MODELLED LOSS OF NUTRIENTS FROM VEGETABLE GROWING SCENARIOS IN HOROWHENUA

OverseerFM 6.3.2 Modelling of Representative Rotations within Hokio_1a, Hokio_1b, and Ohau_1b WMSZ

Report for Pattle Delamore Partners

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1. Executive Summary

As part of the project, “Environmental Effects of Horticultural Practices in the Manawatu-Whanganui Region”, OverseerFM modelling of vegetable production scenarios was completed. The results apply only to the study area of known vegetable production in the Hokio 1a and 1b, and northern edge of Ohau_1b Water Management Sub-Zones (WMSZ) (see Figure 1, page 3).

The tonnages of nitrogen and phosphorous entering the hydrological system were calculated for both pre-2019 and post-2019 using grower supplied data for planted areas, crop rotations and nutrient management practices.

- The total amount of nitrate-N lost by leaching from the vegetable growing areas in the study area was calculated to be 29.59 tonnes pre-2019 and 18.04 tonnes post-2019.
- The total amount of phosphate-P lost by leaching from the vegetable growing areas in the study area was calculated to be 0.66 tonnes pre-2019 and 0.50 tonnes post-2019.

To derive these results, many assumptions and compromises were required. We modelled a range of crop rotations in each of three production system scenarios; an onion/potato rotation, brassica dominated fresh vegetables and intensive fresh vegetables. To estimate catchment impacts, we applied the results on a pro rata basis according to cropped areas provided by growers and Horticulture New Zealand.

We have compared new practice with recommendations in the 2019 guidelines, “*Nutrient Management for Vegetable Crops”.* In general, we find growers often using less fertiliser than the new guidelines might suggest as good practice.

We note that many crops grown are not included in OverseerFM and some alternative must be selected. When selecting surrogate crops, a first option was to select a surrogate from the same family, but in some cases the actual crop has very different yield and different plant parts are harvested. In such cases, a closer representative was selected. We also identify that including grass in a rotation appears to generate unrealistically high levels of crop nitrogen accumulation and subsequent leaching.

Levin currently has no S-Map soil map layer. For modelling, soils were deemed to change at the State Highway with onion/potato on Waitohu deep silt loam (Moko_2a.1) and all other crops on Shannon deep silt loam (Paha_29a.1).

Modelling cropping systems in OverseerFM had limitations. The need to enter grower operations by month in Overseer leads to simplification of crop plans. N leaching increased when we modelled best practice fertiliser management recommendations to split fertiliser applications. The model can give variable results when incorrect yields are entered. However, definition of yield by growers can change greatly between growers and are further compounded when using surrogate crops from the OverseerFM list. For ryegrass as a cover crop, the model predicts excessive N leaching from unrealistic N plant uptake results. We modelled ryegrass Forage Oats (Autumn sown) which gave more realistic N values.

Our observations are that growers in Levin are generally efficient with their fertiliser use and there are few opportunities to further reduce rates of N applied without increasing the risk of crop failure. In most cases, current applications are near or below those recommended in the latest science based best practice guidelines.

2. Introduction

As part of the project, "Environmental Effects of Horticultural Practices in the Manawatu-Whanganui Region", OverseerFM modelling of vegetable production scenarios was completed. The OverseerFM results used in this report were generated on 27 January 2020.

We have used data provided by the growers wherever possible in the belief that this project will be best achieved via use of actual information that is pertinent to, and derived from, horticulture in the region. We also considered theoretical data to cross-validate the modelling and considered outputs against results from our own research and consultancy.

We recognise that land use for commercial vegetable production can be extremely variable, with different areas of land used in different ways at different times. This occurs within paddocks, from paddock to paddock and in and out of sub-catchments and changes seasonally and annually.

We modelled a range of crop rotations in each of three production system scenarios; an onion/potato rotation, brassica dominated fresh vegetables and intensive fresh vegetables.

To estimate catchment impacts, we applied the results on a pro rata basis according to cropped areas provided by growers and Horticulture New Zealand. The relative contribution of each has changed with a much reduced area in intensive fresh vegetables and relatively little change in area for the other scenarios. We have restricted areas of vegetable crops to those in the study, covering the Hokio 1a and 1b, and northern edge of Ohau_1b Water Management Sub-Zones (WMSZ) (see Figure 1).

