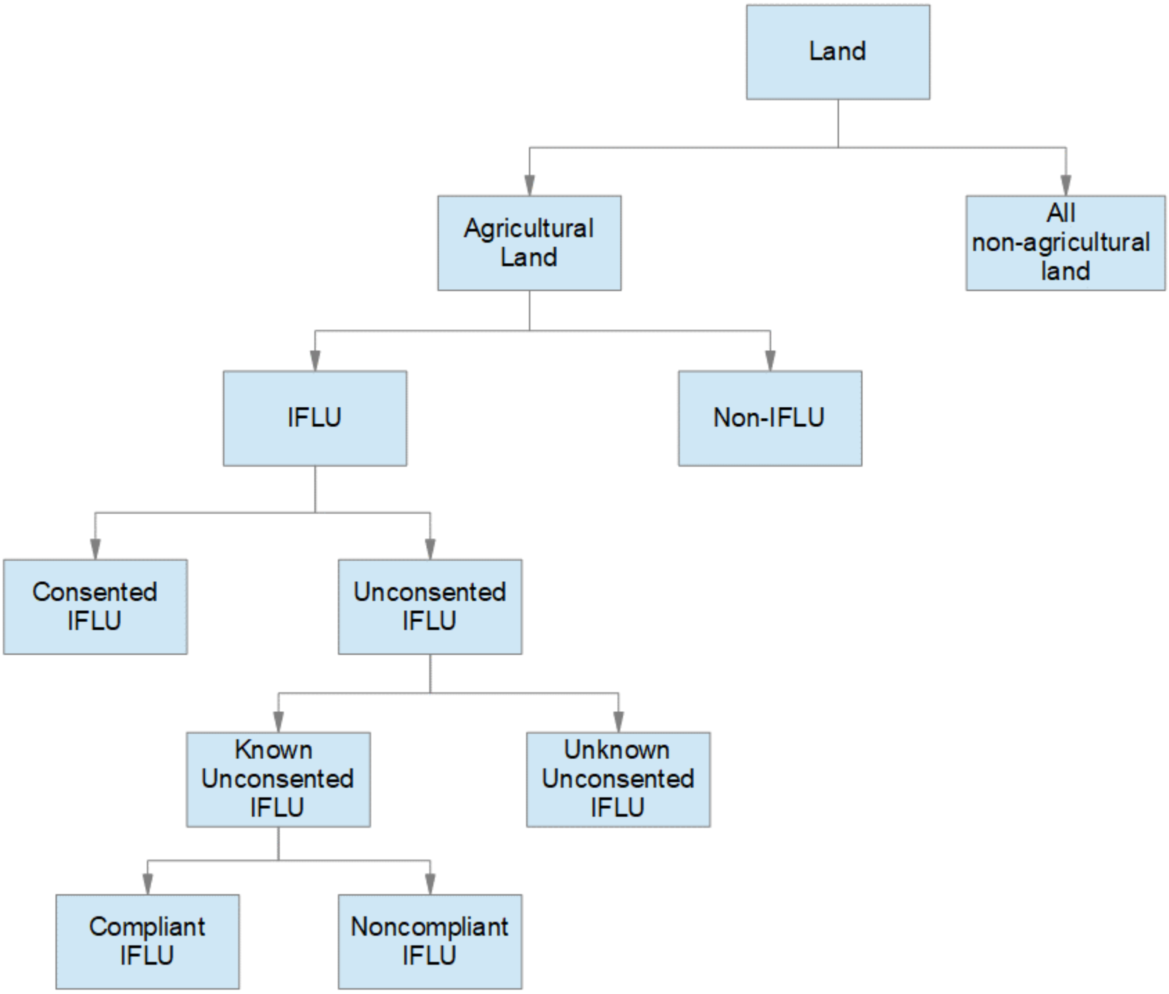

Figure 3. Types of land used to define the scenarios.

Consented-IFLU and Known Unconsented-IFLU were represented in the scenarios by 213 consented and 70 unconsented dairy farms that were described in a database provided by HRC[1] (the HRC database). The 213 consented dairy farms occupy a total area of 42,192 ha

[1] Both the consented and unconsented dairy farms are described in 20200417_Master. dairy farm data_Working Document – For Purposes of Pre-Hearing Conferences on PPC2.xlsx

and were all located in the target catchments (i.e., subzones shown in Figure 4). The 70 unconsented farms occupy an area of 12,902 ha located in subzones of the Upper Manawatū River catchment shown in Figure 4. This subset of farms represents the Compliant and Noncompliant-IFLU in the scenarios. The details of these farms were provided to HRC by DairyNZ (DNZ).

The HRC database detailed the OVERSEER basefile nitrogen leaching rate prior to regulation in 2012 (hereafter referred to as the "basefile" leaching rate) for all 283 farms (i.e., the 213 consented dairy farms and the 70 unconsented farms provided by DNZ). The HRC database also specified the consented (i.e., allowable) nitrogen leaching rate for the Consented-IFLU (i.e., consents issued after 2012 and referred to hereafter as post-regulation). For this study, the basefile nitrogen leaching rates for all farms were recalibrated based on OVERSEER v6.3.2 so that they are consistent with PPC2 Table 14.2. In addition, the consented nitrogen leaching rate was based on a recalibration of the original consented rate to a rate based on OVERSEER v6.3.2.

The consented nitrogen leaching rates varied across the Consented-IFLU and, in most scenarios, were assumed to continue unchanged through time. This is an assumption only because some consents expire before year 20 and may not be renewed at their current rate. In most scenarios described below, Consented-IFLU were simulated by setting the TN export coefficients from these areas to the consented nitrogen leaching rate.

The OVERSEER basefile nitrogen leaching rates for some of the 70 farms representing the Known Unconsented-IFLU in the DNZ database exceed the allowable nitrogen leaching rates in the proposed Table 14.2. In the modelled scenarios, it has been assumed that these Known Unconsented Noncompliant-IFLU will need to either reduce their nitrogen leaching to meet Table 14.2 or, alternatively, obtain a consent through the discretionary activity pathway provided by PPC2. In the scenarios, different assumptions are made concerning the nitrogen leaching rates for these Noncompliant-IFLU. For some scenarios, all Unconsented-IFLU was assumed to comply with Table 14.2, and this is simulated by adjusting TN export coefficients from these areas to the cumulative nitrogen leaching maximums set under the recalibrated Table 14.2). Other scenarios represent four choices of absolute reductions from the current loss rate for the Known Unconsented Noncompliant-IFLU: 9, 12, 15 and 18 kg/ha/yr. These choices represent differing levels of farm management practices with attendant implications for the farming system and its profitability. For some Known Unconsented Noncompliant-IFLU, one or more of the choices of absolute reduction may reduce the TN loss rate to the rate specified by Table 14.2.

Unknown Unconsented-IFLU was represented in the scenarios by all IFLU land shown on Figure 2 apart from those parcels that were accounted for in the HRC database. The nitrogen leaching rate for the Unknown Unconsented-IFLU land has been assumed to be the rate defined by the calibrated model prior to regulation in 2012 (i.e., at the rates defined by Bright *et al.* (2018) with some adjustments).

In most scenarios, the nitrogen leaching rate for non-IFLU land has been assumed to be the rate defined by the calibrated model prior to regulation in 2012 (i.e., at the rates defined by Bright *et al.* (2018) with some adjustments). There are three exceptions to this. First, Scenario 5 allows for an expansion of dairy farming and this is represented by increasing the TN loss rate on some sheep and beef farms to reflect this land use conversion. Second, Scenario 9 allows for an expansion of horticulture and this is represented by changing TN loss rates accordingly. Third, for Scenario 7, nitrogen export coefficients and points sources are set to values corresponding to natural conditions across the entire region to represent water quality in the absence of anthropogenic pressure.

Some scenarios were based on the operative Table 14.2 (as currently defined in the One Plan), but most scenarios focussed on the outcomes of applying the proposed PPC2 Table 14.2 values. Different scenarios represent water quality outcomes at either Year 5 or Year 20[2] of plan implementation. The details of each scenario are described in the following sections.

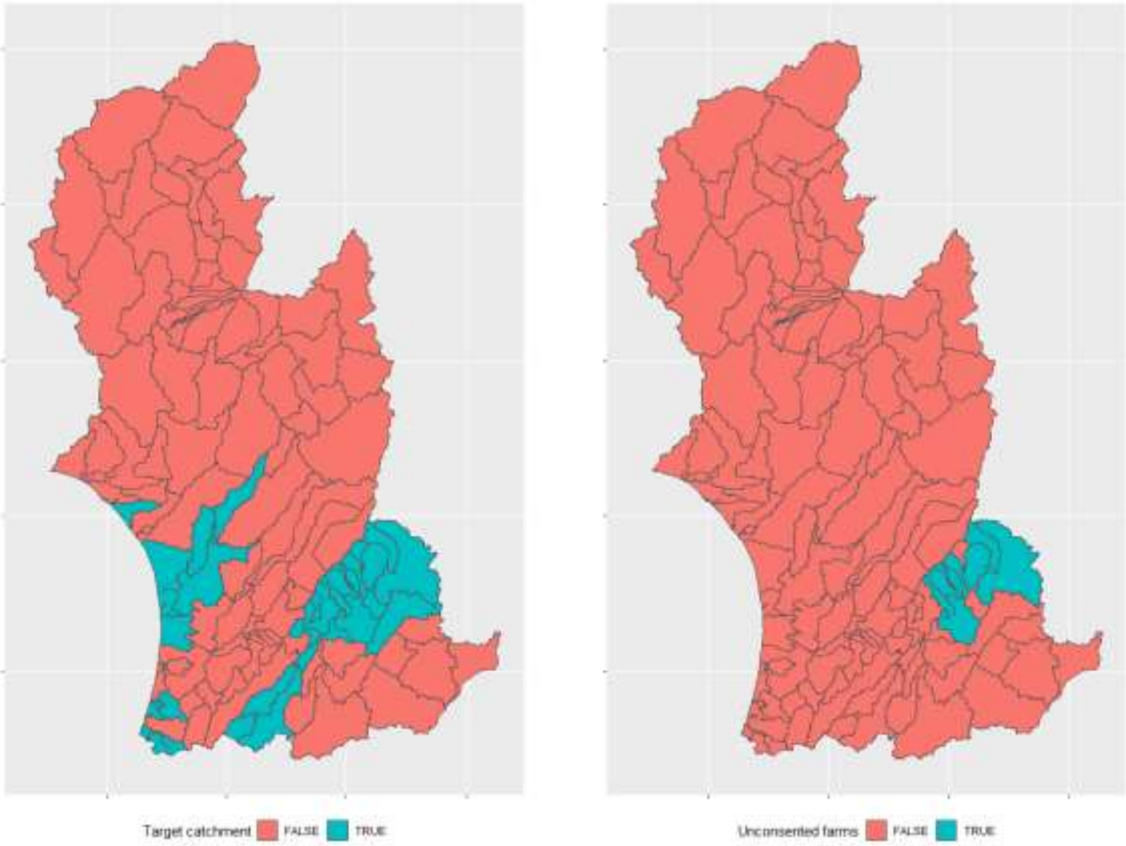

Figure 4. Maps of the region showing the 124 WMSZs. The left map indicates the WMSZs that are target catchments (blue). The right map indicates the WMSZs where the representative 70 currently unconsented dairy farms are located (blue).

3.2 Historical simulations

3.2.1 Calibrated Model Simulation

Simulations undertaken with the calibrated model represent the TN loads and concentrations prior to regulation in 2012. The Calibrated Model Simulation was made by obtaining the predicted TN loads for each WMSZ from the calibrated model.

3.2.2 Pre-regulation Simulation

The Pre-regulation Simulation represents the historical water quality outcome of the basefile leaching rate for Known Consented-IFLU and Known Unconsented-IFLU. The Pre-regulation Simulation is similar to the Calibrated Model Simulation except that nitrogen leaching rates for

[2] Year 5 and Year 20 is five or 20 years respectively after the Rules of the Plan have legal effect, as set out in Table 14.1 of the One Plan i.e. year zero ranges from 1 July 2014 to 1 July 2016.

Known Consented-IFLU and Known Unconsented-IFLU are set to their basefile leaching rates in 2012 rather than the export coefficients used in the calibration (i.e., the rates of Bright *et al.,* 2018).

The Pre-regulation Simulation was made by:

1. setting export coefficients for all non-IFLU and Unknown Unconsented-IFLU to the rates defined by the calibrated model
2. setting export coefficients for all consented-IFLU (i.e., 213 consented dairy farms described by HRC database) to their 2012 basefile leaching rates.
3. setting export coefficients for the Known Unconsented-IFLU (i.e., 70 unconsented dairy farms described by HRC database) to the 2012 basefile leaching rates.

The comparator used to report the results for the Pre-regulation Simulation is the Calibrated Model Simulation. This means the Pre-regulation Simulation results highlight the differences between the export coefficients used in the calibration of the CASM models and the basefile leaching rates obtained from the HRC database.

3.2.3 Point Sources Simulation

The Point Sources Simulation represents the water quality outcome of changes to the large point sources between the model calibration date (2012) and the most recent estimate of annual point source loads (2017). The model included 38 point sources that either increased or decreased between 2012 and 2017. Details of these point sources and changes between 2012 and 2017 are contained in Appendix B of Snelder *et al.* (2020).

The Point Source Change Simulation was made by:

1. setting export coefficients for all land as for the calibrated model
2. updating all point sources to the 2017 estimate.

The comparator used to report the results for the Point Sources Simulation is the Calibrated Model Simulation. This means the Point Sources Simulation results highlight the water quality outcome the changes to point source contributions of nitrogen between 2012 and 2017.

3.2.4 Post-regulation Simulation

There are two Post-regulation simulations. Post-regulation Simulation A represents the historical water quality outcome of consenting the 213 consented dairy farms (the Consented-IFLU; Figure 3). The Post-regulation Simulation A is similar to the Pre-regulation Simulation except that nitrogen leaching rates for Consented-IFLU are set to their consented nitrogen leaching rates in 2012. The Unconsented-IFLU are set to their basefile leaching rates in 2012 rather than the export coefficients used in the calibration (i.e., rates Bright *et al.,* 2018). Post-regulation Simulation B combines with the Point Sources Simulation to provide an assessment of the combined impact of these two water quality management interventions.

Post-regulation Simulation A was made by:

1. setting export coefficients for all non-IFLU and Unknown Unconsented-IFLU to the rates defined by the calibrated model

2. setting export coefficients for all Consented-IFLU (i.e., 213 consented dairy farms described by HRC database) to their consented leaching rates.
3. setting export coefficients for the Known Unconsented-IFLU (i.e., 70 unconsented dairy farms described by DNZ database) to the 2012 basefile leaching rates.

Post-regulation Simulation B was made by:

1. Updating all point sources to the 2017 estimates, added to the settings used for Post-regulation Simulation A.

The comparator used to report the results for both the Post-regulation Simulations is the Pre-regulation Simulation. This means the Post-regulation Simulation A results highlight the water quality outcome of reducing the nitrogen leaching rates from the consented-IFLU and Post-regulation Simulation A results highlight the combined impact of consenting and the point source changes.

3.2.5 Horticulture Mitigation Scenarios

The Horticulture Mitigation Scenarios represent the water quality outcome of recent changes to the management of commercial vegetable growing (CVG) on horticultural land since the model calibration date (2012). The report by Bloomer *et al.* (2020) indicates that improvements in CVG practices can reduce the annual nitrogen leaching rate from the 71 kg/ha/yr used in the model calibration to 46 kg/ha/yr. In addition Jolly *et al.* (2020) indicates that good management practice (GMP) can reduce annual nitrogen leaching rates for CGV by 36%, which is consistent with Bloomer *et al.* (2020). Jolly *et al.* (2020) also indicates that Best Management Practice (BMP) can reduce annual nitrogen leaching rates for CGV by 55%. Horticulture Mitigation Simulation A represents the impact of the Bloomer *et al.* (2020) leaching rate of 46 kg/ha/yr and the equivalent GMP reduction of 36% on CVG land. Horticulture Mitigation Simulation B represents the application of the BMP reduction of 55% on CVG land which results in a nitrogen leaching rate of 32 kg/ha/yr.

The Horticulture Mitigation Scenarios were made by:

1. setting export coefficients for all horticultural land in South West Coast climate zone with a plant available water (PAW) of ≥35 (see Snelder *et al.* (2020) for details) to 46 kg/ha/yr (A Scenario) and to 32 kg/ha/yr (B Scenario). This reduction therefore represents the improvements in CVG practices in the Horowhenua district.
2. Leaving all other nitrogen discharge rates (export coefficients for all land and point sources) unchanged from the calibrated model.

The comparator used to report the results for the Horticulture Mitigation Scenarios is the Calibrated Model Simulation. This means the Horticulture Mitigation Scenario results highlight the water quality outcome of changes to CVG practices in the Horowhenua district since 2012.

3.3 Operative One Plan Scenarios

3.3.1 Operative Scenario

The Operative Scenario represents the outcome of implementing the Operative Plan and assumes that all IFLU can comply with the Operative Plan Table 14.2. The purpose of the Operative Scenario is to simulate the water quality impact anticipated to result in the absence of expansion of dairy farming or any other IFLU, where all IFLU comply with the operative Table 14.2 by Year 20.

The Operative Scenario simulations were made by:

1. setting export coefficients for all non-IFLU to the rates defined by the calibrated model
2. setting export coefficients for all IFLU to the operative One Plan Table 14.2 (year 20).

The comparator used to report the results for the Operative Scenario is the Calibrated Model Simulation. This means the Operative Scenario highlights the impact on water quality of the Operative Plan.

3.3.2 Operative Consented Scenario

The Operative Consented Scenario represents the water quality outcome anticipated to result from implementation of the operative One Plan, with consenting. There are two sub-scenarios (A and B), representing the outcome for year 5 of implementation and year 20 of implementation.

The Operative Consented Year-20 Scenario assumes compliance with the One Plan Table 14.2 at year 20 except for Consented-IFLU. PPC2 changed the regulatory settings from the date it was publicly notified (mid 2019). Therefore, the Operative Consented Year-20 Scenario reflects as accurately as practicable the nitrogen leaching rates anticipated to result from One Plan decision-making prior to PPC2. In particular, the Operative Consented Year-20 Scenario represents the effects of the consented IFLU when it is compared to the Operative Scenario.

The Operative Consented Year-20 Scenario simulations were made by:

1. setting TN export coefficients for all non-IFLU land to the rates defined by the calibrated model
2. setting TN export coefficients for all Consented-IFLU (i.e. 213 farms) to the consented rate until year 20[3].
3. setting export coefficients for all Unconsented-IFLU to the rates specified by the operative One Plan Table 14.2.

The Operative Consented sub-scenarios A and B were distinguished by setting export coefficients for all Unconsented-IFLU (point 2 above) to the 5- and 20-year rates respectively. Only the 20-year results are reported below but the predictions for both years are provided in the supplementary data. The comparator used to report the results for Operative Consented Year-20 Scenario is the Operative Scenario. This means the Operative Consented Year-20 Scenario highlights the marginal impact of the increased nitrogen leaching due to consenting some IFLU above the rate specified in the Operative Plan Table 14.2.

3.3.3 Operative Dairy Expansion Scenario

The Operative Dairy Expansion Scenario represents the year 20 outcome of implementing the Operative Plan with two additional assumptions. First, it is assumed that there is an expansion of dairy farming within each water management subzone of 11%. Second, it is assumed all IFLU can comply with Table 14.2. The purpose of the Operative Dairy Expansion Scenario is to simulate the water quality impact anticipated to result when all IFLU comply with the operative One Plan Table 14.2 and there is some expansion of IFLU. This scenario is most closely aligned with Scenario 6 of Roygard and Clark (2012) and applies the same assumptions.

[3] Note that this is an assumption because some consents expire before year 20 and may not be renewed at their current rate.

The Operative Dairy Expansion Scenario simulations were made by:

1. increasing dairy farming land use within each water management subzone that currently has dairy farming by 11%. This increase is simulated by changing land use from sheep and beef to dairy farming.
2. setting export coefficients for all non-IFLU to the rates defined by the calibrated model
3. setting export coefficients for all IFLU to the rates shown in operative One Plan Table 14.2 (year 20).

The comparator used to report the results for the Operative Dairy Expansion Scenario is the Operative Scenario. This means the Operative Dairy Expansion Scenario results highlight the marginal impact of the increased nitrogen leaching resulting from increasing IFLU by 11%.

3.4 Proposed PPC2 Scenarios

3.4.1 Proposed Consented Scenario

The Proposed Consented Scenario represents the water quality outcome anticipated to result from implementing PPC2 Table 14.2 with no provision for a discretionary activity consent pathway for IFLU to discharge with loss rates higher than the Table 14.2. The Proposed Consented Scenario simulations were made by:

1. setting export coefficients for all non-IFLU land to the rates defined by the calibrated model
2. setting export coefficients for all Consented-IFLU (i.e. 213 consented dairy farms described by HRC database) to their consented rate (unless allowable nitrogen leaching rates specified by the Proposed Plan Table 14.2 are higher, in which case they were set to the rates specified in Table 14.2).
3. setting export coefficients for all Unconsented-IFLU to the cumulative leaching maximums set under the recalibrated Table 14.2 of PPC2.

The Proposed Consented Year-5 and Year-20 Scenarios were distinguished by setting export coefficients for all Unconsented-IFLU (point 3 above) to the 5- and 20-year rates respectively. Results are described below only for Proposed Consented Year-20 Scenario. The comparators used to report the results for the Proposed Consented Year-20 Scenario are the Operative Year-20 Consented Scenario and the Pre-regulation Scenario. This means that the Proposed Consented Scenario results highlight the impacts on water quality of the proposed plan change, compared to both the Operative Plan and un-regulated conditions.

3.4.2 Proposed Year-20 Pathway Scenarios

The Proposed Year-20 Pathway Scenarios represent the year 20 outcome of implementing the Proposed Plan (i.e., as proposed by PPC2) with provision for discretionary consent pathways for unconsented-IFLU that do not comply with Table 14.2. There are a number of sub-scenarios representing provision of discretionary consent pathways for dairy farming, CVG and to incorporate the outcome of changes to point source contributions of nitrogen between 2012 and 2017.

There are four sub-scenarios representing discretionary consent pathways for dairy farms that represent absolute reductions of 9, 12, 15 and 18 kg ha^{-1} yr^{-1} from the current nitrogen loss rates for farms that do not comply with the table. These are labelled Proposed Year-20

Pathway A, B, C and D. Results are described below only for Proposed Year-20 Pathway A and Proposed Year-20 Pathway D.

The Proposed Year-20 Pathway A, B, C and D Scenario simulations were made by:

1. setting export coefficients for all non-IFLU to the rates defined by the calibrated model
2. setting export coefficients for all Consented-IFLU (i.e. 213 consented dairy farms described by HRC database) to their consented rate
3. setting export coefficients for all Known Unconsented-IFLU (i.e., 70 unconsented dairy farms described by DNZ database) that do not comply with Table 14.2 to the larger of either the Table 14.2 value or their baseline nitrogen leaching rates less four choices of absolute reduction of 9, 12, 15 and 18 kg ha^{-1} yr^{-1}.
4. setting export coefficients for all Unknown Unconsented-IFLU to the rates specified by the Proposed Plan Table 14.2.