In the last 12 - 24 months there have been significant changes in growing practices, particularly responding to the new nutrient management requirements. Growers are moving from the 1984 fertiliser recommendations to those in the 2019 recommendations and are adopting the Nitrate Quick Test strip approach. Some are testing very regularly, generally before any fertiliser application, and adjusting fertiliser prescriptions accordingly.

The land area to which no fertiliser is applied has increased significantly with about 40% of cropped area having greatly increased areas of headland and half having adopted crop-free tramlines for irrigation, spraying and harvest lanes.

To understand the likely load entering ground water before present we have modelled scenarios using typical crop rotations, fertiliser practices and areas as they were in years prior to 2019 ("old practice"). To compare this with the likely load in the future we repeated this using the practices growers report they use now and will be in the future ("new" or good management practice").

We have compared new practice with recommendations in the 2019 guidelines, "*Nutrient Management for Vegetable Crops".* In general, we find growers often using less fertiliser than the new guidelines might suggest as good practice. Where we identified potential to further reduce nutrient inputs, we have modelled accordingly and reported results reflect this.

We have been forced to make many assumptions and to substitute actual planted crops with surrogate crops and to assume soils because the area in unmapped. All assumptions and their rationale are described in the following sections.

Importantly we note that many crops grown are not included in OverseerFM and some alternative must be selected. We also identify that including grass in a rotation appears to generate unrealistically high levels of crop nitrogen accumulation and subsequent leaching. Therefore, as described we have replaced grass with forage oats which tends to generate numbers that seem more plausible.

3. Vegetable Growing Areas Used in Modelling

The area selected for this study is restricted to the flatter parts of the Arawhata Catchment south-east of Levin. The area includes Hokio 1a and 1b, and northern edge of Ohau_1b and extends from the Ohau River to Lake Horowhenua with vegetable growing sited on the deeper silt loam soils.