The comparator used to report the results for Proposed Year-20 Pathway A is the Proposed Consented Year-20 Scenario. Proposed Year-20 Pathway D is compared to Proposed Year-20 Pathway A. In addition, Proposed Year-20 Pathway A is compared to the Pre-regulation Scenario and the Proposed Year-20 Consented Scenario B is compared to the Proposed Year-20 Consented Strict Scenario (see below for details). This means that the Proposed Year-20 Pathway Scenarios highlight the marginal impacts of potential discretionary pathways and the impacts of such an implementation of PPC2 compared to an un-regulated scenario.

Further variations on the Proposed Year-20 Pathway Scenarios represent provision for discretionary pathways for CVG and are referred to as the Proposed Year-20 Pathway GMP Scenario and the Proposed Year-20 Pathway BMP Scenario. The Proposed Year-20 Pathway GMP Scenario combines the Proposed Year-20 Pathway A Scenario (absolute reductions in dairy farm leaching rates of 9 kg/ha/yr) with the Horticulture Mitigation Simulation A (reducing CVG leaching rate to 46 kg/ha/yr, which is the same as the 36% reduction that Jolly et al. (2020) consider represents GMP of on CVG land). The Proposed Year-20 Pathway BMP Scenario combines the Proposed Year-20 Pathway D Scenario (absolute reductions in dairy farm leaching rates of 18 kg/ha/yr) with the Horticulture Mitigation Simulation B (a 55% reduction to 32 kg/ha/yr that Jolly et al. (2020) consider represents GMP of on CVG land).

These scenarios are compared to three simulations. Both scenarios are compared to the Operative Consented and the Proposed Consented. The third comparator varies for the GMP and BMP scenario variations. The Proposed Year-20 Pathway GMP Scenario is compared to the Proposed Year-20 A Pathway and the Proposed Year-20 Pathway BMP Scenario is compared to the Proposed Year-20 D Pathway.

Finally, two further variations on the above scenarios were simulated by adding the Point Sources Simulation. These are referred to as the Proposed Year-20 Pathway GMP and Point Sources Scenario and the Proposed Year-20 Pathway BMP and Point Sources Scenario. These scenarios represent the combination of implementation of PC2 with the outcome of changes to significant point source contributions of nitrogen across the Region between 2012 and 2017. The comparators used to report the results for these scenarios are the Proposed Year-20 GMP Pathway and the Proposed Year-20 Pathway BMP Scenario, respectively. This choice of comparator highlights the marginal impacts of the changes to point source contributions of nitrogen between 2012 and 2017.

3.4.3 Proposed Year-5 Pathway Scenarios

The Proposed Year-5 Pathway Scenarios represents the year 5 outcome of implementing the Proposed Plan (i.e., as proposed by PPC2) with provision for discretionary consent pathways for unconsented dairy farms that do not comply with Table 14.2. There are four sub-scenarios representing differing levels of reduction from the current nitrogen loss rates for unconsented-dairy farms that do not comply with the table.

The Proposed Year-5 Pathway Scenarios simulations were made by:

1. setting export coefficients for all non-IFLU to the rates defined by the calibrated model
2. setting export coefficients for all Consented-IFLU (i.e. 213 consented dairy farms described by HRC database) to their consented rate
3. setting export coefficients for all Known Unconsented-IFLU (i.e., 70 unconsented dairy farms described by HRC database) that do not comply with Table 14.2 to the larger of either the Table 14.2 value or the currently estimated rates less four choices of absolute reduction of 9, 12, 15 and 18 kg ha^{-1} yr^{-1}.
4. setting export coefficients for all other Unconsented-IFLU to the rates specified by the Proposed Plan Table 14.2.

The four Proposed Year-5 Pathway Sub-scenarios represent the differing levels of reduction from the current nitrogen loss rates for the unconsented-dairy farms (i.e. HRC database) that are noncompliant with Table 14.2 (i.e., absolute reductions of 9, 12, 15 and 18 kg ha^{-1} yr^{-1}; point 3 above). These are labelled Proposed Year-5 Pathway Scenario A, B, C, and D. Results are described below only for Proposed Year-5 Pathway Scenario A and Proposed Year-5 Pathway Scenario D. The comparator used to report the results for Proposed Year-5 Pathway Scenario A is the Proposed Year-20 Pathway A. The Proposed Year-5 Pathway Scenario D is compared to Proposed Year-20 Pathway D. This means that the Proposed Year-5 Pathway Scenarios highlight the differences between simulated Year-5 and Year-20 conditions under such a regulatory scenario.

3.4.4 Proposed Consented Strict Scenario

The Proposed Consented Strict Scenario represents the water quality outcome anticipated to result at year 20 from implementing the Proposed Plan (i.e., PPC2) Table 14.2 with no provision for a discretionary activity pathway and with strict adherence to the current consent where that consented nitrogen leaching rate is less than Table 14.2. Therefore, where any current consent is more restrictive than Table 14.2, it has been assumed that the consented nitrogen leaching rate applies. There are 76 farms with consented rates less than the table. The average nitrogen leaching rate for these farms is 9 kg/ha/yr less than Table 14.2.

The Proposed Consented Strict Scenario simulations were made by:

1. setting export coefficients for all non-IFLU land to the rates defined by the calibrated model
2. setting export coefficients for all Consented-IFLU that are above Table 14.2 to the rates specified by the Proposed Plan Table 14.2 and setting all consented-IFLU that are below Table 14.2 to maintain the consented rate
3. setting export coefficients for all Unconsented-IFLU to the rates specified by the Proposed Plan Table 14.2.

The comparator used to report the results for Proposed Consented Strict Scenario is the Proposed Consented Scenario. This means that the Proposed Consented Strict Scenario highlights the marginal difference in water quality impacts anticipated from strict enforcement of consented rates, where consented rates are lower than the Proposed Plan Table 14.2.

3.5 Additional scenarios proposed by submitters

3.5.1 Natural State Scenario

The Natural State Scenario represents the water quality outcome of removing all anthropogenic land use from the region and all point sources of nitrogen. The purpose of the Natural State Scenario is to provide an indication of water quality under an unmodified land use state. The Natural State Scenario is based on the assumption that nitrogen export coefficients are equivalent to natural conditions across the entire region.

The Natural State Scenario simulations were made by:

1. setting export coefficients for all land to the rates used in the calibrated model for Native Cover, and setting all point sources to zero (see Snelder *et al.*, 2020 for details).

The comparator used to report the results for The Natural State Scenario is the Calibrated Model Simulation.

3.5.2 Dairy Sector Pathway Scenarios

The Dairy Sector Pathway Scenarios represent an alternative approach to restricting the leaching rates for the unconsented-IFLU. There are two versions of this scenario. The first (A) version is based on applying an alternative pathway for the dairy farms comprising the Known Unconsented-IFLU (Figure 3). These are the 70 unconsented dairy farms described by the HRC database. The second (B) version of the Dairy Sector Pathway Scenario is based on applying an alternative pathway for both the Known Unconsented farms and dairy farms that are Unknown Unconsented-IFLU (Figure 3). In both scenarios it is assumed that the current leaching rates of the unconsented dairy farms are reduced to the PPC2 year 20 value or, if larger: the minimum of 90% of the farm's basefile nitrogen leaching rate or the 75th percentile of the basefile nitrogen leaching rate of all dairy farms within the water management zone[4]. The nitrogen basefile rate means leaching rate modelled with OVERSEER for 2012-2013 but updated with OVERSEER 6.3.2 and as described in the HRC database.

The Dairy Sector Pathway A Scenario simulation was made by:

1. setting export coefficients for all non-IFLU to the rates defined by the calibrated model
2. setting export coefficients for all Consented-IFLU (i.e. 213 consented dairy farms described by HRC database) to their consented rate.
3. setting export coefficients for all Unconsented-IFLU to the rates specified by the Proposed Plan Table 14.2
4. then, if larger: re-setting export coefficients for all Known-Unconsented-IFLU to whichever is the lesser of either
    a. 90% of the land's nitrogen baseline rate or

[4] Note that we have interpreted this to be the water management zone (not the WMSZ).

b. The 75th percentile of the nitrogen baseline rate of all IFLU within the water management zone.

The Dairy Sector Pathway B Scenario simulation was made by:

1. setting export coefficients for all non-IFLU to the rates defined by the calibrated model
2. setting export coefficients for all IFLU to the rates specified by the Proposed Plan Table 14.2
3. For each of the 282 farms in the HRC database, apply the dairy sector pathway as described above to calculate the allowable nitrogen leaching rate.
4. From the above step, calculate the area weighted average allowable nitrogen leaching rate in each WMZ and use this value (if it is higher than the PPC2 Table 14.2 Year 20 rate) to set the export coefficients for all dairy farms in each WMZ. Note that this step is not applied to any WMZ that is not represented by farms in the HRC database and these therefore remain at the PPC2 Table 14.2 Year 20 rate.
5. Re-set export coefficients for all Consented-IFLU (i.e. 213 consented dairy farms described by HRC database) to their consented rate.
6. For each of the Known-Unconsented farms, reset export coefficients to that farm's specific dairy sector pathway rate (i.e., calculated at Step 3 above)

It is noted that the intent of the above steps is to use the farms in the HRC database as a representative sample of all farms in each WMZ. This representative sample is used to infer the outcome of the dairy sector pathway on the Unknown-Unconsented farms in each WMZ. Because the HRC database only has farms for some WMZs, all other IFLU across the region has export coefficients set to the PC2 Table 14.2 Year 20 rate.

The comparator used to report the results for the Dairy Sector Pathway Scenario is the Proposed Consented Scenario.

3.5.3 Horticulture Expansion Scenarios

The Horticulture Expansion Scenarios represent the water quality outcome of increasing commercial vegetable growing across the region. It is assumed that commercial vegetable growing is undertaken on LUC class I, II and III land across the region as a 5-year rotation in combination with the existing land use. The purpose of the Horticulture Expansion Scenarios is to provide bookend estimates of the water quality outcome of changing land use to commercial vegetable growing. The Horticulture Expansion A Scenario (lower bookend) assumes that commercial vegetable growing is undertaken on LUC class I, II and III land across the region that is currently in a Dairy Farming or Sheep and Beef land use. The Horticulture Expansion B Scenario (upper bookend) assumes that commercial vegetable growing is undertaken on LUC class I, II and III land across the region.

The Horticulture Expansion Scenario simulations were made by:

1. setting export coefficients for all non-IFLU on LUC class IV-VIII to the rates defined by the calibrated model
2. modifying export coefficients on all LUC class I-III that is:
    a. currently in a Dairy Farming or Sheep and Beef land use (be Horticulture Expansion A Scenario)

b. currently in in any land use (be Horticulture Expansion B Scenario)

Modification to export coefficients in both the Horticulture Expansion A Scenario and the Horticulture Expansion B Scenario was by adding 80% of their current estimated rate and 20%[5] of the estimated nitrogen leaching rate for potato growing (46 kg/ha/yr; see Bloomer *et al.*, 2020 for details). The comparator used to report the results for the Horticulture Expansion A Scenario and the Horticulture Expansion B Scenario is the Calibrated Model Simulation.

3.5.4 Potato Expansion Scenarios

The Potato Expansion Scenarios represent the water quality outcome of increasing commercial potato growing across the region. It is assumed that commercial potato growing is undertaken on LUC class I, II and III land across the region as a 5-year rotation in combination with the existing land use. The purpose of the Potato Expansion Scenario is to provide bookend estimates of the water quality outcome of changing land use to commercial potato growing. The Potato Expansion A Scenario (upper bookend) assumes that commercial potato growing is undertaken on LUC class I, II and III land across the region that is currently in a Dairy Farming or Sheep and Beef land use and that the nitrogen leaching rate for the potato crop is 24 kg/ha/yr. The Potato Expansion B and C Scenarios (lower bookend) are the same as the A Scenario but assumes nitrogen leaching rate for the potato crop are 13 kg/ha/yr and 9 kg/ha/yr respectively.

The Potato Expansion Scenario simulations were made by:

1. setting export coefficients for all non-IFLU on LUC class IV-VIII to the rates defined by the calibrated model
2. modifying export coefficients on all LUC class I-III that is currently in a Dairy Farming or Sheep and Beef land use to
   a. 24 kg/ha/yr
   b. 13 kg/ha/yr
   c. 9 kg/ha/yr

Modification to export coefficients in all the Potato Expansion Scenarios was by adding 80% of their current estimated rate and 20% of the estimate nitrogen leaching rate for the potato crops. The comparators used to report the results for the Potato Expansion Scenarios are the Calibrated Model Simulation.

[5] 20% is used to represent a 1 in 5 year rotation.

3.6 Summary of scenarios

Table 1. Summary of scenarios.

Scenario	Description	Primary comparator
Calibrated Model	Simulation using the calibrated model representing conditions prior to regulation in 2012	NA
Pre-regulation	Nitrogen leaching rates for consented-IFLU and unconsented-IFLU are set to their 2012 basefile leaching rates rather than the export coefficients used in the calibration	Calibrated Model
Point sources	Change in point source loads between 2012 and 2017	Calibrated Model
Post-regulation A	Export coefficients as for calibrated except N leaching rates for consented-IFLU are set to consented rates and unconsented-IFLU are set to their basefile leaching rates.	Pre-regulation
Post-regulation B	As for Post-regulation A and with point sources are updated to 2017 rates (from calibration 2012 rates).	Pre-regulation
Horticulture Mitigation A	Reduction in leaching rates from horticulture land in South West Coast climate zone to simulate GMP applied to commercial vegetable growing practices in the Horowhenua district.	Calibrated Model
Horticulture Mitigation B	Reduction in leaching rates from horticulture land in South West Coast climate zone to simulate BMP applied to commercial vegetable growing practices in the Horowhenua district.	Calibrated Model
Operative	implementation of the operative One Plan assuming that all IFLU complies with Table 14.2 by year 20.	Calibrated Model
Operative Consented	Implementation of the operative One Plan with all consented-IFLU at the consented rate for year 5 and year 20.	Operative year-20
Operative Dairy Expansion	Year 20 implementation of the operative One Plan with 11% expansion of IFLU within each WMSZ and assumes all IFLU complies with Table 14.2	Operative year-20
Proposed Consented	Implementation of PC2 with no provision for a discretionary activity pathway but existing consents at consented rates for Year 5 and Year 20.	Operative Year-20 Consented
Proposed Year-20 Pathway A	Year 20 implementation of PC2 discretionary pathways for non-consented/non-compliant IFLU with 9kg/ha/yr reduction from basefile leaching rates.	Proposed Consented
Proposed Year-20 Pathway D	Year 20 implementation of PC2 discretionary pathways for non-consented/non-compliant IFLU with 18kg/ha/yr reduction from basefile leaching rates.	Proposed year-20 pathway A
Proposed Year-20 Pathway GMP	Year 20 implementation of PC2 discretionary pathways for non-consented/non-compliant IFLU with 18kg/ha/yr reduction from basefile leaching rates except for CVG for which a GMP reduction of 36% applies	Proposed Consented
Proposed Year-20 Pathway BMP	Year 20 implementation of PC2 discretionary pathways for non-consented/non-compliant IFLU with 18kg/ha/yr reduction from basefile leaching rates except for CVG for which a MMP reduction of 55% applies	Proposed Consented
Proposed Year-20 Pathway GMP + point sources	Combination of Proposed Year-20 Pathway GMP and Point sources Scenario	Proposed Year-20 Pathway GMP Scenario
Proposed Year-20 Pathway BMP + point sources	Combination of Proposed Year-20 Pathway BMP and Point sources Scenario	Proposed Year-20 Pathway BMP Scenario

Proposed Year-5 Pathway A	Year 5 implementation PC2 discretionary pathways for non-consented/non-compliant IFLU with 9kg/ha/yr reduction from basefile leaching rates.	Proposed year-20 pathway A
Proposed Year-5 Pathway D	Year 5 implementation of PC2 discretionary pathways for non-consented/non-compliant IFLU with 18kg/ha/yr reduction from basefile leaching rates.	Proposed year-20 pathway D
Proposed Consented Strict	Year 20 implementation of PC2 with no provision for a discretionary activity pathway and adherence to consented rates where these are below Table 14.2 and reduction of N loss rates to Table 14.2 where consented rates are above Table 14.2.	Proposed Year-20 Consented
Natural state	Natural state (no land use or point sources of nitrogen)	Calibrated Model
Dairy Sector Pathway A	Alternative approach to restricting the leaching rates for the unconsented-IFLU applied only to the 70 Known-Unconsented dairy farms	Proposed Year-20 Consented
Dairy Sector Pathway A	Alternative approach to restricting the leaching rates for the unconsented-IFLU applied to all Unconsented dairy farms in the Target Catchments	Proposed Year-20 Consented
Horticulture Expansion A	Increasing vegetable growing on LUC class I- III land currently in a Dairy Farming or Sheep and Beef land use	Calibrated Model
Horticulture Expansion B	Increasing vegetable growing on LUC class I- III land currently in any land use	Calibrated Model
Potato Expansion A	Potato growing in a one in five year rotation on LUC class I- III land currently in a Dairy Farming or Sheep and Beef land use assuming a nitrogen leaching rate of 24 kg/ha/yr	
Potato Expansion B	Potato growing in a one in five year rotation on LUC class I- III land currently in a Dairy Farming or Sheep and Beef land use assuming a nitrogen leaching rate of 13 kg/ha/yr	
Potato Expansion C	Potato growing in a one in five year rotation on LUC class I- III land currently in a Dairy Farming or Sheep and Beef land use assuming a nitrogen leaching rate of 9 kg/ha/yr	

4 Results

4.1 Model uncertainty and interpretation of results

As described in the model calibration report (Snelder *et al.* 2020), the models are most reliably, and most appropriately, applied to predict *relative* changes in receiving water quality between scenarios. This is particularly true for unmonitored assessment points. The focus, therefore, of the presentation of results below is on predicted relative changes. The exception to this is where we make assessments with respect to compliance with One Plan targets (far right map shown in each section below), which must be based on estimated absolute concentration estimates. While we deem the compliance results useful, and the product of best available science, we acknowledge that these results are less certain than those summarising predicted relative changes in concentration only (centre maps). We encourage the reader to keep this in mind when considering the implications of the results presented below. A more detailed discussion of model uncertainty is provided in Snelder *et al*. (2020).

4.2 Historical simulations

4.2.1 Calibrated Model Simulation

The nitrogen export coefficients and resulting river SIN concentrations for the Calibrated Model Simulation are shown in Figure 5. Under the Calibrated Model Simulation, predicted concentrations of SIN do not comply with One Plan targets in 96 of the 124 assessment points (Figure 5). Predicted concentrations of SIN exceed the target by more than 10%, 20% and 50% at 89, 77 and 48 assessment points respectively.

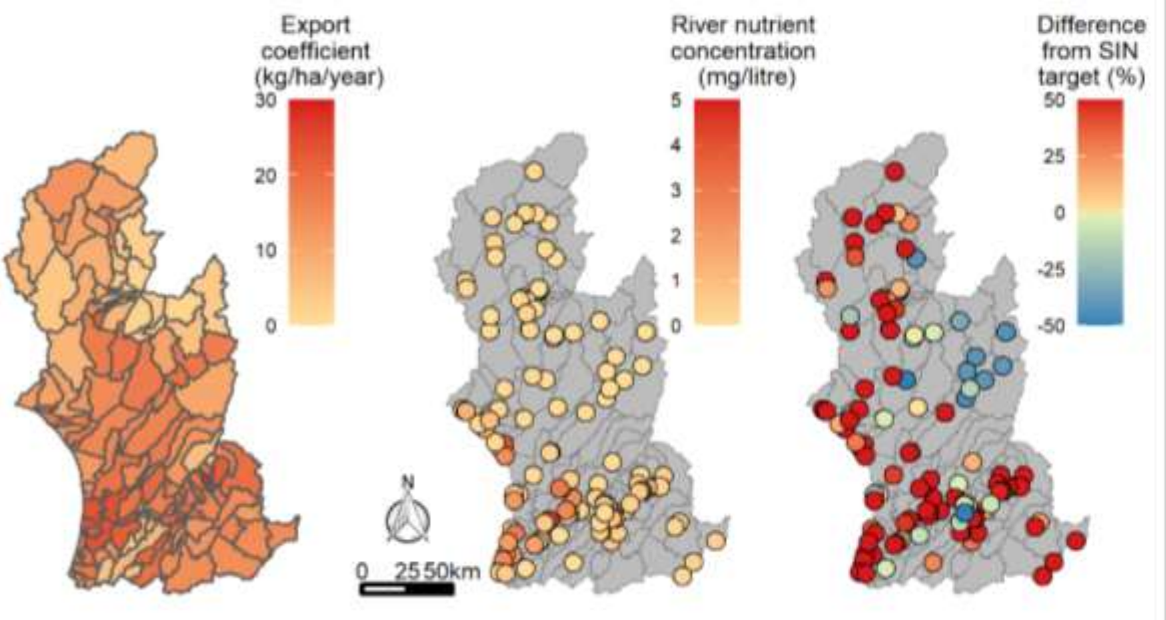

Figure 5. Nitrogen export coefficient and predicted river SIN concentrations for the Calibrated Model Simulation. The values shown on the left map are the mean nitrogen export coefficient in each WMSZ. The values shown on the centre map are the predicted SIN concentrations at each assessment point. The values shown on the right map indicate state in relative terms (i.e., SIN concentration divided by the SIN target) at each assessment point. Negative percentages on the right map indicate achievement of the water quality state target and vice versa.

4.2.2 Pre-regulation Simulation

The difference in the nitrogen export coefficients and resulting river SIN concentrations under the Pre-regulation Simulation compared to the Calibrated Model Simulation is shown in Figure 6. The Pre-regulation Simulation is similar to the Calibrated Model Simulation except that nitrogen leaching rates for consented-IFLU and unconsented-IFLU are set to their basefile rates rather than the export coefficients used in the calibration. TN export coefficients for WMSZs and SIN concentrations at assessment points under the Pre-regulation Simulation were variously lower or higher than the Calibrated Model Simulation (Figure 6).

There is a close match between the Calibrated Model Simulation and the Pre-regulation Simulation (i.e., differences in SIN concentration at assessment points between the Calibrated Model Simulation and the Pre-regulation Simulation are small). In addition, there is an absence of bias (i.e., differences in SIN concentration at assessment points between the Calibrated Model Simulation and the Pre-regulation Simulation are both positive and negative). This indicates that the calibration nitrogen export coefficients are reasonably consistent with the estimated leaching rates for the consented-IFLU and unconsented-IFLU. This observation is consistent with the comparisons of leaching rate estimates made by Snelder *et al.* (2020).

Under the Pre-regulation Simulation, predicted concentrations of SIN do not achieve One Plan targets in 97 of the 124 assessment points (Figure 6). Predicted concentrations of SIN exceed the target by more than 10%, 20% and 50% at 88, 78 and 50 assessment points, respectively.

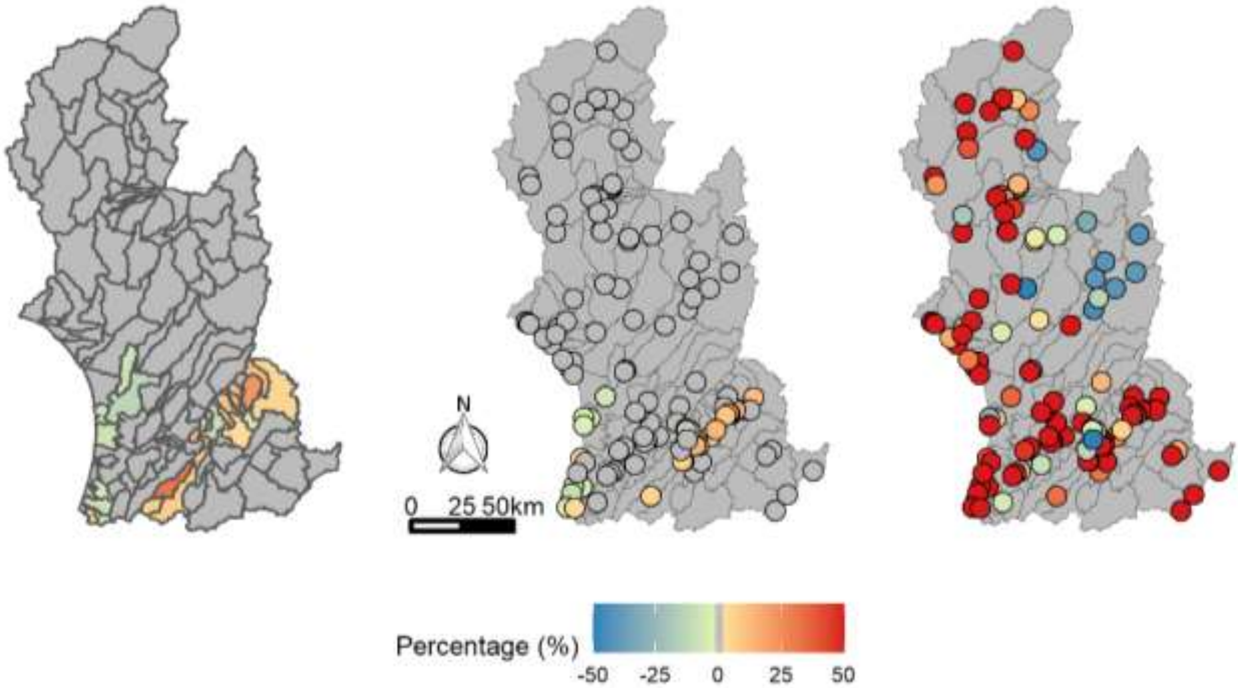

Figure 6. Percentage difference in nitrogen export coefficient (left), percentage difference in river SIN concentrations (centre) and percentage difference between predicted SIN concentration and SIN target (right) for the Pre-regulation Simulation. The differences shown on the left and centre maps were derived by comparing the Pre-regulation Simulation with the Calibrated Model Simulation. Negative percentages on the right map indicate achievement of the water quality state target and vice versa.

4.2.3 Point Sources Simulation

Nitrogen export coefficients under the Point Sources Scenario are unchanged compared to the modelling baseline simulation (Figure 7). However, of the 36 point sources that were common to both 2012 and 2017 simulation years, discharged nitrogen loads decreased at 25 locations and increased at 11 locations. Differences in river SIN concentrations between the Point Sources Scenario (representing point sources in 2017) and the Calibrated Model Simulation (representing point sources in 2012) are shown inFigure 7. Compared to the Calibrated Model Simulation, SIN concentrations under the Point Sources Scenario are predicted to be higher at 18 (i.e., 15%) assessment points and lower at 31 (i.e., 25%) assessment points.

Under the Point Sources Scenario, predicted concentrations of SIN do not achieve the One Plan targets in 95 of the 124 assessment points (Figure 7). Predicted concentrations of SIN exceed the target by more than 10%, 20% and 50% at 88, 76 and 47 assessment points, respectively.

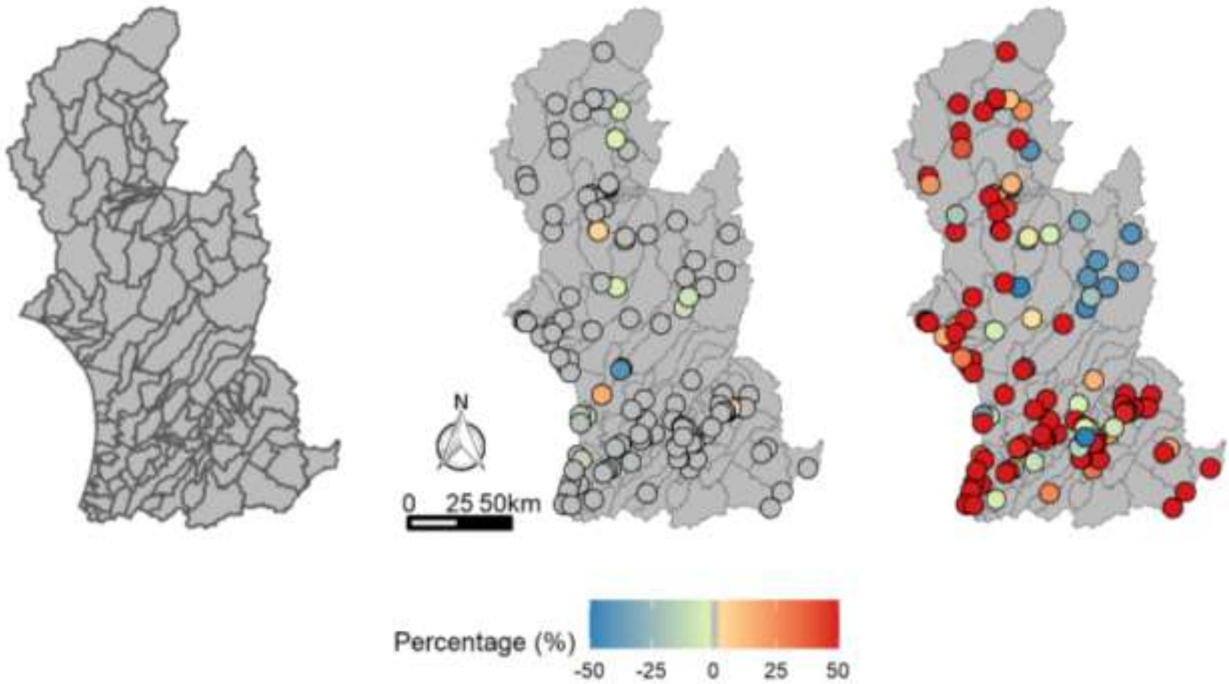

Figure 7. Percentage difference in nitrogen export coefficient (left), percentage difference in river SIN concentrations (centre) and percentage difference between predicted SIN concentration and SIN target (right) for the Point Sources Scenario. The changes shown on the left and centre maps were derived by comparing the Point Sources Scenario with the Calibrated Model Simulation. Negative percentages on the right map indicate achievement of the water quality state target and vice versa.

4.2.4 Post-regulation Simulations

The difference in the nitrogen export coefficients and resulting river SIN concentrations under the Post-regulation Simulation A compared to the Pre-regulation Simulation is shown in Figure 8. The Post-regulation Simulation A is similar to the Pre-regulation Simulation except that nitrogen leaching rates for Consented-IFLU are set to their consented rates. TN export coefficients for WMSZs and SIN concentrations at assessment points under the Pre-regulation Simulation were the same or lower than the Pre-regulation Simulation (Figure 8).

The SIN concentrations at assessment points downstream of the Target Catchments were predicted to be lower for the Post-regulation Simulation compared to the Pre-regulation Simulation. This highlights the water quality impact of the consenting of the consented-IFLU (i.e., 213 consented dairy farms described by HRC database).

Under the Post-regulation A Simulation the predicted concentrations of SIN do not achieve One Plan targets in 97 of the 124 assessment points (Figure 8). Predicted concentrations of SIN exceed the target by more than 10%, 20% and 50% at 88, 77 and 48 assessment points, respectively.

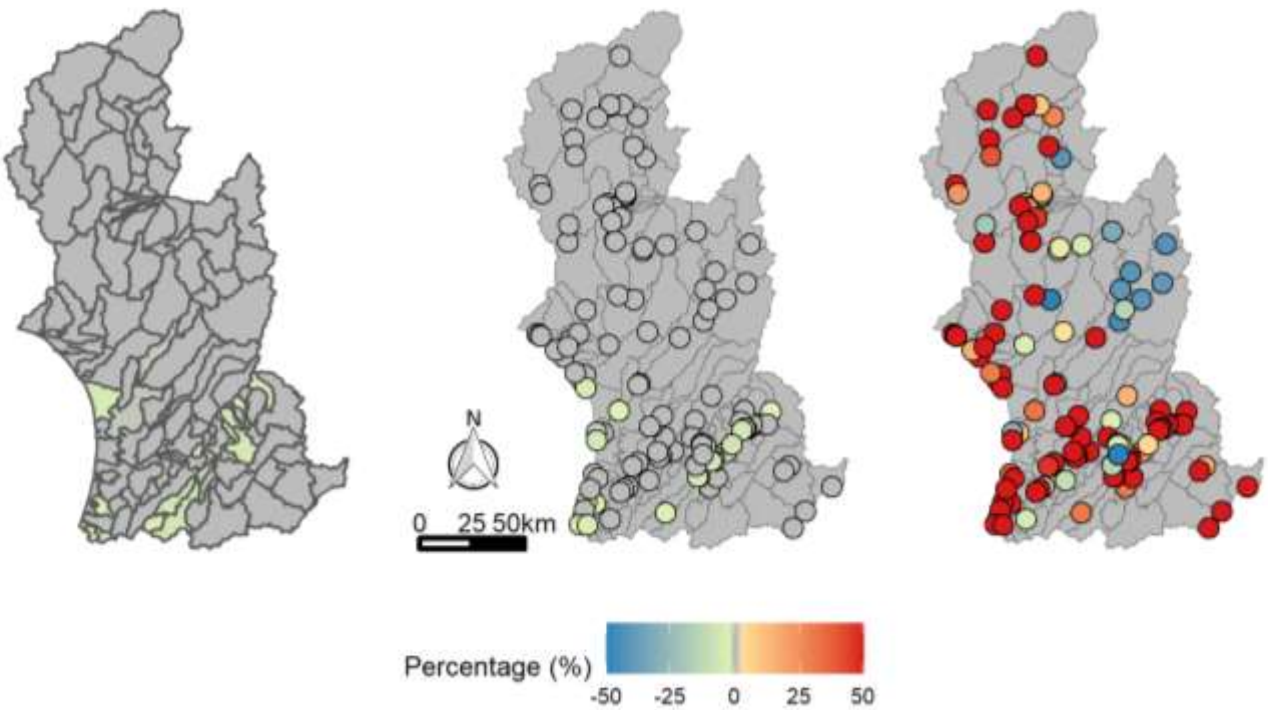

Figure 8. Percentage difference in nitrogen export coefficient (left), percentage difference in river SIN concentrations (centre) and percentage difference between predicted SIN concentration and SIN target (right) for the Post-regulation A Simulation. The differences shown on the left and centre maps were derived by comparing the Post-regulation Simulation with the Pre-regulation Simulation. Negative percentages on the right map indicate achievement of the water quality state target and vice versa.

The SIN concentrations at assessment points were higher and lower for the Post-regulation B Simulation compared to the Pre-regulation Simulation (Figure 9). This highlights the combined water quality impact of the consenting of the consented-IFLU (i.e., 213 consented dairy farms described by HRC database, which uniformly decreased discharges) and the variable changes in nitrogen discharges (i.e., both increases and decreases) associated with point sources.

Under the Post-regulation B Simulation the predicted concentrations of SIN do not achieve One Plan targets in 96 of the 124 assessment points (Figure 9). Predicted concentrations of

SIN exceed the target by more than 10%, 20% and 50% at 88, 76 and 48 assessment points, respectively.

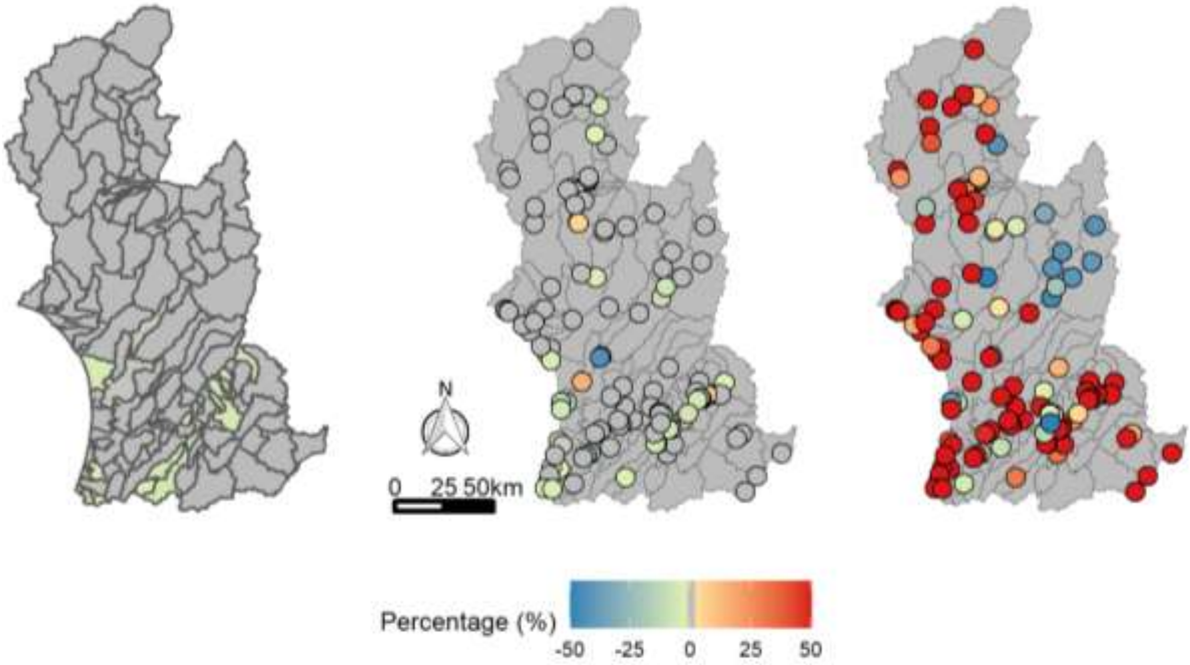

Figure 9. Percentage difference in nitrogen export coefficient (left), percentage difference in river SIN concentrations (centre) and percentage difference between predicted SIN concentration and SIN target (right) for the Post-regulation B Simulation. The differences shown on the left and centre maps were derived by comparing the Post-regulation Simulation with the Pre-regulation Simulation. Negative percentages on the right map indicate achievement of the water quality state target and vice versa.

4.2.5 Horticulture Mitigation Scenarios

Nitrogen export coefficients under the Horticulture Mitigation A Scenario reduced slightly in WMSZs located in South West Coast climate zone (Horowhenua district) compared to the modelling baseline simulation (Figure 10). Differences in river SIN concentrations between the Horticulture Mitigation A Scenario and the Calibrated Model Simulation are shown in Figure 10. Compared to the Calibrated Model Simulation, SIN concentrations under the Horticulture Mitigation A Scenario are predicted to be lower at 29 (i.e., 23%) assessment points and were not predicted to be higher at any assessment points.

Under the Horticulture Mitigation A Scenario, predicted concentrations of SIN do not achieve the One Plan targets in 96 of the 124 assessment points (Figure 10). Predicted concentrations of SIN exceed the target by more than 10%, 20% and 50% at 89, 77 and 48 assessment points, respectively. The mean relative difference indicates the mean amount by which the predicted concentration at assessment points deviate from the target. Positive values indicate the predicted SIN concentration exceeds the target (i.e., the objective is not achieved). The mean relative difference for the Horticulture Mitigation A Scenario indicated that, on average, predicted SIN concentrations at assessment points were 29.7% greater than the One Plan target. (Note that the percentage is given to one decimal place here in order to illustrate the very marginal difference to the results for the next scenario below).

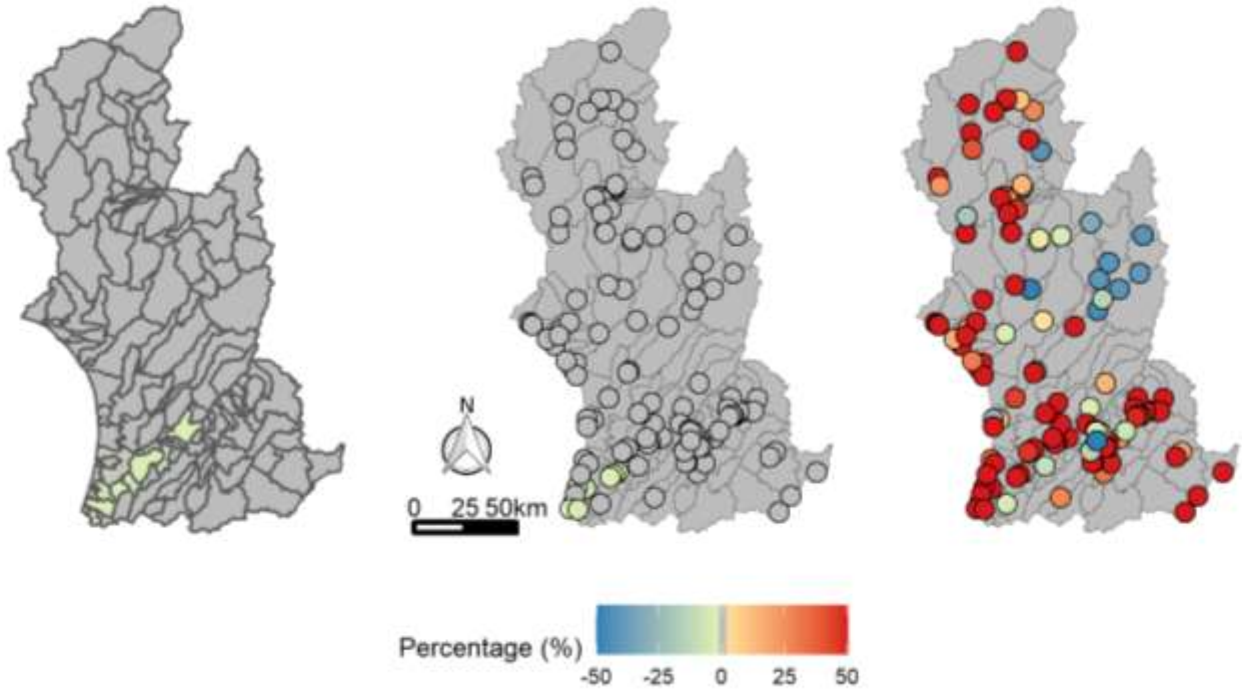

Figure 10. Percentage difference in nitrogen export coefficient (left), percentage difference in river SIN concentrations (centre) and percentage difference between predicted SIN concentration and SIN target (right) for the Horticulture Mitigation A Scenario. The changes shown on the left and centre maps were derived by comparing the Horticulture Mitigation Scenario with the Calibrated Model Simulation. Negative percentages on the right map indicate achievement of the water quality state target and vice versa.

Differences in river SIN concentrations between the Horticulture Mitigation B Scenario and the Calibrated Model Simulation are shown in

Figure 11. Compared to the Calibrated Model Simulation, SIN concentrations under the Horticulture Mitigation B Scenario are predicted to be lower at 32 (i.e., 26%) assessment points and were not predicted to be higher at any assessment points. Under the Horticulture Mitigation B Scenario, predicted concentrations of SIN do not achieve the One Plan targets in 96 of the 124 assessment points (Figure 11Figure 10). Predicted concentrations of SIN exceed the target by more than 10%, 20% and 50% at 89, 77 and 48 assessment points, respectively. The mean relative difference for the Horticulture Mitigation B Scenario indicated that, on average, predicted SIN concentrations at assessment points were 29.6% greater than the One Plan target. There is therefore no significant difference between the A and B Scenarios in terms of the evaluated water quality outcomes.

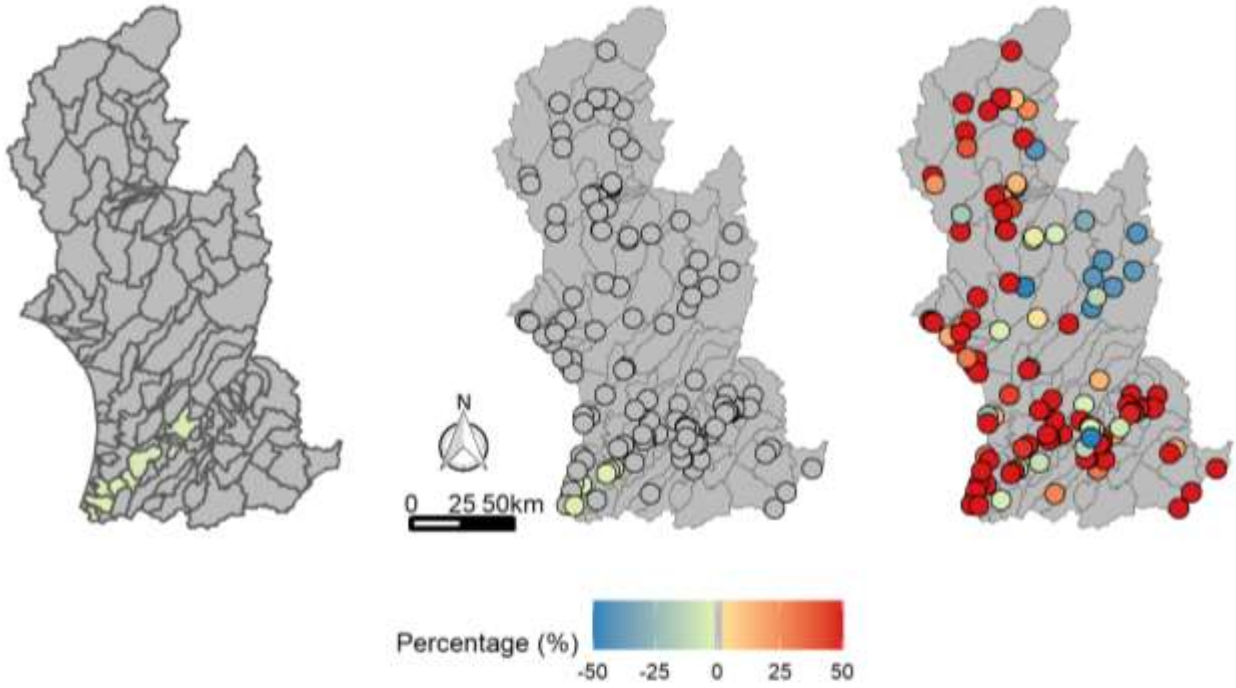

Figure 11. Percentage difference in nitrogen export coefficient (left), percentage difference in river SIN concentrations (centre) and percentage difference between predicted SIN concentration and SIN target (right) for the Horticulture Mitigation B Scenario. The changes shown on the left and centre maps were derived by comparing the Horticulture Mitigation Scenario with the Calibrated Model Simulation. Negative percentages on the right map indicate achievement of the water quality state target and vice versa.

4.3 Operative One Plan Scenarios

4.3.1 Operative Scenario

The differences in the nitrogen export coefficients and resulting river SIN concentrations under the Operative Scenario compared to the Calibrated Model Simulation are shown in Figure 12. The Operative Scenario represents the year 20 outcome of implementing the Operative Plan and assumes that all IFLU comply with the Operative Plan Table 14.2. TN export coefficients for WMSZs and SIN concentrations at assessment points under the Operative Year-20 Scenario were variously lower or higher than the Calibrated Model Simulation (Figure 12). Compared to the Calibrated Model Simulation, nitrogen export coefficients under the Operative Year-20 Scenario are higher in 2 (i.e., 2%) and lower in 85 (i.e., 69%) WMSZs. Compared to the Calibrated Model Simulation, SIN concentrations are predicted to be lower at 97 assessment points. Compared to the modelling baseline, SIN concentrations are predicted to be higher at six assessment points (Figure 12).