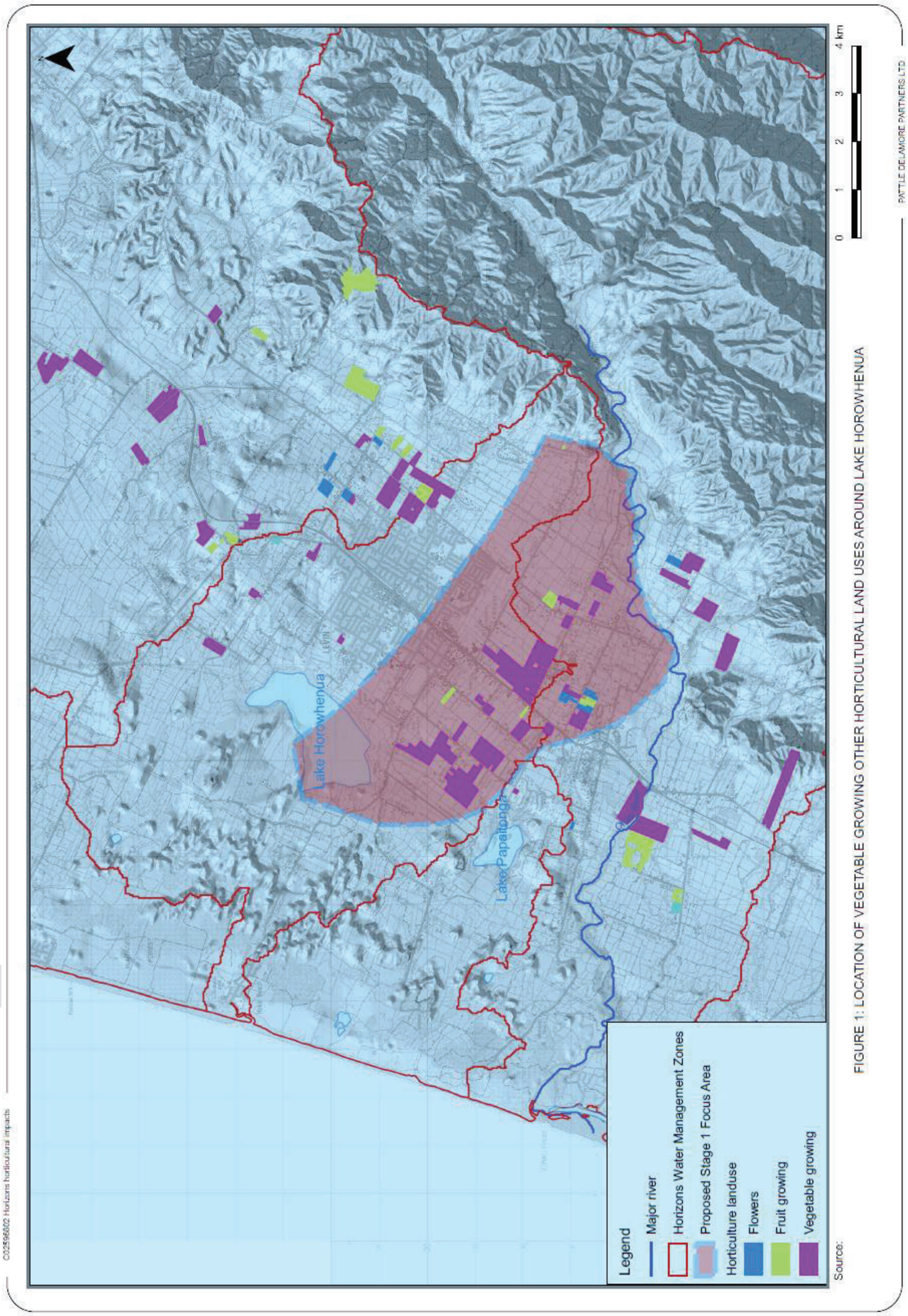


Figure 1 Location of Vegetable Growing within Water Management Sub-Zones around Lake Horowhenua

4. Details of Assumptions

Throughout data procurement and analysis, a number of compromises and assumptions had to be made in order to enter suitable data into OverseerFM and complete the work within the specified timeframe.

4.1 Cropped Area

These results apply only to the area of known vegetable production in the study area. We were supplied with details from the main eight growers who believe they represent 95% of all production in the area covered.

A vast array of potential crops, planting times and rotations are possible and realistically not all can be modelled.

Since 2019, the area in intensive fresh vegetables has reduced much more than the others because some land is no longer used for cropping, headlands are much wider, and areas used for unplanted tramlines have increased. Therefore, the relative areas of each farm system scenario changed between pre- and post-2019.

We believe that pre-2019 there were 419 title hectares of which 90% or 377 hectares were cropped. Post-2019 the title area reduced by 9.5% to 379 ha, but the area with crops reduced by 20% to 302 ha or about 80% of title area cropped (Table 1).

Table 1 The extent and relative contributions of different vegetable farm system types pre- and post-2019

	Pre-2019		Post-2019	
Farm System Type	Title Area	Cropped Area	Title Area	Cropped Area
All Vegetable Areas	419 ha	377 ha	379 ha	302 ha
Intensive Fresh Vegetables		62%		52%
Brassica Dominant Rotation		11%		13%
Onion/Potato Rotation		27%		34%

The OverseerFM modelling has been completed assuming blocks have 100% of their area cropped. The catchment load is derived from the modelled losses from each block and each farm system scenario on a pro rata basis according to the actual area in crop once buildings, driveways, headlands and uncropped irrigator/sprayer alleys are deducted.

4.2 Crop Rotations

Onion/Potato Rotation

The onion/potato system typically sees each crop type grown for two years in a paddock before it switches to the other crop type for two more years. Planting and harvest dates, nutrient additions and yields vary according to variety and timing, so a range of scenarios were determined and modelled. The weighted average N and P losses were used to determine the resultant quantity of nutrient loss in total from the full cropped area.

The two year OverseerFM period may have onion-onion and potato-potato or onion-potato and potato-onion or some combination of these. We have compared the results of repeating and switching crops and get very minimal difference across the total modelled area.

We did identify that using the OverseerFM defaults for inter-crop annual ryegrass phases greatly increased the modelled leaching, even more so than if land was left fallow. On the recommendation of Bruce Searle, we substituted the grass with forage oats.