Under the Operative Scenario, predicted concentrations of SIN do not achieve One Plan targets in 91 of the 124 assessment points (Figure 12). Predicted concentrations of SIN exceed the target by more than 10%, 20% and 50% at 81, 65 and 42 assessment points, respectively.

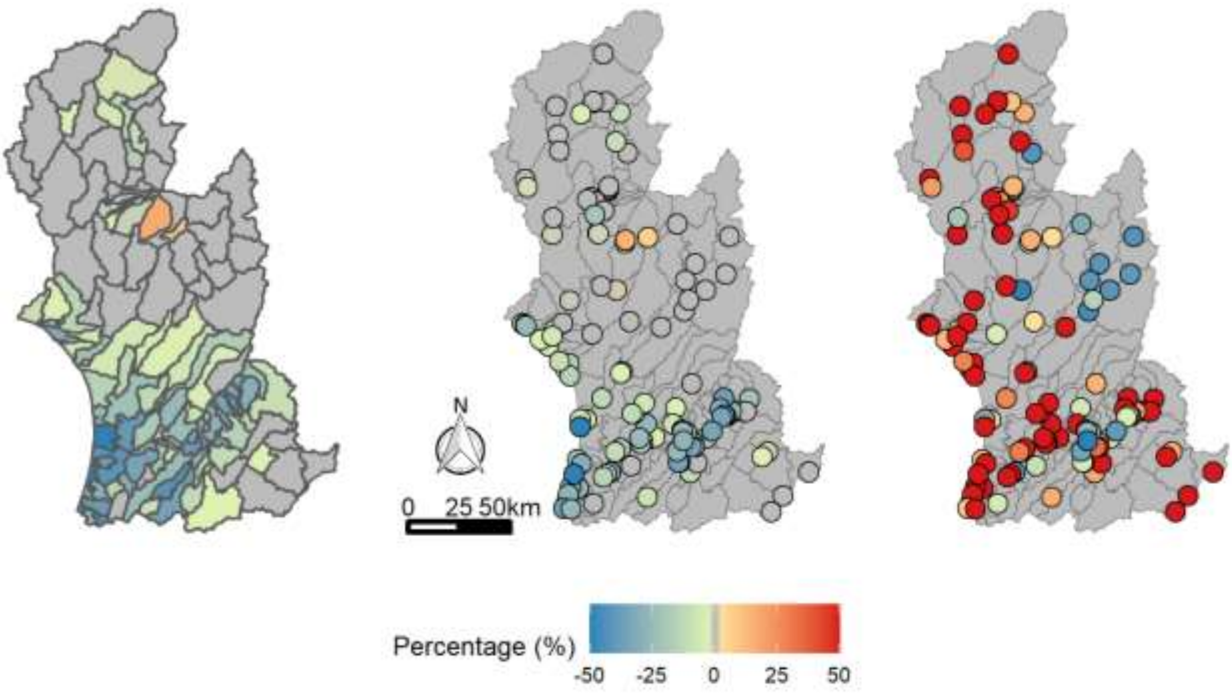

Figure 12. Percentage difference in nitrogen export coefficient (left), percentage difference in river SIN concentrations (centre) and percentage difference between predicted SIN concentration and SIN target (right) for the Operative Scenario. The differences shown on the left and centre maps were derived by comparing the Operative Scenario with the Calibrated Model Simulation. Negative percentages on the right map indicate achievement of the water quality state target and vice versa.

4.3.2 Operative Consented Scenario

The differences in the nitrogen export coefficients and resulting river SIN concentrations under the Operative Consented Year-20 Scenario compared to the Operative Scenario are shown in Figure 13. The Operative Consented Year-20 Scenario represents the year 20 outcome of implementation of the operative One Plan (note that the Operative Year-20 Consented A Scenario represents the year 5 outcome, but the results are not presented below). Nitrogen export coefficients in all WMSZs and SIN concentrations at all assessment points under the Operative Year-20 Consented B Scenario are the same or higher than the Operative Year-20 Scenario. Compared to the Operative Year-20 Scenario, nitrogen export coefficients under the Operative Year-20 Consented B Scenario are higher in 29 (i.e., 23%) of WMSZs. Compared to the Operative Year-20 Scenario, SIN concentrations under the Operative Year-20 Consented B Scenario are predicted to be higher at 36 (i.e., 29%) assessment points. These assessment points are all located downstream of target catchments where there are consented IFLU.

Under the Operative Consented Year-20 Scenario, predicted concentrations of SIN do not achieve the One Plan targets in 96 of the 124 assessment points (Figure 13). Predicted concentrations of SIN exceed the target by more than 10%, 20% and 50% at 87, 73 and 43 assessment points, respectively.

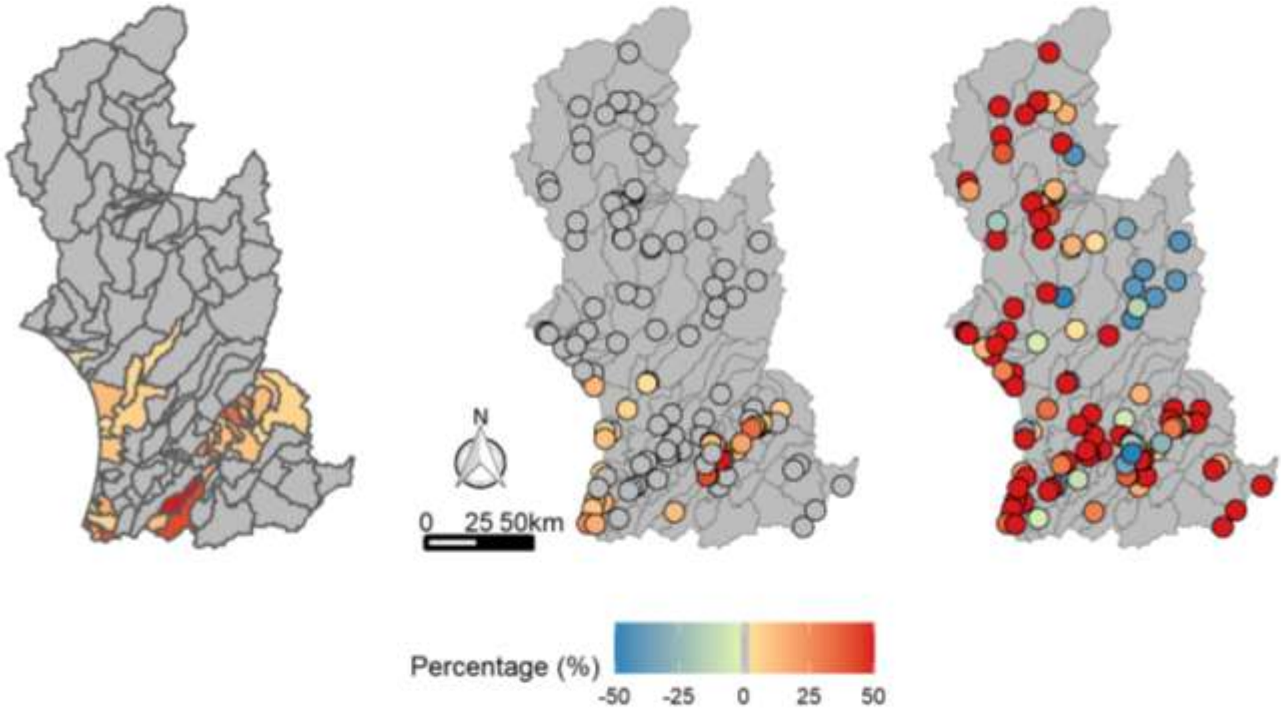

Figure 13. Percentage difference in nitrogen export coefficient (left), percentage difference in river SIN concentrations (centre) and percentage difference between predicted SIN concentration and SIN target (right) for the Operative Consented Year-20 Scenario. The differences shown on the left and centre maps were derived by comparing the Operative Consented Year-20 Scenario with the Operative Scenario. Negative percentages on the right map indicate achievement of the water quality state target and vice versa.

4.3.3 Operative Dairy Expansion Scenario

The difference in the nitrogen export coefficients and resulting river SIN concentrations under the Operative Dairy Expansion Scenario compared to the Operative Scenario are shown in Figure 14. The Operative Dairy Expansion Scenario represents the year 20 outcome of the Operative Plan and the assumption that there is an 11% expansion of dairy farming that complies with Table 14.2.

Nitrogen export coefficients in all WMSZs and SIN concentrations at all assessment points under the Operative Dairy Expansion Scenario are the same or higher than the Operative Scenario. Compared to the Operative Scenario, SIN concentrations under the Operative Dairy Expansion Scenario are predicted to be higher at 76 (i.e., 62%) assessment points.

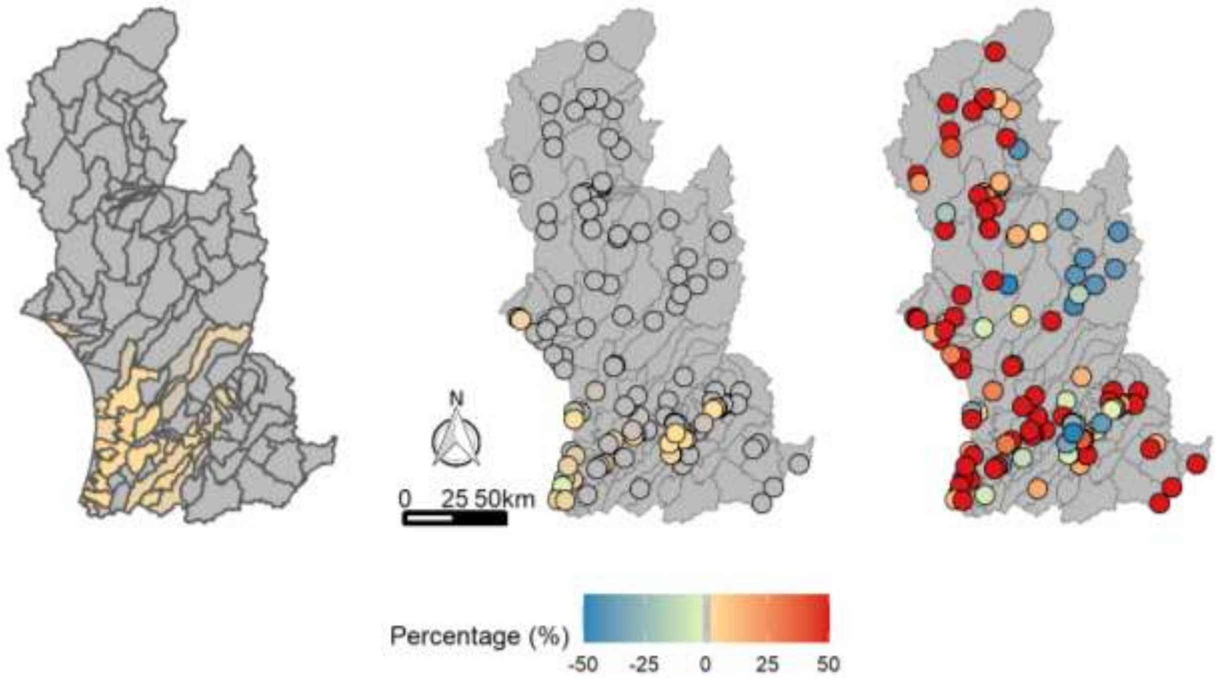

Figure 14. Percentage difference in nitrogen export coefficient (left), percentage difference in river SIN concentrations (centre) and percentage difference between predicted SIN concentration and SIN target (right) for the Operative Dairy Expansion Scenario. The differences shown on the left and centre maps were derived by comparing the Operative Dairy Expansion Scenario with the Operative Scenario. Negative percentages on the right map indicate achievement of the water quality state target and vice versa.

4.4 Proposed Plan Changes

4.4.1 Proposed Consented Scenarios

The difference in the nitrogen export coefficients and resulting river SIN concentrations under the Proposed Consented Year-20 Scenario compared to Operative Consented Scenario are shown in Figure 15. The Proposed Consented Year-20 Scenario represents outcome of the Proposed Plan (i.e., PPC2 and new Table 14.2) for year 20 with no provision for a discretionary activity consent pathway. TN export coefficients in all WMSZs and SIN concentrations at all assessment points under the Proposed Consented Year-20 Scenario are the same or higher than the Operative Consented Scenario. Compared to the Operative Consented Scenario, nitrogen export coefficients under Proposed Consented Year-20 Scenario are higher in 86 (i.e., 69%) of WMSZs. Compared to the Operative Consented Scenario the SIN concentrations under Proposed Consented Year-20 Scenario are higher at 100 (i.e., 81%) assessment points (Figure 15).

Under the Proposed Consented Year-20 Scenario, predicted concentrations of SIN do not achieve the One Plan targets in 98 of the 124 assessment points (Figure 15). Predicted concentrations of SIN exceed the target by more than 10%, 20% and 50% at 89, 77 and 47 assessment points, respectively.

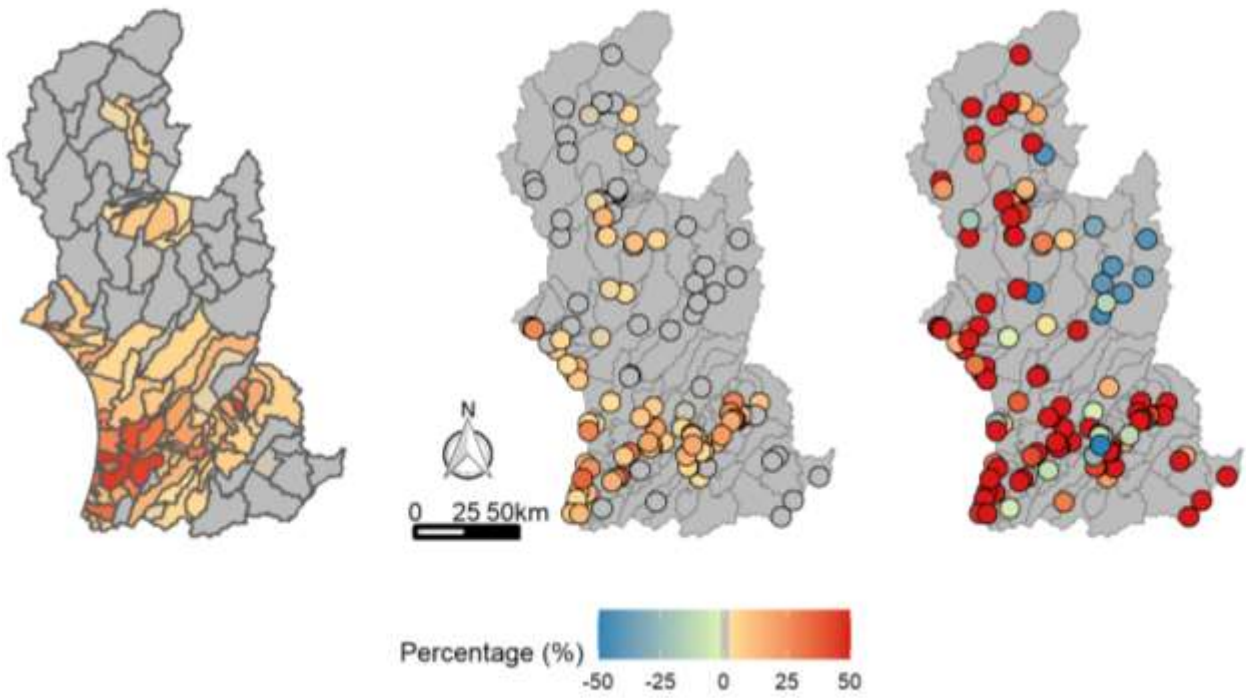

Figure 15. Percentage difference in nitrogen export coefficient (left), percentage difference in river SIN concentrations (centre) and percentage difference between predicted SIN concentration and SIN target (right) for the Proposed Consented B Scenario. The differences shown on the left and centre maps were derived by comparing Proposed Consented Year-20 Scenario with the Operative Consented Scenario. Negative percentages on the right map indicate achievement of the water quality state target and vice versa.

Compared to the Pre-regulation Scenario, SIN concentrations under Proposed Consented Year-20 Scenario were higher at 29 (i.e., 23%) assessment points and were lower at 81 (i.e., 65%) of assessment points (Figure 16). The assessment points where SIN concentrations were lower tended to be downstream of target catchments (Figure 16). The assessment points where SIN concentrations were higher tended to be downstream of non-target catchments (i.e., catchments where there was not consented IFLU) and where there was significant area of IFLU with export coefficients in the calibrated model that are below the cumulative leaching maximums set under the recalibrated Table 14.2 of PPC2 (see Figure 2). This indicates that under the Proposed Consented Year-20 Scenario, some existing IFLU is assumed to increase its nitrogen leaching rate to the limit specified in Table 14.2.

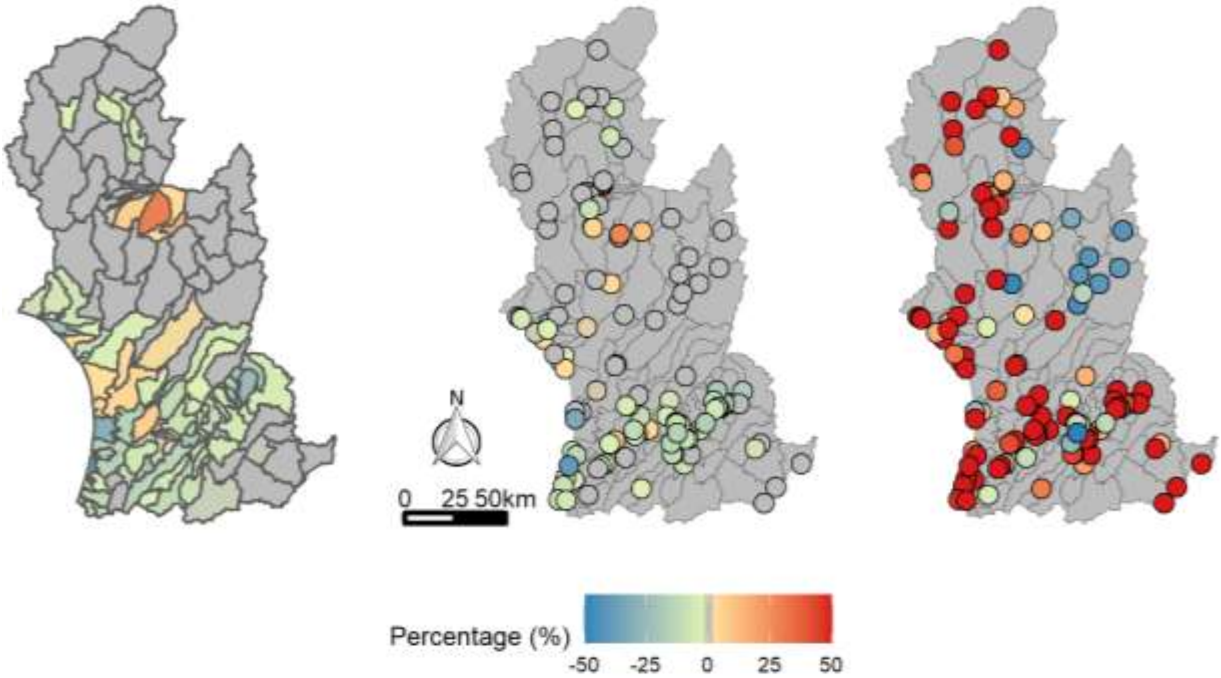

Figure 16. Percentage difference in nitrogen export coefficient (left) and percentage difference in river SIN concentrations (right) between the Proposed Consented Scenario and the Pre-regulation Scenario.

4.4.2 Proposed Year-20 Pathway Scenarios

The change in the nitrogen export coefficients and resulting river SIN concentrations under the Proposed Year-20 Pathway A Scenario compared to the Proposed Consented Year 20 Scenario are shown in Figure 17. The Proposed Year-20 Pathway A Scenario represents the year 20 outcome of implementing the Proposed Plan (i.e., as proposed by PPC2) with provision for discretionary pathways for non-consented and non-compliant dairy farms. The Proposed Year-20 Pathway A Scenario assumes that non-consented, non-compliant dairy farms reduce their loss rates by 9 kg/ha/yr. It is noted that farms pertaining to this scenario are limited to a sample of properties within the target water management sub zones as shown in Figure 2.

TN export coefficients in all WMSZs and SIN concentrations at all assessment points under the Proposed Year-20 Pathway A Scenario are the same or higher than the Proposed Consented Year-20 Scenario. Compared to the Proposed Consented Year-20 Scenario, nitrogen export coefficients were higher in 8 (i.e., 6%) of WMSZs (Figure 17). Compared to the Proposed Consented Year-20 Scenario, SIN concentrations under the Proposed Year-20 Pathway A Scenario were predicted to be higher at 14 assessment points in the Manawatu River Catchment (Figure 17).

Under the Proposed Year-20 Pathway A Scenario, predicted concentrations of SIN do not achieve the One Plan targets in 99 of the 124 assessment points (Figure 17). Predicted concentrations of SIN exceed the target by more than 10%, 20% and 50% at 89, 77 and 47 assessment points, respectively.

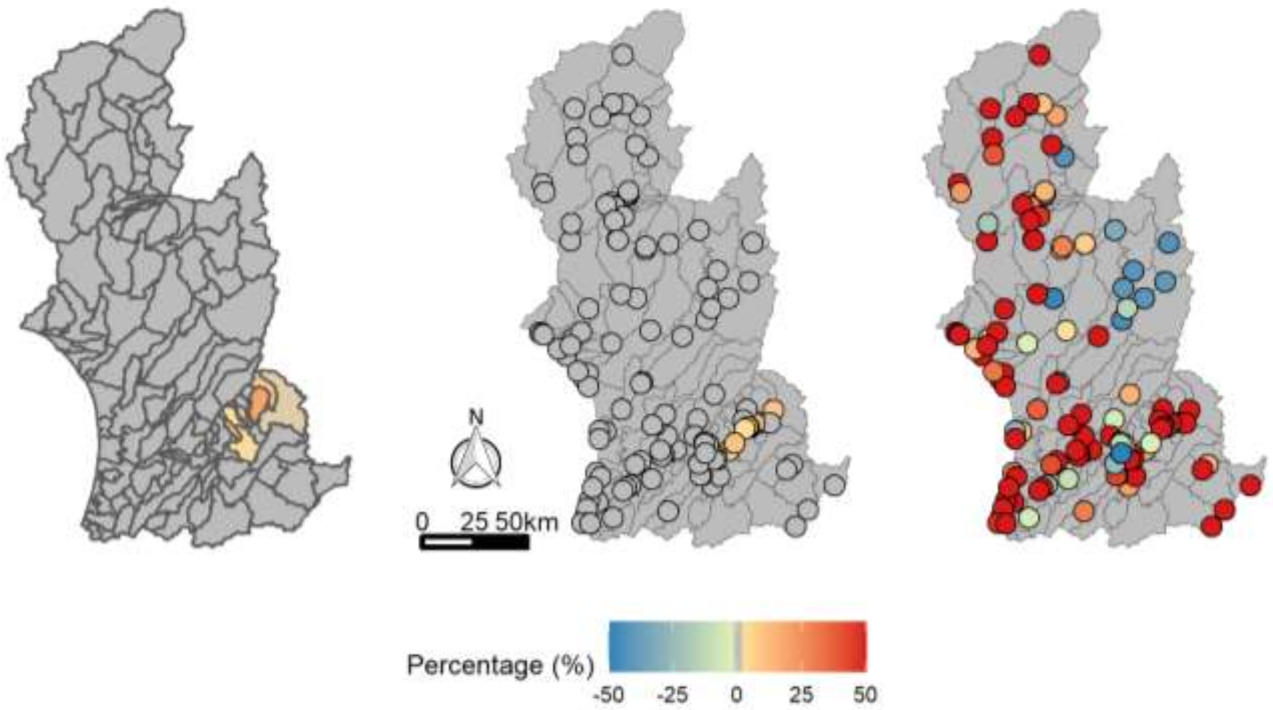

Figure 17. Percentage difference in nitrogen export coefficient (left), percentage difference in river SIN concentrations (centre) and percentage difference between predicted SIN concentration and SIN target (right) for the Proposed Year-20 Pathway A Scenario. The differences shown on the left and centre maps were derived by comparing the Proposed Year-20 Pathway A Scenario with the Proposed Consented Year-20 Scenario. Negative percentages on the right map indicate achievement of the water quality state target and vice versa.

Compared to the Pre-regulation Scenario, SIN concentrations under the Proposed Year-20 Pathway A Scenario were higher at 29 (i.e., 23%) assessment points and were lower at 81 (i.e., 65%) of assessment points (Figure 18). The assessment points where SIN concentrations were lower tended to be downstream of target catchments (Figure 18). The assessment points where SIN concentrations were higher tended to be downstream of non-target catchments (i.e., catchments where there was not consented IFLU) and where there was significant areas of IFLU with export coefficients in the calibrated model that are below the limits set by Table 14.2 of PPC2 (see Figure 2). This indicates that under the Proposed Year-20 Pathway A Scenario, some existing IFLU is assumed to increase its nitrogen leaching rate to the limit specified in Table 14.2.

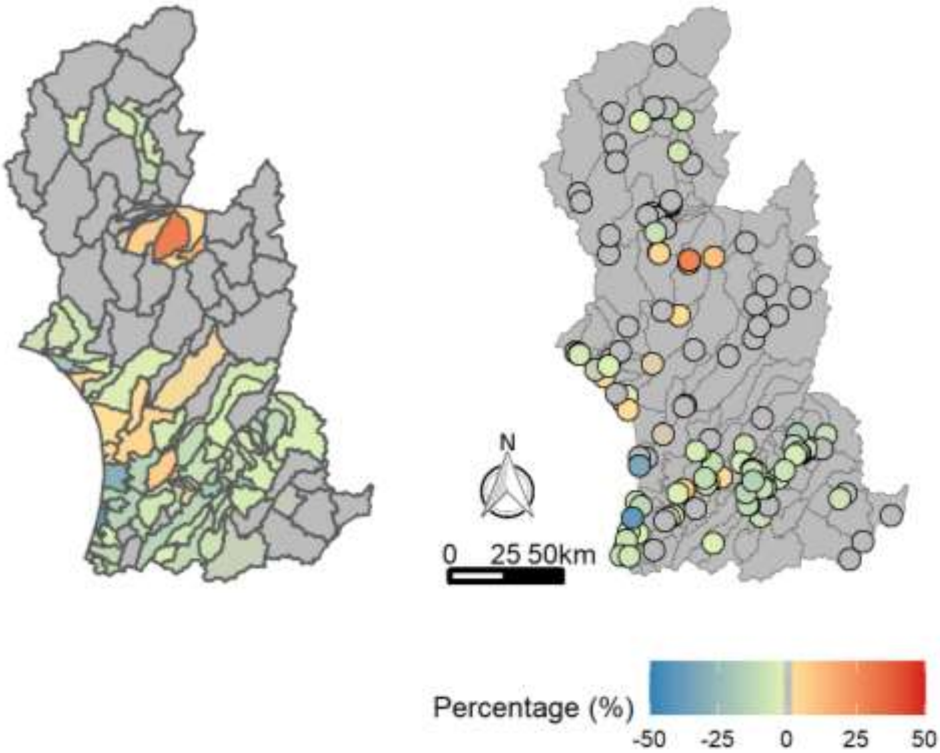

Figure 18. Percentage difference in nitrogen export coefficient (left) and percentage difference in river SIN concentrations (right) between the Proposed Year-20 Pathway A Scenario and the Pre-regulation Scenario.

Compared to the Proposed Year-20 Consented Strict Scenario, SIN concentrations under the Proposed Year-20 Pathway A Scenario were higher at 32 (i.e., 26%) assessment points (Figure 19). The assessment points where SIN concentrations were higher tended to be downstream of target catchments. This indicates that the Proposed Year-20 Pathway A Scenario is less restrictive than the Proposed Consented Strict Scenario.

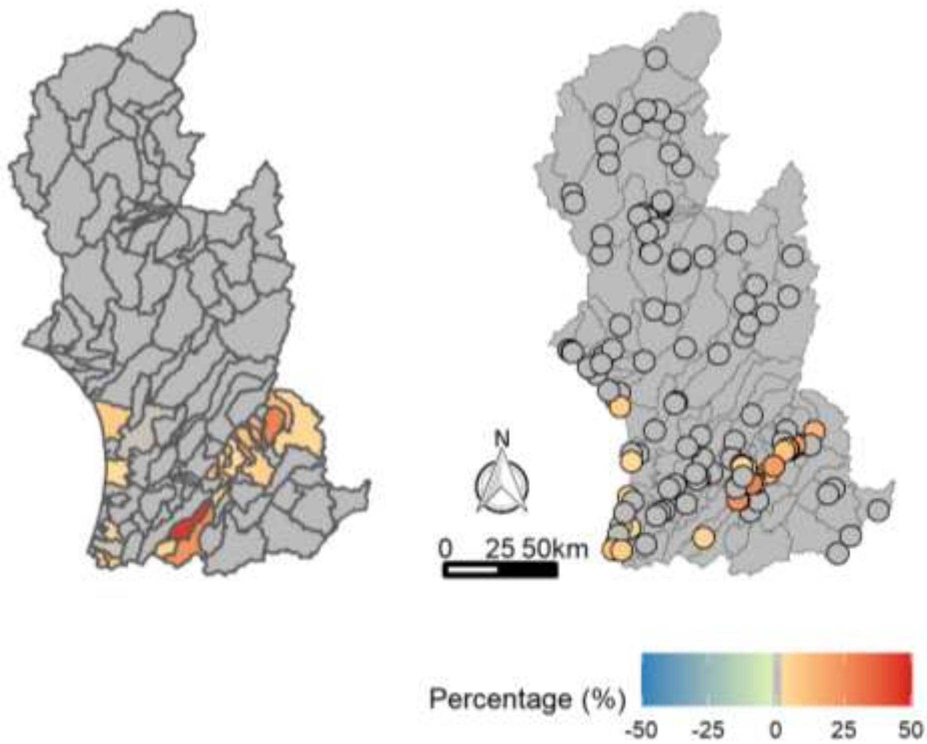

Figure 19. Percentage difference in nitrogen export coefficient (left) and percentage difference in river SIN concentrations (right) between the Proposed Year-20 Pathway A Scenario and the Proposed Consented Strict Scenario.

The change in the nitrogen export coefficients and resulting river SIN concentrations under the Proposed Year-20 Pathway D Scenario compared to the Proposed Year-20 Pathway A Scenario are shown in Figure 20. The Proposed Year-20 Pathway D Scenario assumes that non-consented, non-compliant dairy farms reduce their loss rates by 18 kg/ha/yr (whereas the Proposed Year-20 Pathway A Scenario assumes a reduction of 9 kg/ha/yr). Compared to the A Scenario, nitrogen export coefficients under the Proposed Year-20 Pathway D Scenario are lower in 8 (i.e., 6%) of WMSZs. Compared to the A Scenario, TN concentrations under the Proposed Year-20 Pathway D Scenario are predicted to be lower at 14 (i.e., 11%) assessment points.

Under the Proposed Year-20 Pathway D Scenario, predicted concentrations of SIN do not achieve the One Plan targets in 99 of the 124 assessment points (Figure 20). Predicted concentrations of SIN exceed the target by more than 10%, 20% and 50% at 89, 77 and 47 assessment points, respectively.

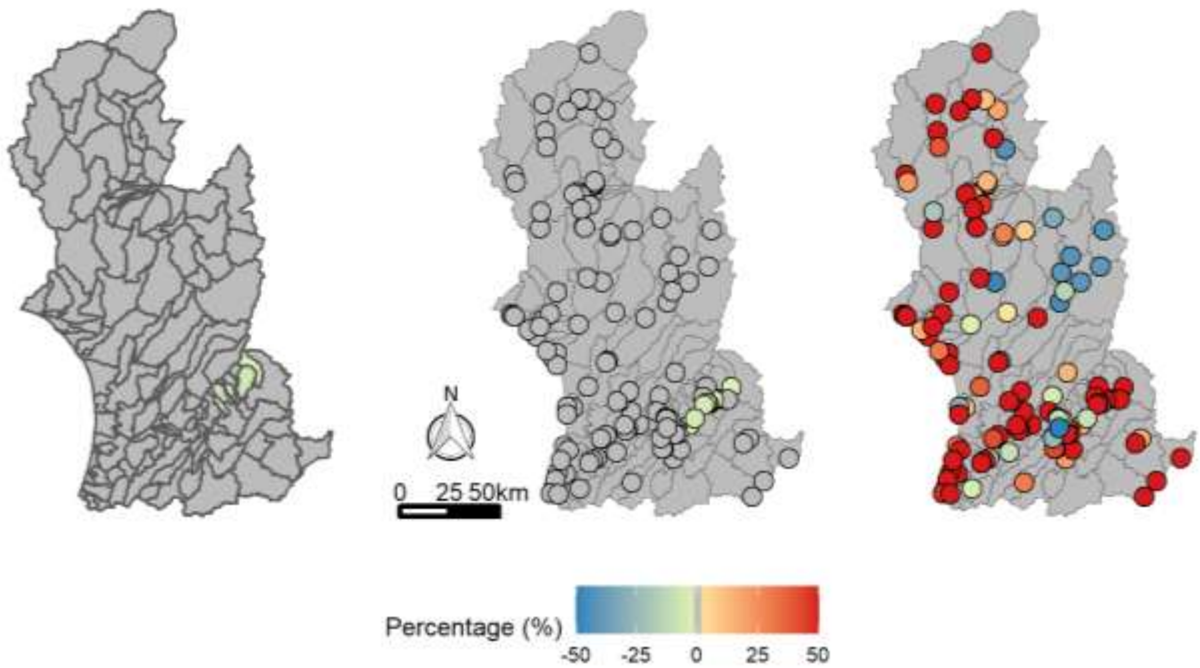

Figure 20. Percentage difference in nitrogen export coefficient (left), percentage difference in river SIN concentrations (centre) and percentage difference between predicted SIN concentration and SIN target (right) for the Proposed Year-20 Pathway D Scenario. The changes shown on the left and centre maps were derived by comparing the Proposed Year-20 Pathway D Scenario with the Proposed Year-20 Pathway A Scenario. Negative percentages on the right map indicate achievement of the water quality state target and vice versa.

Compared to the Pre-regulation Scenario, SIN concentrations under the Proposed Year-20 Pathway D Scenario were higher at 29 (i.e., 23%) assessment points and were lower at 81 (i.e., 65%) of assessment points (Figure 21). The assessment points where SIN concentrations were lower tended to be downstream of target catchments (Figure 21). The assessment points where SIN concentrations were higher tended to be downstream of non-target catchments (i.e., catchments where there was not consented IFLU) and where there was significant areas of IFLU with export coefficients in the calibrated model that are below that specified in Table 14.2 of PPC2 (see Figure 2). This indicates that under the Proposed Year-20 Pathway D Scenario, some existing IFLU (mainly outside of the target catchments) is assumed to increase its nitrogen leaching rate to the limit specified in Table 14.2.

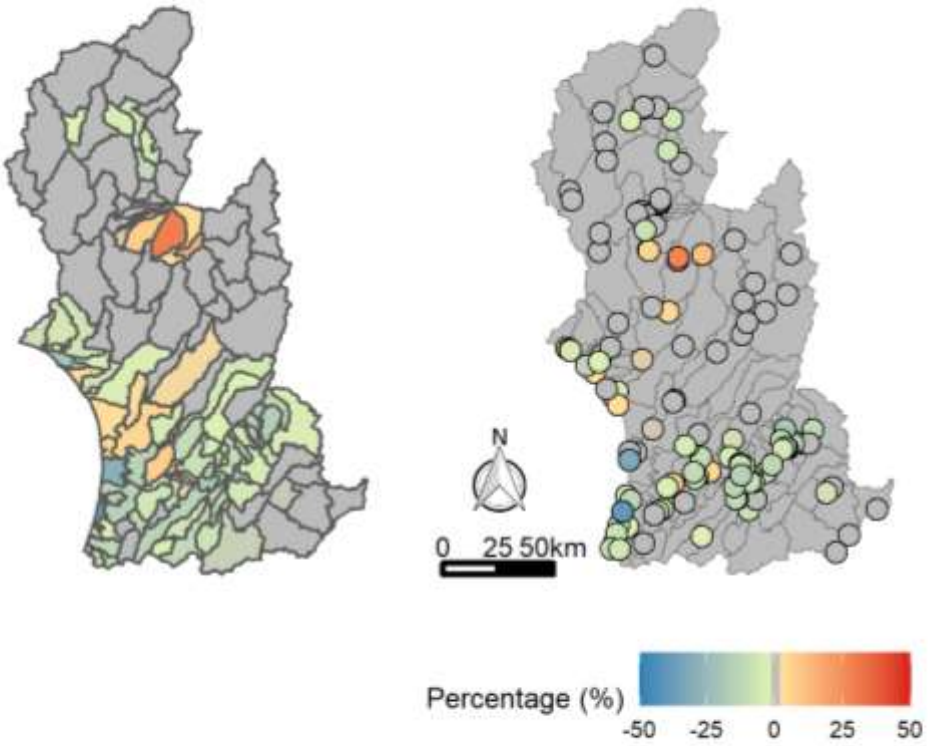

Figure 21. Percentage difference in nitrogen export coefficient (left) and percentage difference in river SIN concentrations(right) between the Proposed Year-20 Pathway D Scenario and the Pre-regulation Scenario.

Compared to the Proposed Year-20 Consented Strict Scenario, SIN concentrations under the Proposed Year-20 Pathway D Scenario were higher at 32 (i.e., 26%) assessment points (Figure 22). The assessment points where SIN concentrations were higher tended to be downstream of target catchments. This indicates that the Proposed Year-20 Pathway D Scenario is less restrictive than the Proposed Year-20 Consented Strict Scenario.

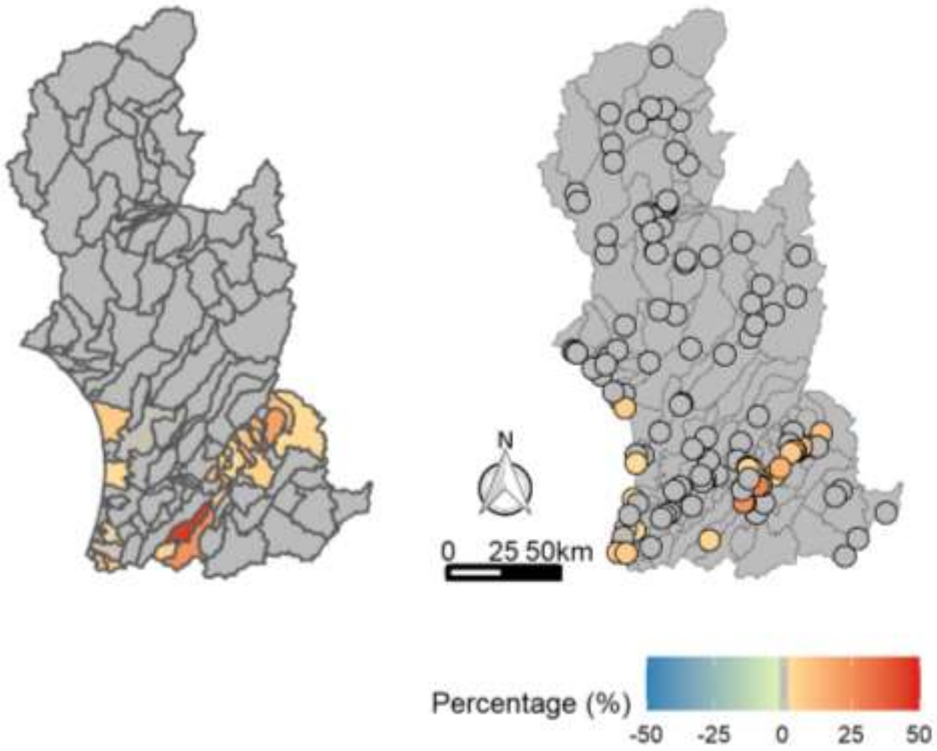

Figure 22. Percentage difference in nitrogen export coefficient (left) and percentage difference in river SIN concentrations (right) between the Proposed Year-20 Pathway D Scenario and the Proposed Year-20 Consented Strict Scenario.

The Proposed Year-20 Pathway GMP Scenario and Proposed Year-20 Pathway BMP Scenarios simulate the impact at 20 years of implementing PPC2 with provision for discretionary consent pathways for both dairy farms and CVG. Comparison of these scenarios with the Operative Consented Scenario (Figure 23, Figure 24) indicates that WMSZ export coefficients and SIN concentrations at assessment points are higher than under the Operative Consented Scenario. This is an expected outcome because the recalibration of Table 14.2 for PC2 has increased allowable nitrogen leaching rates compared to the operative plan.

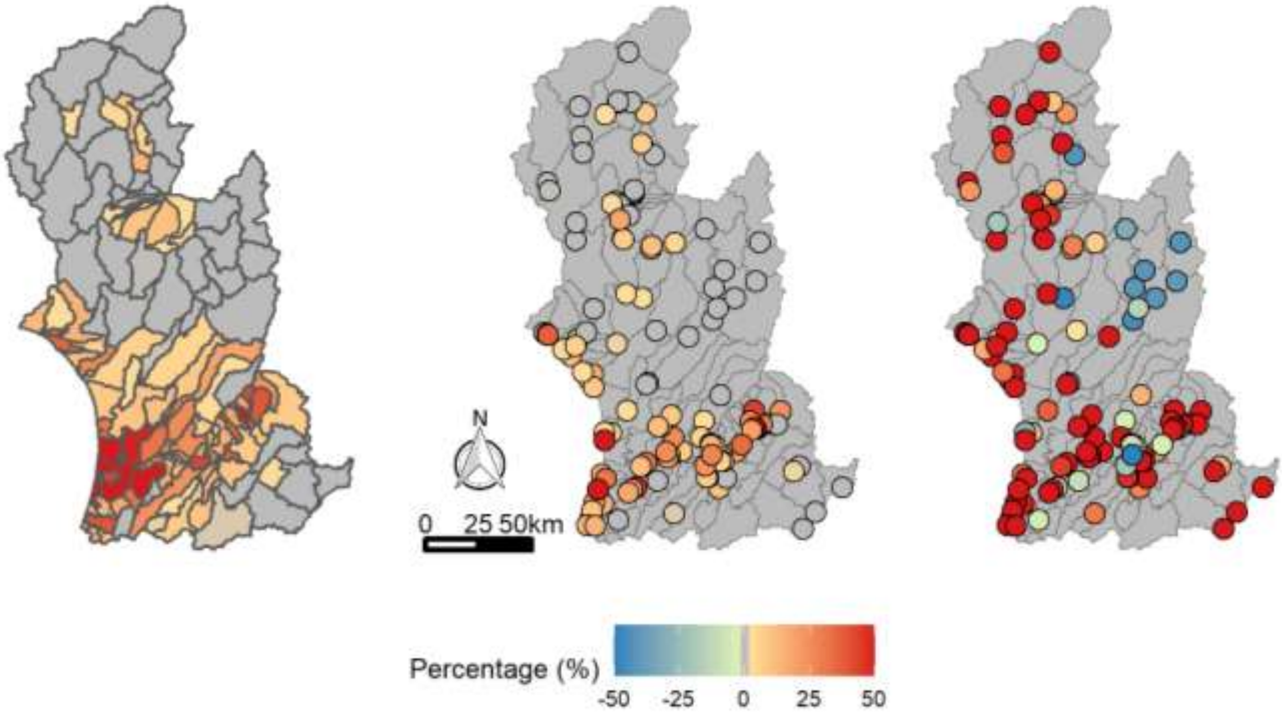

Figure 23. Percentage difference in nitrogen export coefficient (left) and percentage difference in river SIN concentrations (right) between the Proposed Year-20 Pathway GMP Scenario and the Operative Consented Scenario.

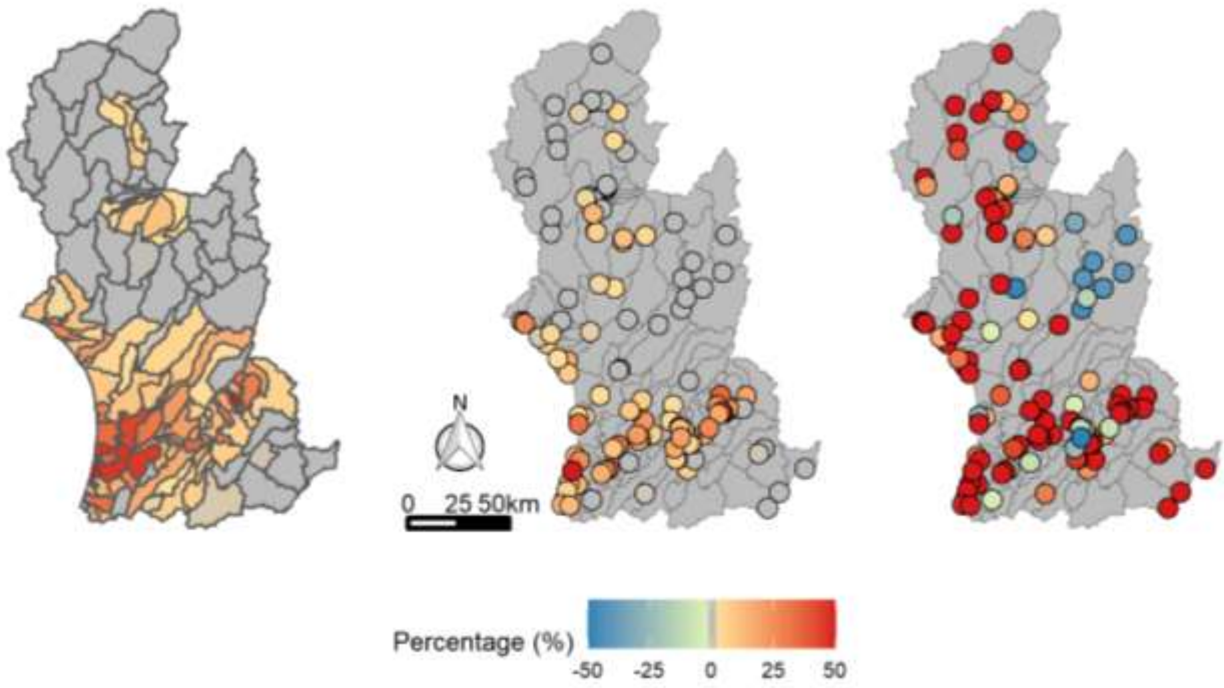

Figure 24. Percentage difference in nitrogen export coefficient (left) and percentage difference in river SIN concentrations (right) between the Proposed Year-20 Pathway BMP Scenario and the Operative Consented Scenario.