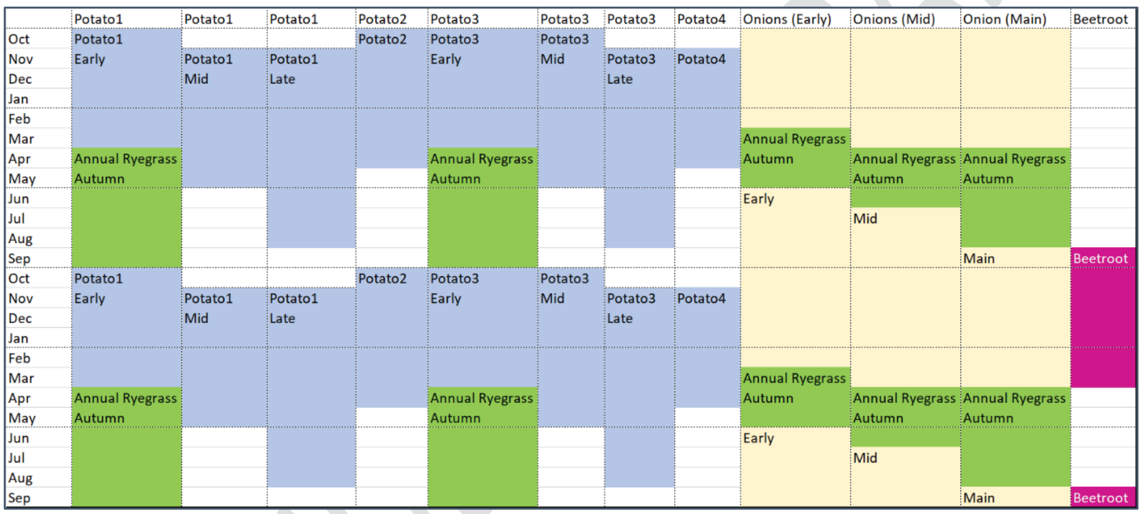


Figure 2 The modelled farm system scenario for onion and potato cropping as practised in Arawhata shows crops and dates in a range of representative blocks.

Brassica Dominant Vegetables

A significant part of the WMSZ is used to produce brassicas for year-round sales. To ensure sufficient crop is available every day, multiple smaller plantings are made approximately twice weekly. A degree of crop rotation is needed for disease management and some alternative crops are grown.

To fully represent this system, a rolling rotation with 36 variations was designed and twelve of these selected for OverseerFM modelling. These are weighted by crop area and harvest time to give a fair overall average leaching value for the scenario as a whole.

The same rotation is used for both pre- and post-2019 scenarios, but cropped area and fertiliser applied vary somewhat. We noted that if we split fertiliser into three or more applications, OverseerFM generated increased leaching values. This appears to be due to the OverseerFM algorithm assuming the crop finishes growing and taking up nutrients and later applications are wasted. Grower experience, published results and best practice recommendations suggest otherwise.

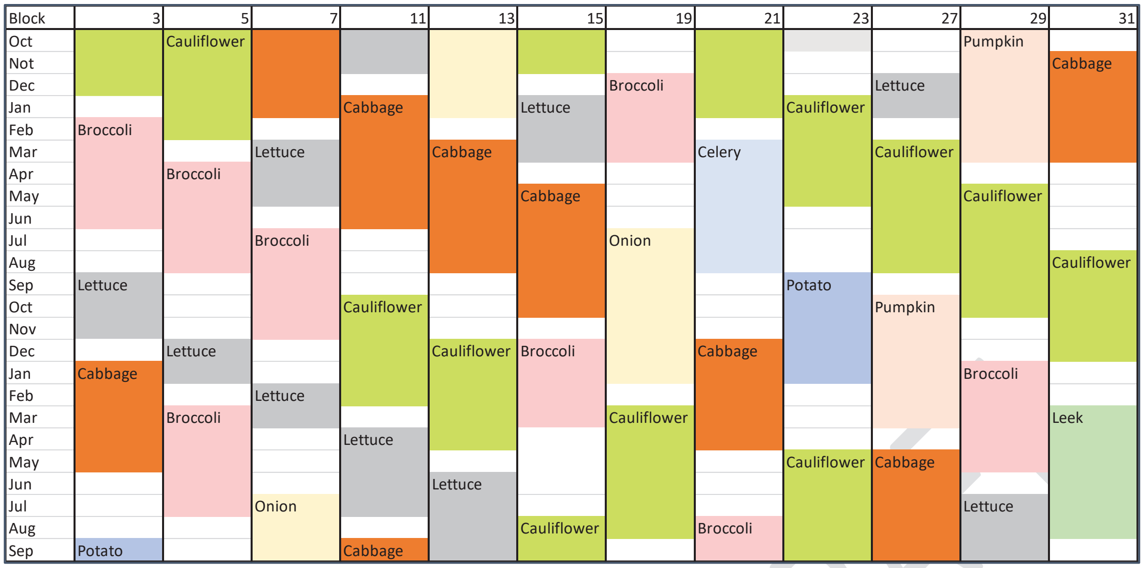


Figure 3 The modelled farm system scenario for Brassica dominant cropping as practised in Arawhata shows crops and dates in a range of representative blocks.