Comparison of the Proposed Year-20 Pathway GMP Scenario and Proposed Year-20 Pathway BMP Scenarios with the Proposed Consented Scenario are shown on Figure 25 and Figure 26. The comparison indicates that WMSZ export coefficients and SIN concentrations at assessment points are slightly higher than under the Proposed Consented Scenario. This is an expected outcome because the consent pathway option under PPC2 allows higher nitrogen leaching rates than PPC2 Table 14.2.

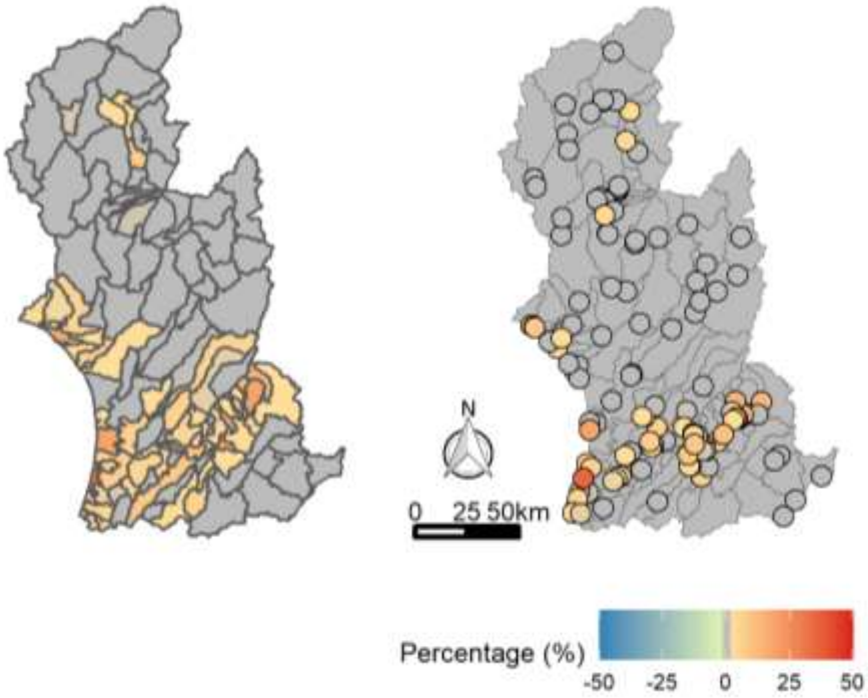

Figure 25. Percentage difference in nitrogen export coefficient (left) and percentage difference in river SIN concentrations (right) between the Proposed Year-20 Pathway GMP Scenario and the Proposed Consented Scenario.

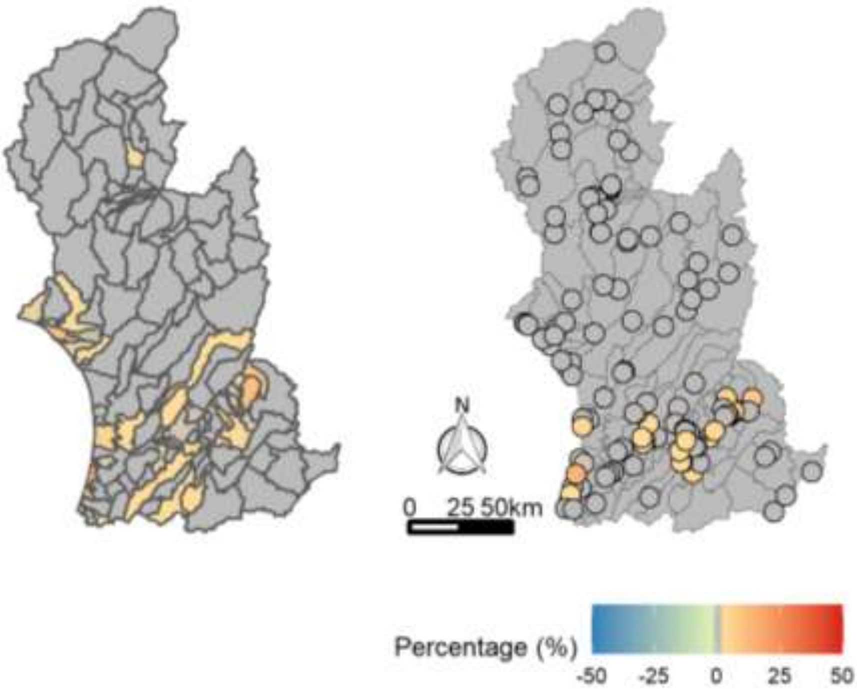

Figure 26. Percentage difference in nitrogen export coefficient (left) and percentage difference in river SIN concentrations (right) between the Proposed Year-20 Pathway BMP Scenario and the Proposed Consented Scenario.

Comparison of the Proposed Year-20 Pathway GMP Scenario with the Proposed Year-20 Pathway A is shown in Figure 27 and comparison of the Proposed Year-20 Pathway BMP Scenario with the Proposed Year-20 Pathway D is shown in Figure 28. The comparisons indicate that WMSZ export coefficients and SIN concentrations at assessment points are slightly higher than under the GMP and BMP scenarios compared to their comparators. This is an expected outcome because the GMP and BMP scenarios allow higher nitrogen leaching rates for CVG to than the comparator scenarios.

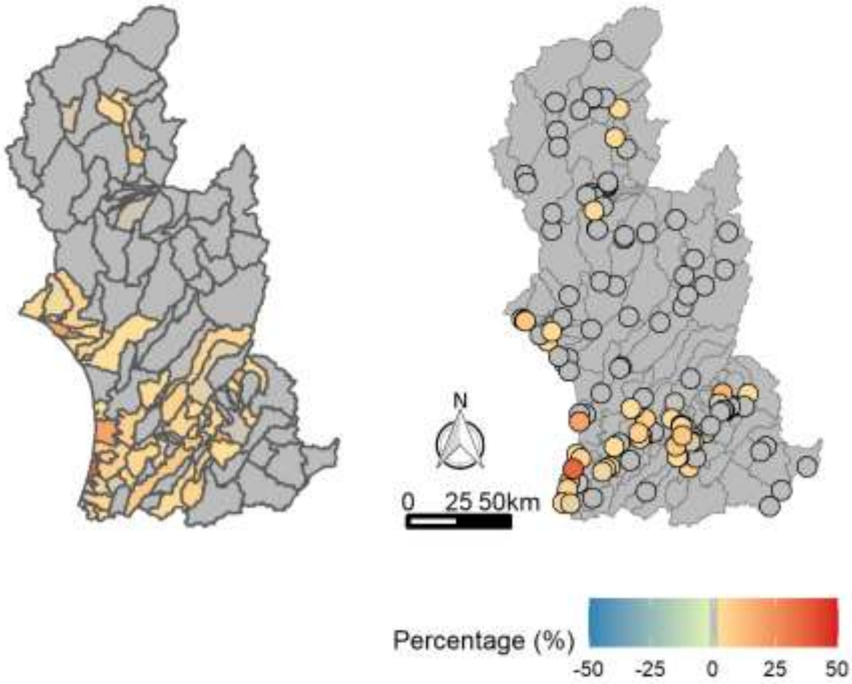

Figure 27. Percentage difference in nitrogen export coefficient (left) and percentage difference in river SIN concentrations (right) between the Proposed Year-20 Pathway GMP Scenario and the Proposed Year-20 Pathway A Scenario.

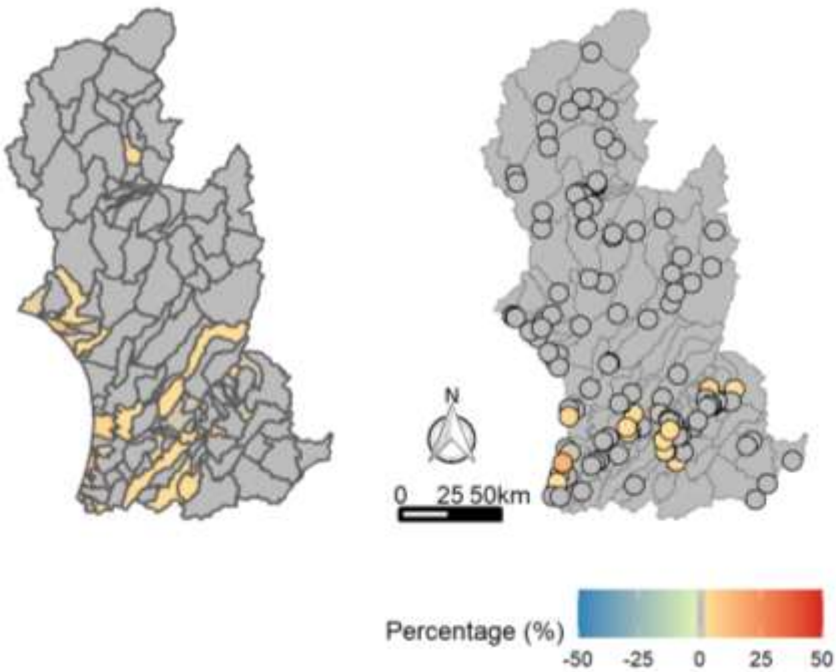

Figure 28. Percentage difference in nitrogen export coefficient (left) and percentage difference in river SIN concentrations (right) between the Proposed Year-20 Pathway BMP Scenario and the Proposed Year-20 Pathway D Scenario.

The results of the Proposed Year-20 Pathway GMP and Point Sources Scenario and the Proposed Year-20 Pathway BMP and Point Sources Scenario are not reported here but are summarised in the summary and conclusion section of this report. These scenarios represent the combination of implementation of PC2 with discretionary consent pathways (the scenarios described immediately above) with the changes to significant point source contributions of nitrogen across the Region between 2012 and 2017.

4.4.3 Proposed Year-5 Pathway Scenarios

The change in the nitrogen export coefficients and resulting river SIN concentrations under the Proposed Year-5 Pathway A Scenario compared to Proposed Year-20 Pathway A Scenario are shown in Figure 29. The Proposed Year-5 Pathway A Scenario represents the year 5 outcome of implementing the Proposed Plan (i.e., as proposed by PPC2) with provision for discretionary consent pathways for non-consented and non-compliant dairy farms. The A Scenario assumes that non-consented, non-compliant properties reduce their loss rates by 9 kg/ha/yr. It is noted that farms pertaining to this scenario are limited to a sample of properties within the “target” water management sub zones as shown in Figure 4.

Nitrogen export coefficients in all WMSZs and SIN concentrations at all assessment points under the Proposed Year-5 Pathway A Scenario are the same or higher than the Proposed Year-20 Pathway A Scenario. Compared to the Proposed Year-20 Pathway A Scenario, nitrogen export coefficients under the Proposed Year-5 Pathway A Scenario are greater in 76 (i.e., 61%) of WMSZs. Compared to the Proposed Year-20 Pathway A Scenario, SIN concentrations under the Proposed Year-5 Pathway A Scenario were predicted to be higher at 98 (i.e., 79%) assessment points. In comparison to the Proposed Year-20 Pathway A Scenario, nitrogen export coefficients and predicted SIN concentrations are higher because the Proposed Year-5 Pathway A Scenario is based on the assumption of compliance with the year 5 nitrogen leaching rates in Table 14.2, which are higher than the rates for year 20.

Under the Proposed Year-5 Pathway A Scenario, predicted concentrations of SIN do not achieve the One Plan targets in 100 of the 124 assessment points (Figure 29). Predicted concentrations of SIN exceed the target by more than 10%, 20% and 50% at 89, 76 and 47 assessment points, respectively.

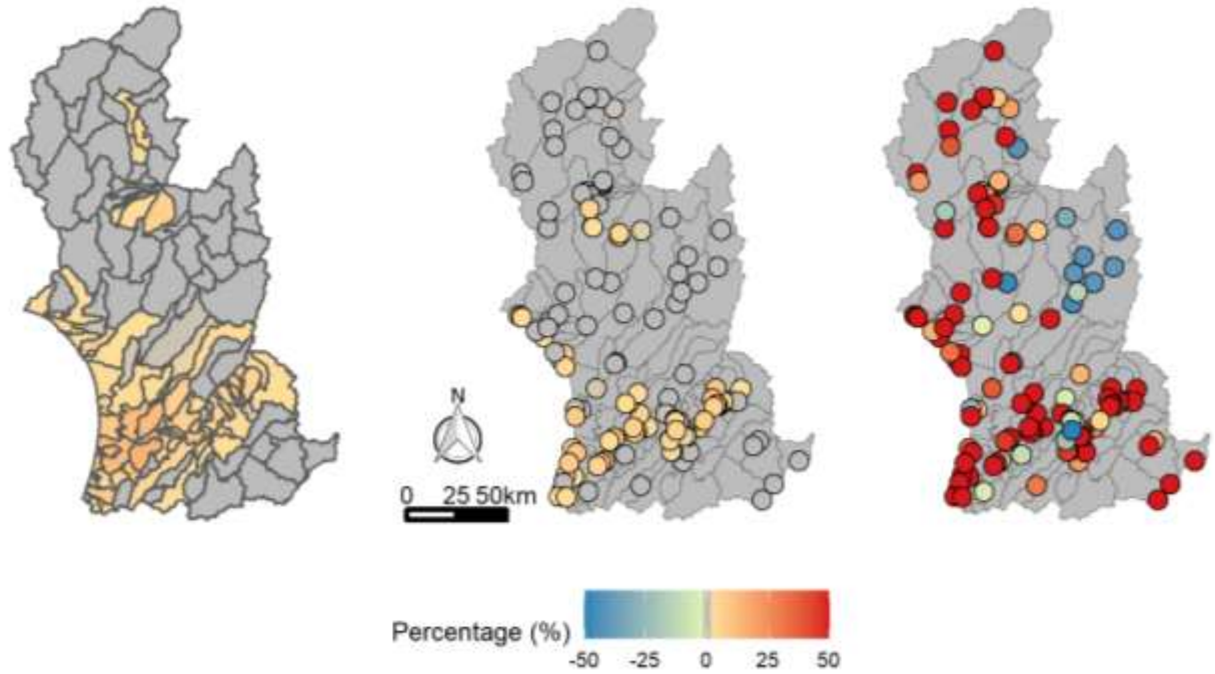

Figure 29. Percentage difference in nitrogen export coefficient (left), percentage difference in river SIN concentrations (centre) and percentage difference between predicted SIN concentration and SIN target (right) for the Proposed Year-5 Pathway A Scenario. The differences shown on the left and centre maps were derived by comparing the Proposed Year-5 Pathway A Scenario with the Proposed Year-20 Pathway A Scenario. Negative percentages on the right map indicate achievement of the water quality state target and vice versa.

The difference in the nitrogen export coefficients and resulting river SIN concentrations under the Proposed Year-5 Pathway D Scenario compared to the Proposed Year-20 Pathway D Scenario are shown in Figure 30. The D Scenario is based on the assumption that non-consented, non-compliant properties reduce their estimated loss rates by 18 kg/ha/yr. It is noted that farms pertaining to this scenario are limited to a sample of properties within the “target” water management sub zones as shown in Figure 2.

Nitrogen export coefficients in all WMSZs and SIN concentrations at all assessment points under the Proposed Year-5 Pathway D Scenario are the same or higher than the Proposed Year-20 Pathway D Scenario (Figure 30). Compared to the Proposed Year-20 Pathway D Scenario, predicted SIN concentrations under the Proposed Year-5 Pathway D Scenario are higher at 98 (i.e., 79%) assessment points. This occurs because the Proposed Year-5 Pathway D Scenario is based on an assumption of compliance with the year 5 nitrogen leaching rates in Table 14.2, which are higher than the rates for year 20.

Under the Proposed Year-5 Pathway D Scenario, predicted concentrations of SIN do not achieve the One Plan targets in 99 of the 124 assessment points (Figure 30). Predicted concentrations of SIN exceed the target by more than 10%, 20% and 50% at 89, 76 and 46 assessment points, respectively.

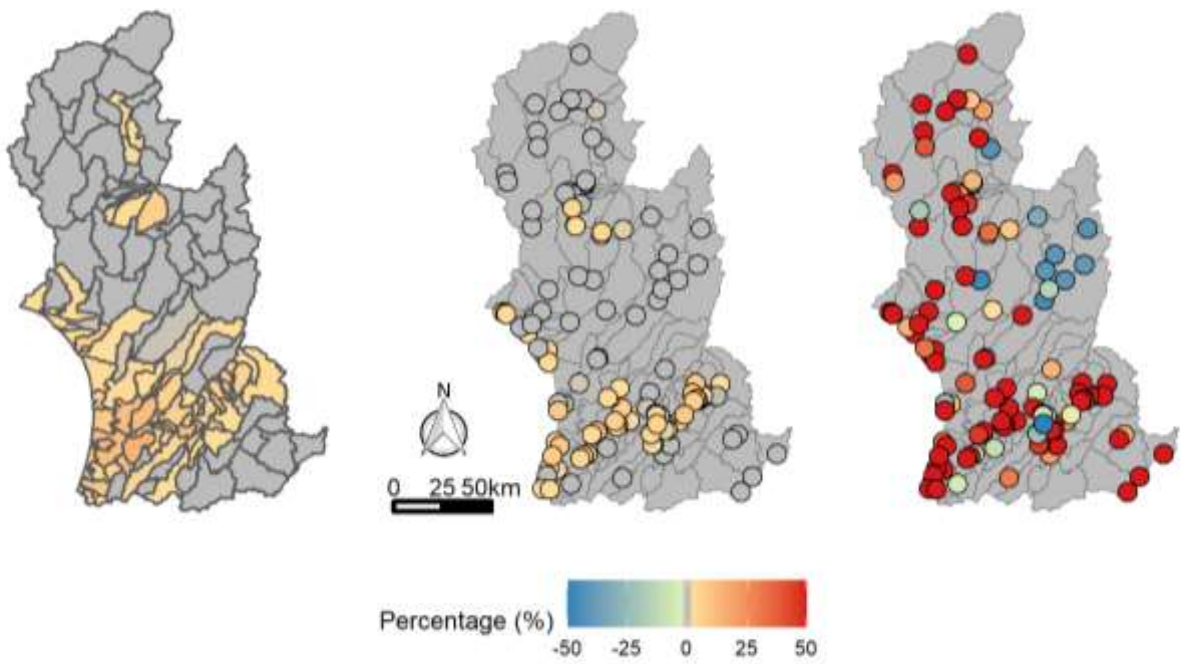

Figure 30. Percentage difference in nitrogen export coefficient (left), percentage difference in river SIN concentrations (centre) and percentage difference between predicted SIN concentration and SIN target (right) for the Proposed Year-5 Pathway D Scenario. The differences shown on the left and centre maps were derived by comparing the Proposed Year-5 Pathway D Scenario with the Proposed Year-20 Pathway D Scenario. Negative percentages on the right map indicate achievement of the water quality state target and vice versa.

4.4.4 Proposed Consented Strict Scenario

The change in the nitrogen export coefficients and resulting river SIN concentrations under the Proposed Consented Strict Scenario compared to the Proposed Consented Year-20 Scenario are shown in Figure 31. The Proposed Consented Strict Scenario represents the year 20 outcome of implementing the Proposed Plan (i.e., PPC2) Table 14.2 with no provision for a discretionary activity consent pathway and with strict adherence to the current consent where the consented nitrogen leaching rate is less than Table 14.2. Nitrogen export coefficients in all WMSZs and SIN concentrations at all assessment points under the Proposed Year-20 Consented Strict Scenario are the same or less than the Proposed Consented Year-20 Scenario (Figure 31). Compared to the Proposed Consented Year-20 Scenario, nitrogen export coefficients under the Proposed Consented Strict Scenario are lower in 24 (i.e., 19%) WMSZs. Compared to the Proposed Consented Year-20 Scenario, SIN concentrations under the Proposed Consented Strict Scenario are predicted to lower at 32 (i.e., 26%) assessment points.

Under the Proposed Consented Strict Scenario, predicted concentrations of SIN do not achieve the One Plan targets in 97 of the 124 assessment points (Figure 31). Predicted concentrations of SIN exceed the target by more than 10%, 20% and 50% at 86, 73 and 45 assessment points, respectively.

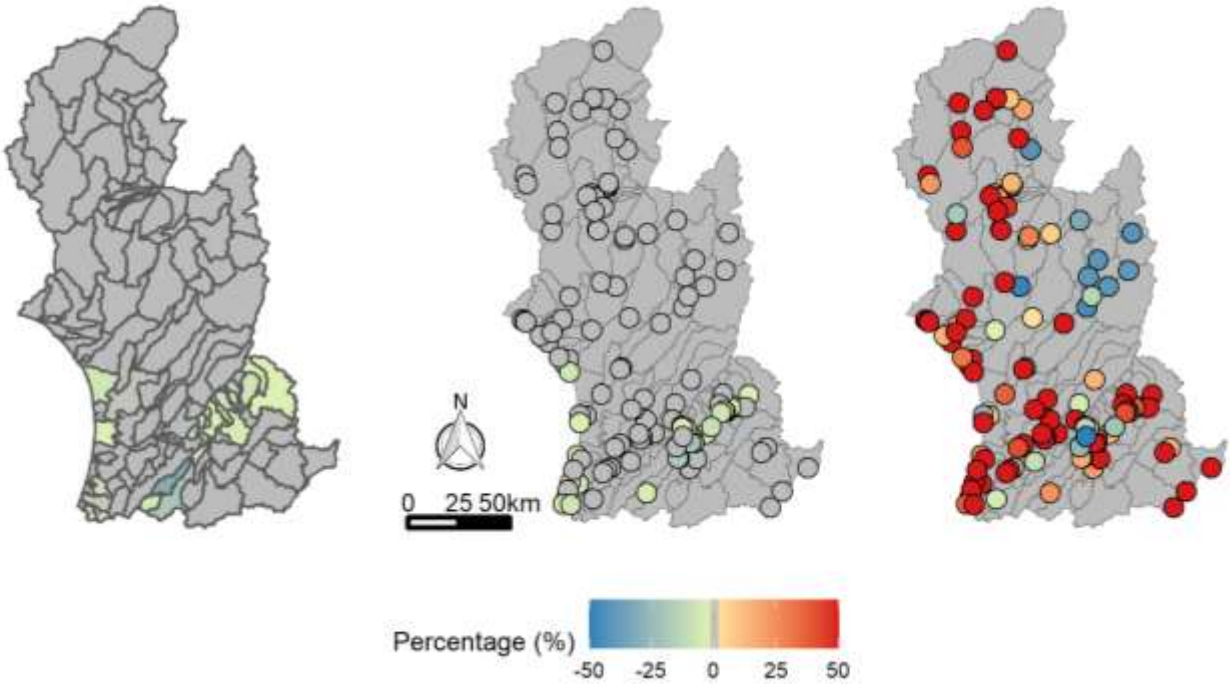

Figure 31. Percentage difference in nitrogen export coefficient (left), percentage difference in river SIN concentrations (centre) and percentage difference between predicted SIN concentration and SIN target (right) for the Proposed Consented Strict Scenario. The changes shown on the left and centre maps were derived by comparing the Proposed Consented Strict Scenario with Proposed Consented Scenario. Negative percentages on the right map indicate achievement of the water quality state target and vice versa.

4.5 Additional scenarios

4.5.1 Natural State Scenario

The change in the nitrogen export coefficients and resulting river SIN concentrations under the Natural State Scenario compared to the Calibrated Model Simulation are shown in Figure 32. the Natural State Scenario represents the outcome of removing all anthropogenic land use from the region and all point sources of nitrogen.