Intensive Fresh Vegetables

The Intensive Fresh Vegetables scenario is the most complex with numerous crops and multiple sowings and plantings to meet daily market demands. This scenario has also seen more significant change since pre-2019.

The introduction of tramlines has increased average planted-area yields, the amount of fertiliser used is much reduced, there has been a reduction or removal of some crop types, and catch-crops (maize, grass and oats) have been introduced. Because of these changes, two related but significantly different scenarios were modelled, one pre-2019 and one post-2019.

The post-2019 scenario is based on actual grower planting plans for the 2019-2022 period, block by block and planting by planting. To model this in detail in OverseerFM we would need to create hundreds of blocks of 0.1 – 1.0 ha each. Once plantings were clumped into months and some other rationalisation was done, 38 different blocks representing different crops and rotations were identified and modelled.

These 38 blocks were adjusted for the pre-2019 scenario, replacing catch-crops with fresh vegetables or fallow. Replacement crops were selected from the other fresh vegetables grown according to grower advice of historic practice. Yields and fertiliser applications were adjusted to reflect changes between pre- and post-2019.

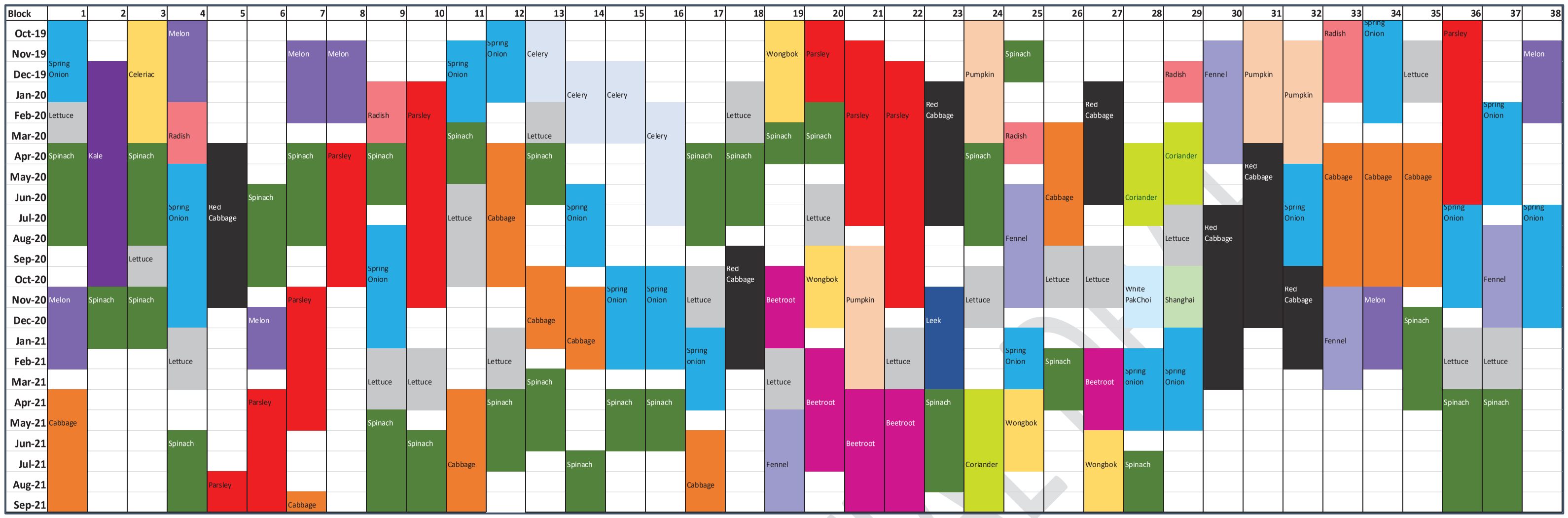


Figure 4 PRE-2019 Intensive Fresh Vegetable Rotations

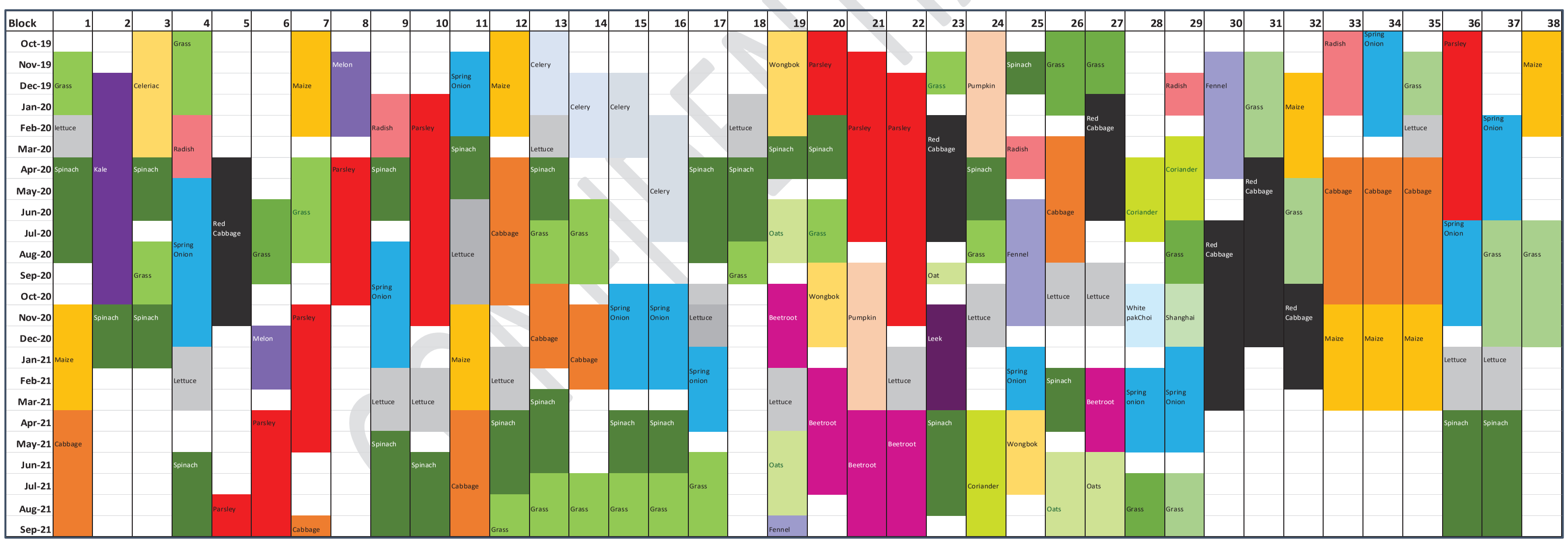
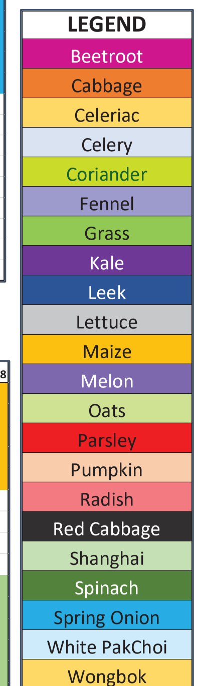


Figure 5 POST-2019 Intensive Fresh Vegetable Rotations



4.3 Crop Assumptions

Many vegetable crops grown are not included in the OverseerFM options so surrogates must be chosen.

When selecting surrogate crops, we considered information from other sources including "*Nutrient Management for Vegetable Crops in NZ*"[1] and the UK Agriculture and Horticulture Development Board "*Nutrient Management Guide (RB209)*"[2]. A first option was to select a surrogate from the same family, but in some cases the actual crop has very different growth form and yield and different plant parts are harvested. In such cases, a closer representative was selected.

Between crop pasture phases are a particular issue. The defaults from OverseerFM can produce much higher crop nitrate leaching than our other experience shows. Following discussions with Bruce Searle (Plant and Food Research) we substituted grass with forage oats which generates nitrogen values in line with Plant and Food Research's research.

Table 2 Actual crops grown, the surrogate crops elected in OverseerFM and rationale for the selection

Actual Crop	Overseer Crop	Reason for crop choice	Notes
Annual Ryegrass	Forage Oats (Autumn)	Plant type - grasses	Representative N Uptake
Celery	Spinach	Petiole/leaf	Similar harvest index
Coriander	Spinach	Petiole/leaf	Significantly lower yield
Fennel	Parsnips	Plant family	Similar harvest index
Kale	Kale (Forage)	Plant family	Default yield
Leek	Onion	Plant family	Lower harvest index
Parsley	Spinach	Petiole/leaf	Similar harvest index
Pumpkin	Squash	Plant family	
Radish	Beet	Swollen stem	Similar harvest index
Red Cabbage	Cabbage	Plant type	
Rockmelon	Squash	Plant Family	
Shanghai	Cabbage	Plant family	Default yield
Spring Onion	Onion	Plant family	Similar harvest index (RB209 Guide)
Watermelon	Squash	Plant Family	
White Pak Choi	Cabbage	Plant family	Default yield
Wong Bok	Cabbage	Plant family	Default yield

4.4 Yield Assumptions

We have used the higher of grower reported yield and the OverseerFM defaults in line with advice received from Horticulture New Zealand. Overseer stated yield should be entered as the crop default yield or higher because the model has simple assumptions that can be wrong when yield is lower than the crop default yield.

We used typical or average crop yields provided by growers. We generalised these and used the same yields throughout the year. However, we selected summer (planted October – January) or winter/spring crop (planted February – September) where this is a relevant OverseerFM option.

[1] JB Reid and JD Morton 2019

[2] https://ahdb.org.uk/nutrient-management-guide-rb209

4.5 Soil Assumptions:

Levin currently has no S-Map soil map layer. There are various indicated soil distributions, so advice was sought. The S-Map soil definitions used were as per recommendations from Prof. A. Palmer.

For modelling, soils were deemed to change at the State Highway with onion/potato are on one soil, all the other crops on another.

The onion/potato rotation was modelled using Waitohu deep silt loam – (Moko_2a.1) with the drainage class changed from imperfect to moderately well drained and ASC to 60.

The intensive vegetable and brassica rotations were modelled on a Shannon deep silt loam (Paha_29a.1) with the ASC changed to 25. ASC modifications were made based on past detailed soil tests indicating higher ASC content that suggested by the S-Map factsheets.

Alternative soil options are Levin deep silt loam or Levin deep silt loam on sand (Levi_1b.1 and Levi_4a.2). The proportion of cropping that might fall on this soil is unknown. Its leaching potential is lower than the two soils used for modelling for this report, so our results may over-estimate losses by some margin on some of the area.

5. Modelling Issues

Modelling cropping systems in Overseer had some technical difficulties due to limitations of the model. Some technical difficulties came with crop types and yield definitions. Overseer has a limited range of crops with unclear definitions of yield: total biomass grown, harvested plant part, exported plant part. Similarly, the portion of plant biomass returned as residues to the soil is not clear. For crop types, changing a Summer Cauliflower to a Winter Cauliflower at a critical period can change predicted N loss by 40% for that block.

5.1 Annual Ryegrass:

Good grower practice is to plant cover-crops on ground that will be bare in winter. Current practice for some growers is to plant an annual ryegrass and graze overwinter with lambs.

When we enter annual ryegrass in OverseerFM, the model estimates very significant plant uptake (300-400kg N/ha) when either default grazing or estimated grazing concentration is used. When the annual ryegrass crop is terminated and the subsequent crop is grown, only a small portion of the resulting soil mineral N pool is used. During the following winter period, modelled leaching rates are high – caused by the elevated soil mineral N pool. The modelled plant uptake is extremely high and is shown to be incorrect based on field-trials completed by Plant and Food Research (B. Searle. Pers.com.).

To avoid excessive N leaching from unrealistic N plant uptake results, in our analysis the actual planted ryegrass was modelled as Forage Oats (Autumn sown) which gives much more realistic N uptake by the growing crop.

5.2 Yield/Weight Definition

The Overseer model can give variable results when incorrect yields are entered. However, definition of yield by growers can change greatly between growers. Yield errors are further compounded when trying to fit actual crops to similar OverseerFM recognised crop types e.g. Asian brassicas to a cabbage or cauliflower crop based on a similar harvest index, but substantially lower yields.