Nitrogen export coefficients in all WMSZs and SIN concentrations at all assessment points under the Natural State Scenario are the same or less than the Calibrated Model Simulation (Figure 32). Compared to the Calibrated Model Simulation, nitrogen export coefficients under the Natural State Scenario are predicted to be lower in 123 (i.e., 99%) WMSZs. Compared to the model baseline simulation, SIN concentrations under Scenario 7 are predicted to be lower or the same at 124 (i.e., 100%) assessment points.

Under the Natural State Scenario, predicted concentrations of SIN do not achieve the One Plan targets in 13 of the 124 assessment points (Figure 32). Predicted concentrations of SIN exceed the target by more than 10%, 20% and 50% at 12, 2 and zero assessment points, respectively.

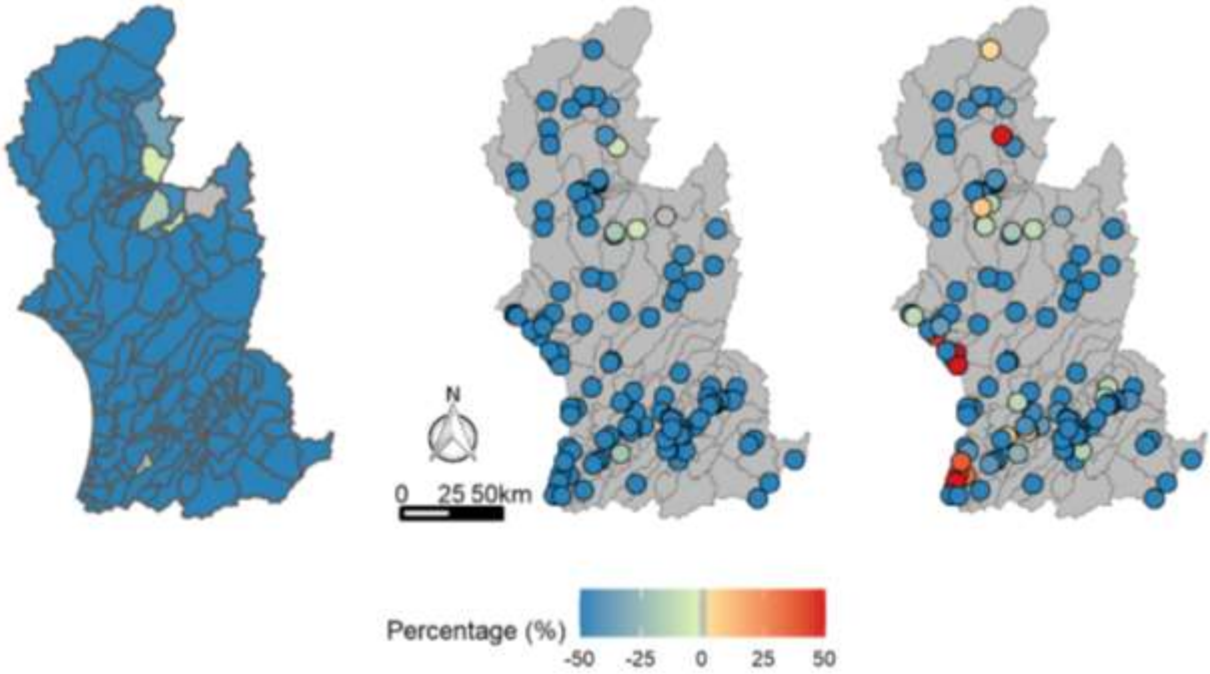

Figure 32. Percentage difference in nitrogen export coefficient (left), percentage difference in river SIN concentrations (centre) and percentage difference between predicted SIN concentration and SIN target (right) for the Natural State Scenario. The differences shown on the left and centre maps were derived by comparing the Natural State Scenario with the Calibrated Model Simulation. Negative percentages on the right map indicate achievement of the water quality state target and vice versa.

4.5.2 Dairy Sector Pathway Scenarios

The change in the nitrogen export coefficients and resulting river SIN concentrations under the Dairy Sector Pathway A Scenario compared to the Proposed Consented Year-20 Scenario are shown in Figure 33. The Dairy Sector Pathway A Scenario represents an alternative approach to restricting the leaching rates for the 70 Known Unconsented-dairy farms that are represented in the HRC database.

Nitrogen export coefficients in all WMSZs and SIN concentrations at all assessment points under the Dairy Sector Pathway A Scenario are the same or greater than the Proposed Consented Year-20 Scenario (Figure 33). Compared to the Proposed Consented Scenario, nitrogen export coefficients under the Dairy Sector Pathway Scenario are predicted to be higher in 9 (i.e., 7%) WMSZs. This is an expected result because the Dairy Sector Pathway A Scenario is slightly less stringent than the PPC2 Table 14.2 requirements. Compared to the Proposed Consented Scenario, SIN concentrations under the Dairy Sector Pathway A Scenario are predicted to be greater at 17 (i.e., 11%) assessment points.

Under the Dairy Sector Pathway A Scenario, predicted concentrations of SIN do not achieve the One Plan targets in 98 of the 124 assessment points (Figure 33). Predicted concentrations of SIN exceed the target by more than 10%, 20% and 50% at 85, 72 and 34 assessment points, respectively.

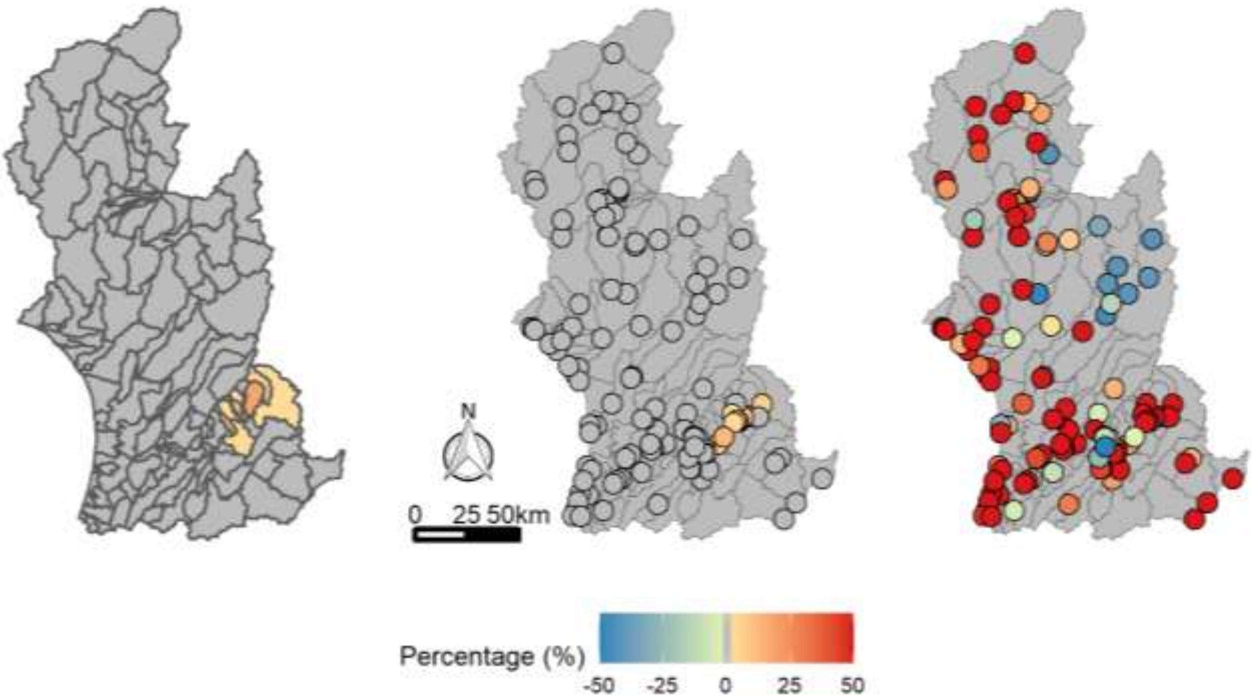

Figure 33. Percentage difference in nitrogen export coefficient (left), percentage difference in river SIN concentrations (centre) and percentage difference between predicted SIN concentration and SIN target (right) for the Dairy Sector Pathway A Scenario. The differences shown on the left and centre maps were derived by comparing the Dairy Sector Pathway A Scenario with the Proposed Consented Scenario. Negative percentages on the right map indicate achievement of the water quality state target and vice versa.

Compared to the Proposed Year-20 Pathway A Scenario, nitrogen export coefficients under the Dairy Sector Pathway A Scenario were higher in some WMSZs and lower in others (Figure 34). This outcome is due to the differences in leaching rate reduction requirements implied by the two pathways.

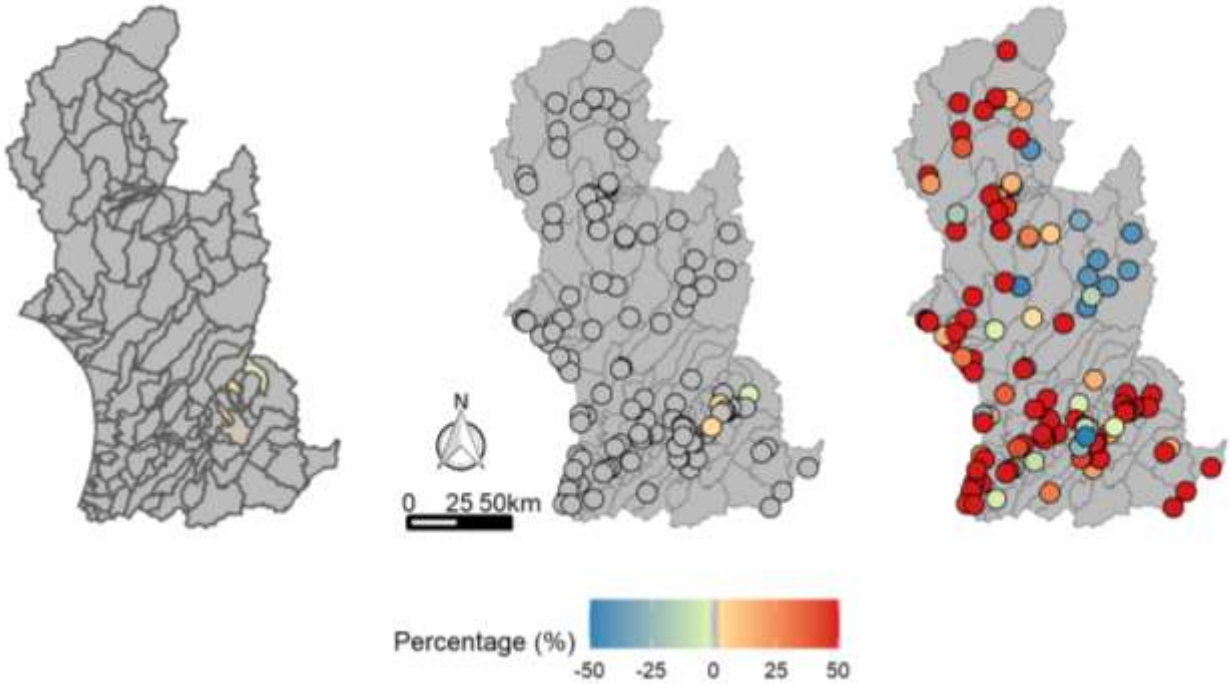

Figure 34. Percentage difference in nitrogen export coefficient (left), percentage difference in river SIN concentrations (centre) and percentage difference between predicted SIN concentration and SIN target (right) for the Dairy Sector Pathway A Scenario. The differences shown on the left and centre maps were derived by comparing the Dairy Sector Pathway A Scenario with the Proposed Year-20 Pathway A Scenario. Negative percentages on the right map indicate achievement of the water quality state target and vice versa.

When the Dairy Sector Pathway Scenario was generalised to all dairy farms within water management zones that were represented by farms in the HRC database (i.e., the Dairy Sector Pathway B Scenario), one additional WMSZ (i.e., total of 10 WMSZ) had higher export coefficients than the Proposed Consented scenario (Figure 35). Compared to the Proposed Consented Scenario, SIN concentrations under the Dairy Sector Pathway B Scenario are predicted to be greater at 18 (i.e., 12%) assessment points.

Under the Dairy Sector Pathway B Scenario, predicted concentrations of SIN do not achieve the One Plan targets in 99 of the 124 assessment points (Figure 35). Predicted concentrations of SIN exceed the target by more than 10%, 20% and 50% at 85, 72 and 34 assessment points, respectively.

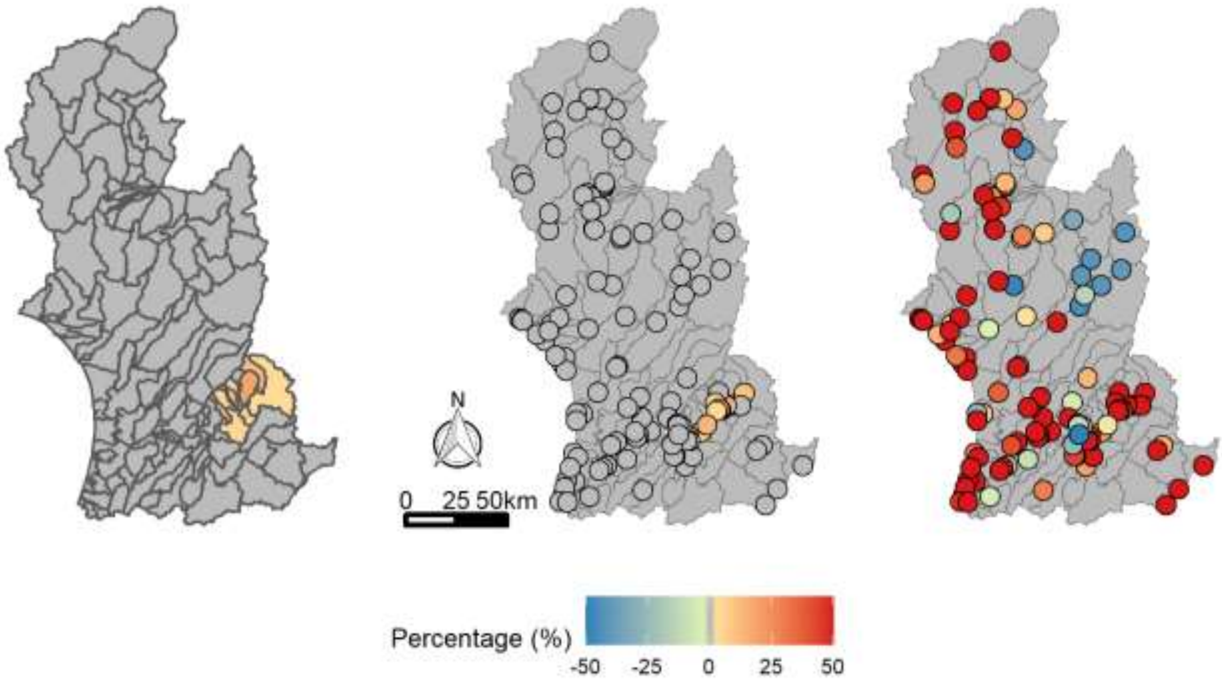

Figure 35. Percentage difference in nitrogen export coefficient (left), percentage difference in river SIN concentrations (centre) and percentage difference between predicted SIN concentration and SIN target (right) for the Dairy Sector Pathway B Scenario. The differences shown on the left and centre maps were derived by comparing the Dairy Sector Pathway B Scenario with the Proposed Consented Scenario. Negative percentages on the right map indicate achievement of the water quality state target and vice versa.

Compared to the Proposed Year-20 Pathway D Scenario, nitrogen export coefficients under the Dairy Sector Pathway D Scenario were higher WMSZs (Figure 36). This outcome is due to the differences in leaching rate reduction requirements implied by the two pathways.

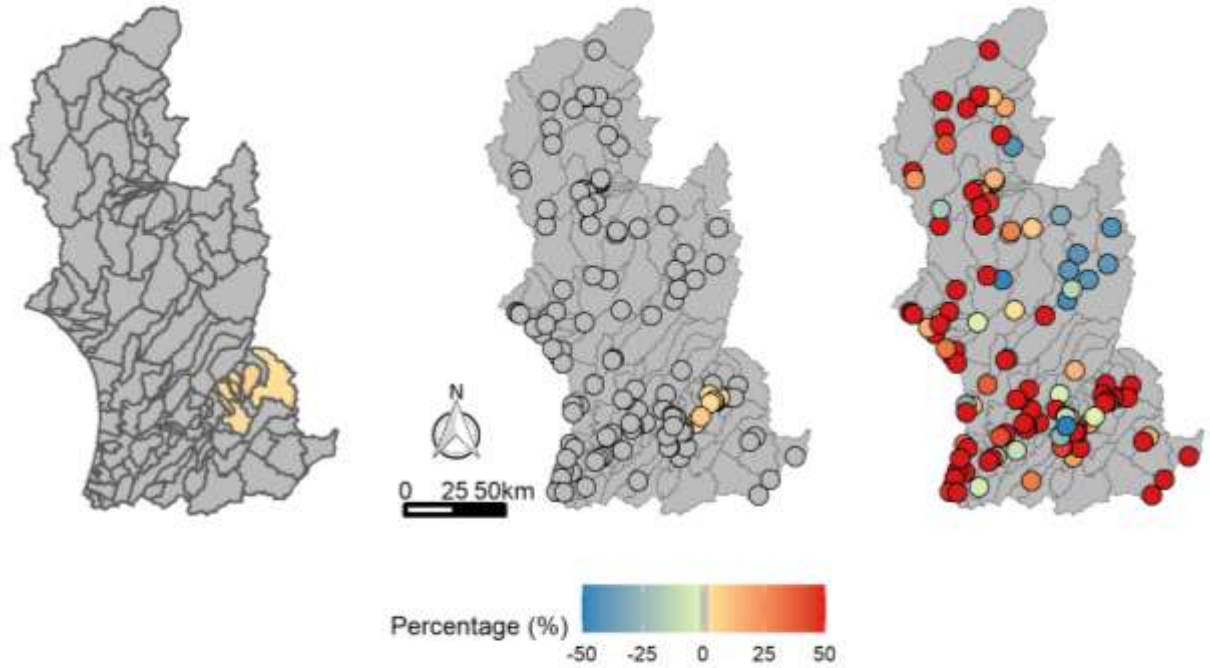

Figure 36. Percentage difference in nitrogen export coefficient (left), percentage difference in river SIN concentrations (centre) and percentage difference between predicted SIN concentration and SIN target (right) for the Dairy Sector Pathway D Scenario. The differences shown on the left and centre maps were derived by comparing the Dairy Sector Pathway D Scenario with the Proposed Year-20 Pathway D Scenario. Negative percentages on the right map indicate achievement of the water quality state target and vice versa

4.5.3 Horticulture Expansion Scenarios

The change in the nitrogen export coefficients and resulting river SIN concentrations under the Horticulture Expansion A Scenario compared to the Calibrated Model Simulation are shown in Figure 37. The Horticulture Expansion Scenarios (comprising Scenario A and B) represent the water quality outcome of increasing commercial vegetable growing across the region.

Nitrogen export coefficients in all WMSZs and SIN concentrations at all assessment points under the Horticulture Expansion A Scenario are the same or greater than the Calibrated Model Simulation. Compared to the Calibrated Model Simulation, nitrogen export coefficients under the Horticulture Expansion A Scenario are predicted to increase in 113 (i.e., 91%) WMSZs. Compared to the Calibrated Model Simulation, SIN concentrations under the Horticulture Expansion A Scenario are predicted to be greater at 120 (i.e., 97%) assessment points.

Under the Horticulture Expansion A Scenario, predicted concentrations of SIN do not achieve the One Plan targets at 104 of the 124 assessment points (Figure 37). Predicted concentrations of SIN exceed the target by more than 10%, 20% and 50% at 92, 79 and 49 assessment points, respectively.

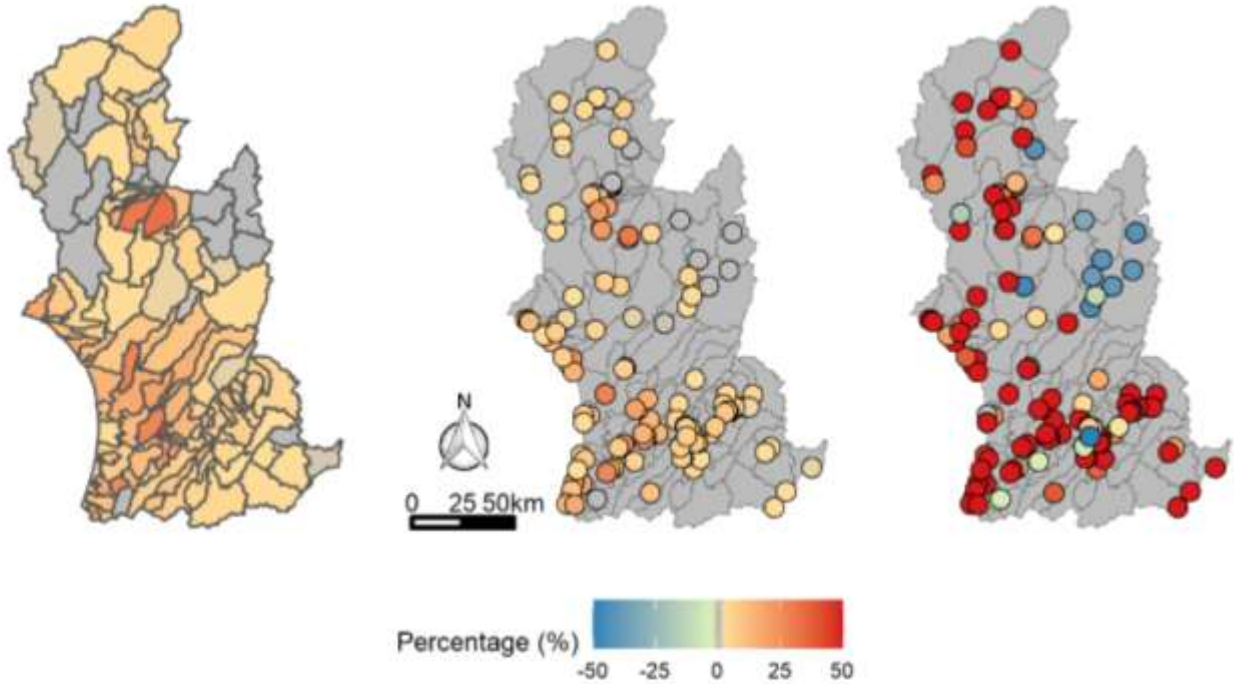

Figure 37. Percentage difference in nitrogen export coefficient (left), percentage difference in river SIN concentrations (centre) and percentage difference between predicted SIN concentration and SIN target (right) for the Horticulture Expansion A Scenario. The differenced shown on the left and centre maps were derived by comparing the Horticulture Expansion A Scenario with the Calibrated Model Simulation. Negative percentages on the right map indicate achievement of the water quality state target and vice versa.

The difference in the nitrogen export coefficients and resulting river SIN concentrations under the Horticulture Expansion B Scenario compared to the Calibrated Model Simulation are shown in Figure 38. Nitrogen export coefficients in all WMSZs and SIN concentrations at all assessment points under the Horticulture Expansion B Scenario are the same or greater than the Calibrated Model Simulation. Compared to the Calibrated Model Simulation, nitrogen export coefficients under the Horticulture Expansion B Scenario are predicted to increase in 116 (i.e., 94%) WMSZs. Compared to the Calibrated Model Simulation, SIN concentrations under the Horticulture Expansion B Scenario are predicted to be greater at 121 (i.e., 98%) assessment points.

Under the Horticulture Expansion B Scenario, predicted concentrations of SIN do not achieve the One Plan targets in 105 of the 124 assessment points (Figure 38). Predicted concentrations of SIN exceed the target by more than 10%, 20% and 50% at 93, 81 and 50 assessment points, respectively.

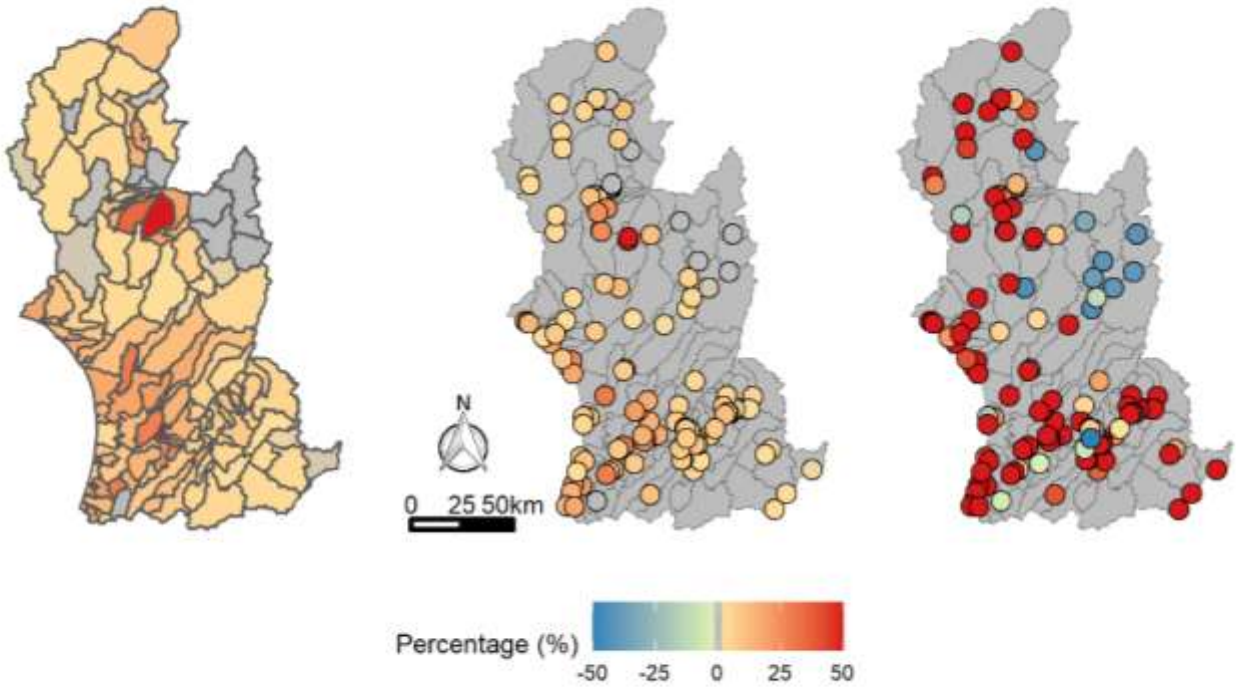

Figure 38. Percentage difference in nitrogen export coefficient (left), percentage difference in river SIN concentrations (centre) and percentage difference between predicted SIN concentration and SIN target (right) for the Horticulture Expansion B Scenario. The differences shown on the left and centre maps were derived by comparing the Horticulture Expansion B Scenario with the Calibrated Model Simulation. Negative percentages on the right map indicate achievement of the water quality state target and vice versa.

4.5.4 Potato Expansion Scenarios

The difference in the nitrogen export coefficients and resulting river SIN concentrations under the Potato Expansion A Scenario compared to the Calibrated Model Simulation are shown in Figure 39. The Potato Expansion Scenarios (comprising Scenario A, B and C) represent the water quality outcome of increasing commercial potato growing across the region.

Nitrogen export coefficients in WMSZs and SIN concentrations at assessment points variously increased and decreased under the Potato Expansion A Scenario compared to the Calibrated Model Simulation. Compared to the Calibrated Model Simulation, SIN concentrations under the Potato Expansion A Scenario are predicted to be higher at 102 (i.e., 82%) assessment points and lower at 10 (i.e., 15%) assessment points (Figure 39).

Under the Potato Expansion A Scenario, predicted concentrations of SIN do not achieve the One Plan targets at 98 of the 124 assessment points (Figure 39). Predicted concentrations of SIN exceed the target by more than 10%, 20% and 50% at 79, 67 and 48 assessment points, respectively.

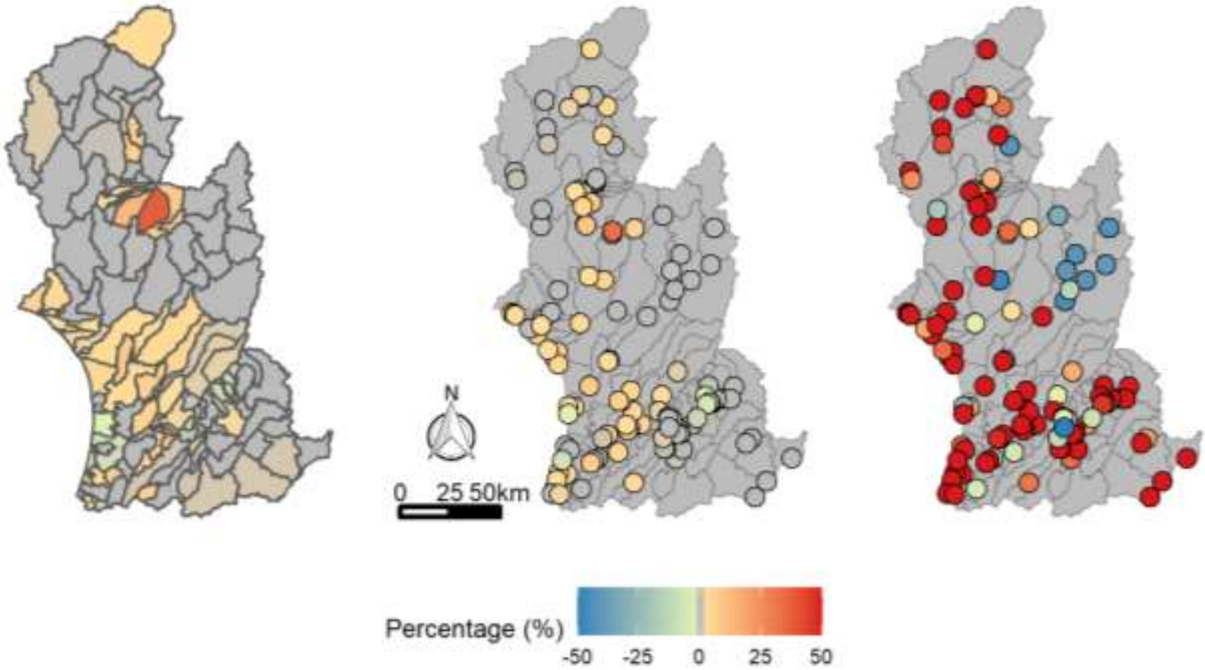

Figure 39. Percentage difference in nitrogen export coefficient (left), percentage difference in river SIN concentrations (centre) and percentage difference between predicted SIN concentration and SIN target (right) for the Potato Expansion A Scenario. The differences shown on the left and centre maps were derived by comparing the Potato Expansion A Scenario with the Calibrated Model Simulation. Negative percentages on the right map indicate achievement of the water quality state target and vice versa.

The difference in the nitrogen export coefficients and resulting river SIN concentrations under the Potato Expansion B Scenario compared to the Calibrated Model Simulation are shown in Figure 40. Nitrogen export coefficients in WMSZs and SIN concentrations at assessment points variously increased and decreased under the Potato Expansion B Scenario compared to the Calibrated Model Simulation. Compared to the Calibrated Model Simulation, SIN concentrations under the Potato Expansion B Scenario are predicted to be higher at 22 (i.e., 18%) assessment points and lower at 98 (i.e., 79%) of assessment points (Figure 40).

Under the Potato Expansion B Scenario, predicted concentrations of SIN do not achieve the One Plan targets at 95 of the 124 assessment points (Figure 40). Predicted concentrations of SIN exceed the target by more than 10%, 20% and 50% at 88, 77 and 47 assessment points, respectively.

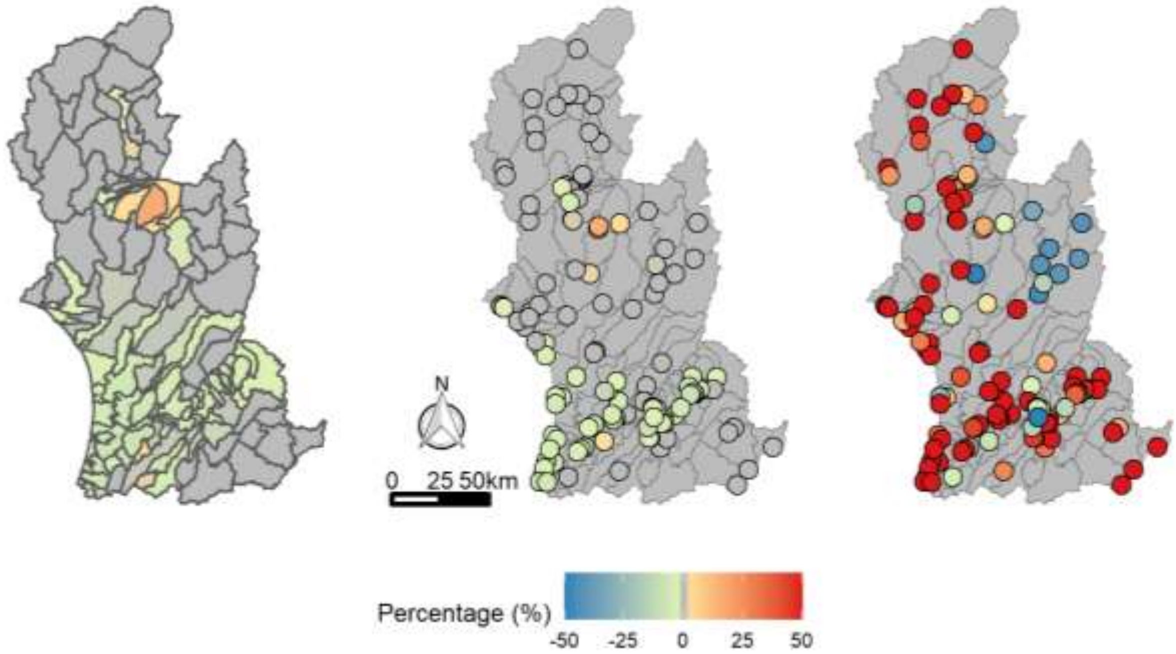

Figure 40. Percentage difference in nitrogen export coefficient (left), percentage difference in river SIN concentrations (centre) and percentage difference between predicted SIN concentration and SIN target (right) for the Potato Expansion B Scenario. The differences shown on the left and centre maps were derived by comparing the Potato Expansion B Scenario with the Calibrated Model Simulation. Negative percentages on the right map indicate achievement of the water quality state target and vice versa.

The difference in the nitrogen export coefficients and resulting river SIN concentrations under the Potato Expansion C Scenario compared to the Calibrated Model Simulation are shown in Figure 41. Nitrogen export coefficients in WMSZs and SIN concentrations at assessment points variously increased and decreased under the Potato Expansion C Scenario compared to the Calibrated Model Simulation. Compared to the Calibrated Model Simulation, SIN concentrations under the Potato Expansion C Scenario are predicted to be higher at 7 (i.e., 6%) assessment points and lower at 113 (i.e., 91%) of assessment points (Figure 41).

Under the Potato Expansion C Scenario, predicted concentrations of SIN do not achieve the One Plan targets at 95 of the 124 assessment points (Figure 41). Predicted concentrations of SIN exceed the target by more than 10%, 20% and 50% at 87, 76 and 46 assessment points, respectively.

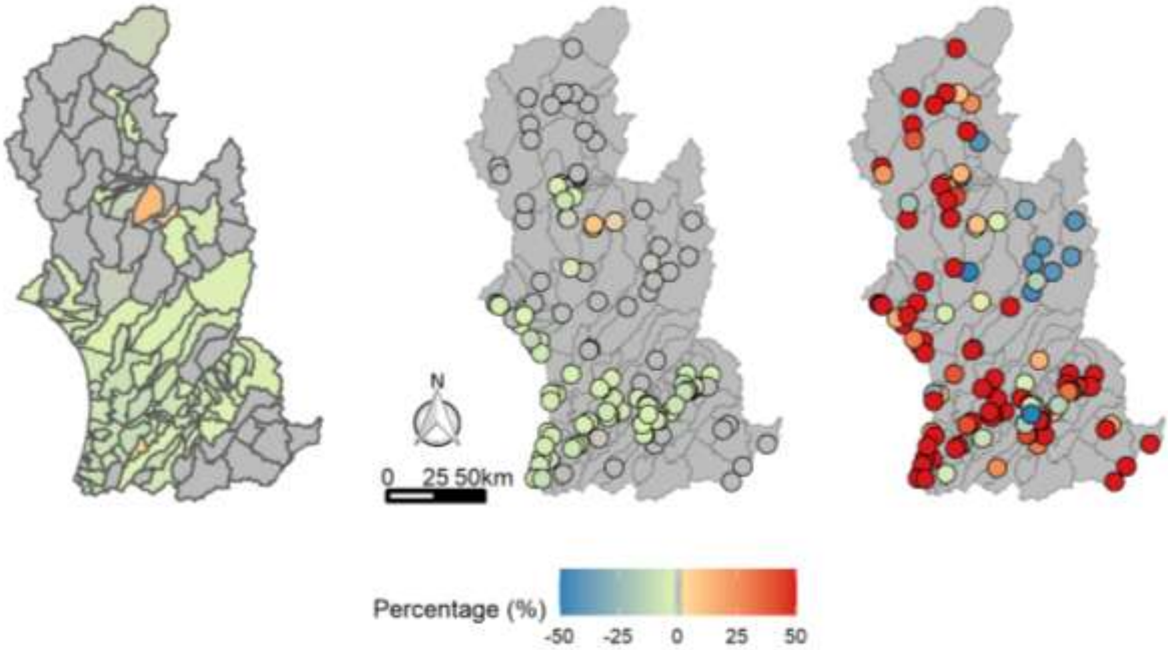

Figure 41. Percentage difference in nitrogen export coefficient (left), percentage difference in river SIN concentrations (centre) and percentage difference between predicted SIN concentration and SIN target (right) for the Potato Expansion C Scenario. The differences shown on the left and centre maps were derived by comparing the Potato Expansion C Scenario with the Calibrated Model Simulation. Negative percentages on the right map indicate achievement of the water quality state target and vice versa.

5 Summary and conclusions

The results of water quality impact simulations for all scenarios and all assessment points (i.e., region-wide) are summarised in Table 2 and are summarised for assessment points downstream of Target Catchments in Table 3.

Table 2 Summary of achievement of One Plan SIN targets at the 124 region-wide assessment points. The mean relative difference indicates the mean percentage amount by which the predicted concentration at assessment points deviate from the target. Positive values indicate the predicted SIN concentration exceeds the target (i.e., the objective is not achieved). The rows in the table are colour coded to reflect the four groups of scenarios: Historical Simulations, Operative Plan Scenarios, Proposed Plan Scenarios and Additional Scenarios.

Scenario	**No. of points that do not achieve the target (% in brackets)**	**Mean relative difference (%)**
Calibrated Model (2012)	96 (77%)	30
Pre-regulation (2012)	97 (78%)	31
Point Sources	95 (76%)	29
Post-regulation A	97 (78%)	30
Post-regulation B	96 (77%)	29
Horticulture Mitigation A	96 (77%)	30
Horticulture Mitigation B	96 (77%)	30
Operative Year-20	90 (73)	22
Operative Year-20 Consented	95 (76%)	24
Operative Year-20 Expansion	95 (76%)	22
Proposed Consented	97 (78%)	28
Proposed Year-20 Pathway A	98 (79%)	29
Proposed Year-20 Pathway D	98 (79%)	29
Proposed Year-20 Pathway GMP	98 (79%)	30
Proposed Year-20 Pathway BMP	98 (79%)	29
Proposed Year-20 Pathway GMP + point sources	96 (77%)	29
Proposed Year-20 Pathway BMP + point sources	96 (77%)	28
Proposed Year-5 Pathway A	100 (81%)	30
Proposed Year-5 Pathway D	99 (80%)	30
Proposed Consented Strict	97 (78%)	27
Natural State	13 (10%)	-294
Dairy Sector Pathway A	98 (79%)	23
Dairy Sector Pathway B	99 (80%)	23
Horticulture Expansion A	104 (84%)	33
Horticulture Expansion B	105 (85%)	34
Potato Expansion A	98 (79%)	31
Potato Expansion B	95 (76%)	29
Potato Expansion C	95 (76%)	28

The region-wide results indicate that the SIN concentrations predicted by the Calibrated Model Simulation and the Pre-regulation Simulation exceed the One Plan targets at a large majority of assessment points (i.e., ≥77%; Table 2). In addition, for these two simulations on average, assessment points have SIN concentrations that are 30% higher than the target (Table 2). These two historic simulations represent the estimated water quality conditions in 2012 prior to regulation of nitrogen leaching from IFLU.

The Calibrated Model and the Pre-regulation Simulations indicate that SIN concentrations at assessment points downstream of the Target Catchments exceed the One Plan targets at a large majority of assessment points (i.e., ≥89%; Table 3). In addition, in 2012, prior to regulation of nitrogen leaching from IFLU, assessment points downstream of the Target Catchments have SIN concentrations that are, on average, ≥42% higher than One Plan targets.

Region-wide, the majority of scenarios produce only small changes in the water quality state Compared to the Calibrated Model Simulation. In general, the group of Operative One Plan scenarios produce the most notable improvements. All the Operative One Plan scenarios represent improvements to water quality outcomes; there are small improvements in the number of assessment points that exceed the One Plan targets, but significant improvements in the mean relative difference (i.e., the average amount by which SIN concentrations exceed the target at assessment sites).

Table 3. Summary of achievement of One Plan SIN targets at Target Catchment assessment points. Note that there are a total of 35 assessment points that are downstream of the Target Catchments. The details for this table are identical to Table 2 above.

Scenario	No. of points that do not achieve the target (% in brackets)	Mean relative difference (%)
Calibrated Model (2012)	31 (89%	42
Pre-regulation (2012)	32 (91%)	45
Point Sources	30 (86%)	40
Post-regulation A	32 (91%)	43
Post-regulation B	31 (89%)	42
Horticulture Mitigation A	31 (89%)	42
Horticulture Mitigation B	31 (89%)	42
Operative Year-20	24 (69%)	24
Operative Year-20 Consented	29 (83%)	34
Operative Year-20 Expansion	29 (83%)	25
Proposed Consented	29 (83%)	40
Proposed Year-20 Pathway A	30 (86%)	41
Proposed Year-20 Pathway D	30 (86%)	40
Proposed Year-20 Pathway GMP	30 (86%)	42
Proposed Year-20 Pathway BMP	30 (86%)	41
Proposed Year-20 Pathway GMP + point sources	29 (83%)	40
Proposed Year-20 Pathway BMP + point sources	29 (83%)	39
Proposed Year-5 Pathway A	32 (91%)	43
Proposed Year-5 Pathway D	31 (89%)	42
Proposed Consented Strict	29 (83%)	35
Natural State	6 (17%)	-401
Dairy Sector Pathway A	30 (86%)	33
Dairy Sector Pathway B	31 (89%)	33
Horticulture Expansion A	33 (94%)	46
Horticulture Expansion B	34 (97%)	46
Potato Expansion A	30 (86%)	42
Potato Expansion B	29 (83%)	40
Potato Expansion C	29	38.7

Region-wide and downstream of the Target Catchments, compared to the Pre-regulation Scenario, the group of scenarios based on the Proposed Plan represent small improvements in mean relative difference and small improvements in the number of assessment points that do not achieve the target. This indicates that generally, the Proposed Plan, is anticipated to modestly improve water quality (i.e., reduce SIN concentrations) compared to 2012, but the improvement is less than with the Operative One plan scenarios.

Key general findings of the Proposed Plan Scenarios are:

1. Continued leaching from all IFLUs (consented and unconsented) at their pre-consented (2012 basefile) nitrogen leaching rates (the Pre-regulation Simulation) produced the worst water quality outcome (except for the two Horticulture Expansion scenarios). This is indicated by the highest mean relative difference and number of assessment points that do not achieve the target for the Pre-regulation Simulation in Tables 2 and 3.
2. There is a general improvement in water quality over the predicted 2012 (Pre-regulation) outcomes if all consented IFLUs operate at their consented N loss rates, and unconsented IFLUs operate at up to, but not exceed, the PPC2 Table 14.2 limits. This is indicated by comparing the Proposed Consented Scenario with the Pre-regulation Simulation in Tables 2 and 3.
3. The water quality outcome is improved over the Proposed Consented Scenario if IFLUs operate at their consented nitrogen leaching rates where those rates do not exceed PPPC2 Table 14.2 limits, consented IFLU that have consented nitrogen leaching rates higher than PPPC2 Table 14.2 are reduced to the Table 14.2 limits, and unconsented IFLUs operate at up to, but not exceeding, the PPC2 Table 14.2 limits. This is indicated by comparing the Proposed Consented Scenario with the Proposed Consented Strict Scenario in Tables 2 and 3.
4. The discretionary consent pathway options for unconsented farms (Proposed Year-20 Pathway) improves WQ relative to taking no action on unconsented farms (Scenario 12). This is indicated by comparing the Proposed Year-20 Pathway with the Post-regulation Scenario in Tables 2 and 3.
5. The impact on water quality of reducing the baseline nitrogen leaching rates from the Known Unconsented-IFLU is small at the regional level. This is indicated by comparing the Proposed Year-20 Pathway A Scenario with the Proposed Year-20 Pathway D Scenario in Tables 2 and 3.

The above key findings apply generally; however, under some of the Proposed Plan Scenarios there are increases in SIN concentrations at individual assessment points. For example, compared to the Pre-regulation Scenario, SIN concentrations were predicted to increase at some locations under the Proposed Consented Year-20 Scenario (see Figure 16). These increases occur because the calibrated model defined some areas of IFLU with export coefficients that are less than the nitrogen leaching rates specified in PPC2 Table 14.2, and under several scenarios these leaching rates are assumed to increase up to those specified in PPC2 Table 14.2. The areas where this can occur are shown in blue on Figure 2.

Areas with increased nitrogen leaching rates from IFLU land occur in some non-target catchments and therefore the overall export coefficients in the model and the predicted SIN concentrations increase under several of the Proposed Plan Scenarios. The conclusion is that the Proposed Plan will lead to modest water quality improvements in the Target Catchments but may allow some IFLU land to increase its nitrogen leaching rates up to levels specified in Table 14.2, and this will decrease water quality (i.e., increase SIN concentrations) in some locations.

The Natural State scenario indicates that some assessment points would not achieve the One Plan SIN target in the absence of any anthropogenic water quality pressure. This suggests that some of the One Plan SIN targets are too strict and should be reviewed in the future.

6 References

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