Yield is typically defined as typical harvest portion of the crop - Overseer suggests default yields for most crops – however, when substitute crops are used as Overseer only has models for a few generic crops, yields entered can be meaningless. To give repeatable results, there needs to be further information for interpreting definitions of yield for each crop to allow correct entry of the correct plant parts. One example is broccoli; Chinese cut broccoli harvests twice as much plant biomass as a regular cut broccoli, yet yield is still measured as the same across both crops in OverseerFM. To give repeatable results, yield needs to be entered consistently by all users: when there is disagreement on how yield is to be entered, there is a lower level of certainty around the accuracy of the modelled scenarios.

5.3 Nutrient Uptake

The need to enter grower operations by month in Overseer leads to simplification of crop plans. This can result in a crop that is growing for 14 weeks appearing to be in the ground for 5 months (20 weeks).

Nitrogen leaching increased when we modelled best practice fertiliser management recommendations to split fertiliser applications to no more that 50kgN/ha/application spread at one application per month. This appears due to the limited monthly time-step in the Overseer model predicting that N uptake is complete when additional fertiliser is applied. In reality the plants are still actively growing and taking up nutrients. This OverseerFM modelling apparently assumes excess fertiliser goes into the soil mineral-N pool and increases the block's leaching risk over the winter period.

6. Results of Modelling

In accordance with the Memorandum of Understanding agreed between project parties, no individual grower data is to be disclosed. As the farm system scenarios modelled do effectively describe individuals, only gross results are presented here. Full details are available for peer reviewers as required.

Nitrogen Loss

The total amount of nitrate-N lost by leaching from the vegetable growing areas of the in the study area was calculated to be 29.59 tonnes pre-2019 and 18.04 tonnes post-2019. This is a reduction of 39%.

Phosphorous Loss

The total amount of phosphate-P lost by leaching from the vegetable growing areas of the in the study area was calculated to be 0.66 tonnes pre-2019 and 0.50 tonnes post-2019. This is a reduction of 24.4%.

7. Discussion

Our observations are that growers in Levin are generally efficient with their fertiliser use and there are few opportunities to further reduce rates of N applied without increasing the risk of crop failure. In most cases, current applications are near or below those recommended in the latest science based best practice guidelines.

Many vegetable crops grow large amounts of biomass and do take up significant quantities of nitrogen (>200kg N/ha). A primary issue when growing vegetable crops is crop residue management. Crop residue breaks down and releases significant quantities of mineral N into the soil profile, but the timing is dependent on soil temperature and moisture and there is little certainty when that nitrogen might be in a plant-available form (soil mineral N pool).

Levin's climate and soils provide good winter growing conditions for many vegetable crops. If soil mineral N levels can be minimised coming into winter through good crop residue management and catch crops, winter crops will leach significantly less nitrogen. Winter/Spring crops could require increased fertiliser inputs as the soil supply of nutrients will be reduced, but the timing of these applications can be targeted to match plant requirements and minimise leaching risk.

Some growers are using winter cover crops to remove excess N from the soil, and other growers are planning to introduce cover crops where their crop rotations allow. OverseerFM modelling does not appear to adequately represent nutrient balances in this case.

8. References

Publications

Anon. 2019. "*OverseerFM User Guide*". via https://docs.overseer.org.nz/fm/OverseerUserGuide.pdf

Reid, JB and Morton, JD. 2019. "*Nutrient Management for Vegetable Crops in NZ*" Horticulture New Zealand

Agriculture and Horticulture Development Board, 2020. Nutrient Management Guide (RB209) via https://ahdb.org.uk/nutrient-management-guide-rb209

Personal Communications

Crop areas planted, rotations, yields, dates and fertiliser practices

- Jay Clarke, Woodhaven Gardens, Levin
- Chris Pescini, Pescini Bros, Levin
- Travis and Nigel Sue, B S Young, Levin
- John Young, Levin
- Jeffery Wong, Levin
- Chung Sue, Garden of York, Levin
- Harry Su, Levin
- Harry Li, Levin

Recommendations for OverseerFM input values

- Dr David Horne, Massey University
- Prof. Alan Palmer, Massey University
- Dr Bruce Searle, Plant and Food Research

Appropriateness of Scenarios and OverseerFM assumptions

- Stuart Ford, Agribusiness Group
- Charlotte Irving, Agribusiness Group