Freshwater quality and eco-verification of kiwifruit orchard practices

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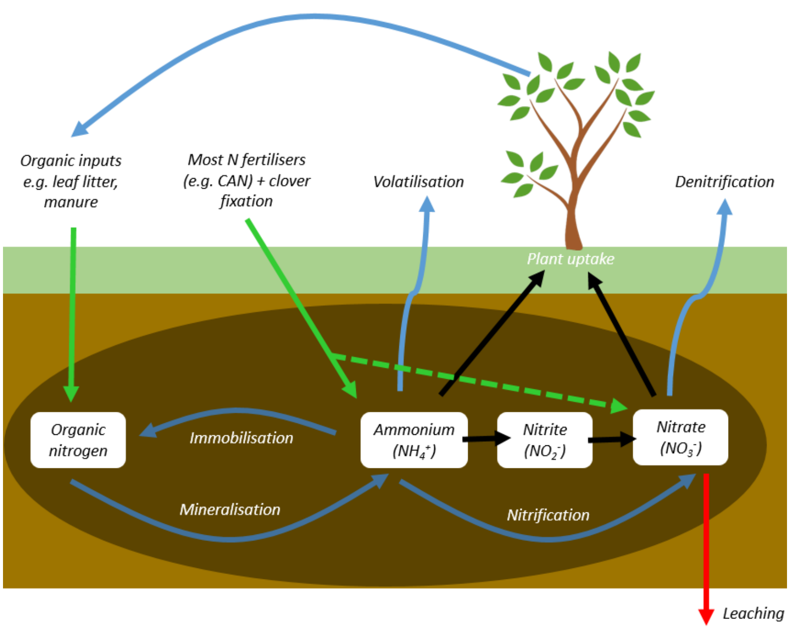
Introduction

Declining freshwater quality and availability are major concerns globally, nationally and locally. To address this in New Zealand, regional councils must implement freshwater management plans by 2025, and they will be directed under the National Objectives Framework (NOF) of the National Policy Statement on Freshwater Management (NPS-FM). Currently, stakeholder community groups (SCGs) in each region are determining freshwater values and any limits and management to protect those values.

The purpose of this report is to inform discussions relating to the impact of kiwifruit production on freshwater values, particularly freshwater quality. Reasonable amounts of modelling have occurred to estimate nitrogen (N) losses associated with kiwifruit production; however, direct measurement to verify these has been limited. Given this, a new Zespri-funded project being undertaken by Plant & Food Research has just commenced to measure N losses from orchards and to eco-verify kiwifruit practices not only for market value and to identify good orchard practices, but also to show good compliance with the regulatory processes. It's win-win-win. **This report is intended as an interim source of information, until the results of this project become available.**

The focus is on nitrogen (N), which is the main nutrient risk for kiwifruit production on water quality. Specifically, it is the nitrate form of nitrogen (i.e. NO_3^-) which readily leaches down through the soil profile. Although N is usually available in the soil for plant uptake initially in the form of ammonium, which leaches much less, this is converted to nitrate through the microbial process of nitrification (Figure 1).

Figure 1. The nitrogen cycle.



Drivers of nutrient losses

Climate, soil characteristics, irrigation, fertiliser practices and yield are the main drivers of nutrient loss in a kiwifruit system. Differences in losses between orchards will be due to differences in one or more of these factors.

Nitrogen losses

Direct measurement of nutrient losses on individual farms and orchards has to date not been practical given the scale and variability of the issue. But new technologies are becoming available for local measurements. Yet for widespread regional management of water quality, and the prescription of good orchard management practices, models are valuable complements to measurements, and modelling is recognised in judicial hearings for both policy development and compliance with regulations. SPASMO (Soil Plant Atmosphere System Model) and OVERSEER® are the most relevant models for kiwifruit and are referred to here. Previously, good agreement has been found between the N losses reported by these two tools[1], although they are quite different in their procedural protocols, and data requirements.

Kiwifruit nitrogen requirements

Previous research indicated that kiwifruit vines require between 140 and 170 kg N/ha annually and typically 100 to 150 kg N/ha/y has been applied to match this (incl. to organic orchards, although this is usually in the form of compost and fish-based products). In addition to applied N, the soil process of mineralisation can supply significant amounts of N, from an estimated 50 kg N/ha/y[22].

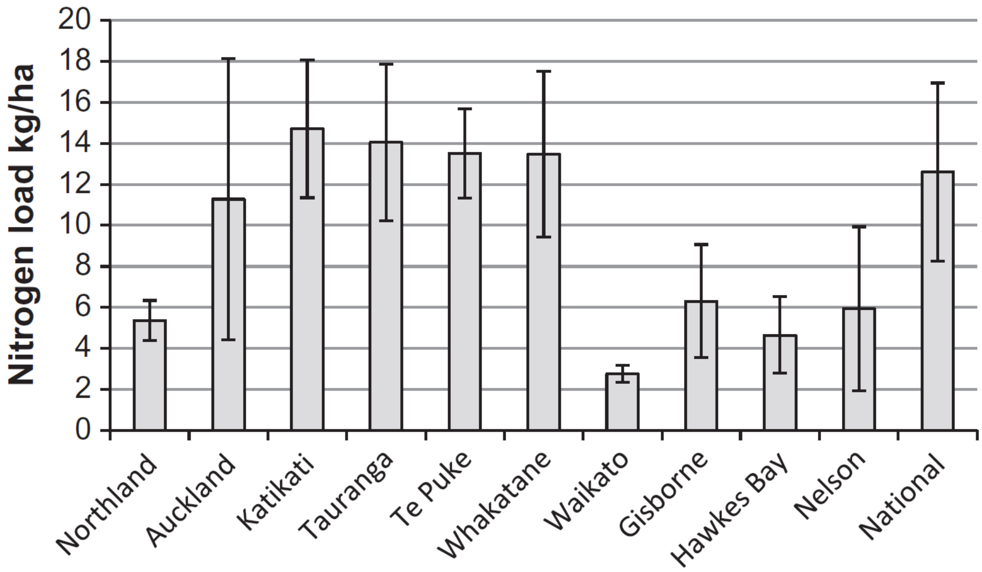
Modelled N losses

According to SPAMSO, N losses for kiwifruit have been modelled to between 3 and 15 kg N/ha depending on the region[2]. These losses are low relative to other non-horticultural land-uses. For kiwifruit, the Bay of Plenty and Auckland had the highest modelled losses, with the other regions being notably lower (Figure 2). These differences are due largely to differences in rainfall and soil drainage, which are major drivers of N loss through the soil. Orchards in all regions were modelled to receive the same amount of N fertiliser i.e. 112 kg N/ha.

According to OVERSEER®, losses for Bay of Plenty orchards were modelled to be similar at approximately 15 - 20 kg NO_3-N/ha/y for conventional orchards, and 10 kg NO_3-N/ha/y for organic[A]. In another study, higher values were reported, of 30 – 40 kg NO_3-N/ha/y for a mostly Green (90%) kiwifruit orchard (under different yield, N input and irrigation scenarios) in the Waimea catchment in the Nelson District[3]. Presumably this is the result of higher soil drainage, as fertiliser inputs were similar to those in the ARGOS study[A] i.e. 120 kg N/ha.

[A] The ARGOS study (www.argos.org.nz) previously reported average losses of 25 and 30 kg N /ha for conventional Hayward and Hort16A kiwifruit respectively, and 10 kg NO_3-N/ha/y for organic[22]. However, these were based on higher than typical rainfall values. Adjusting for this, modelled losses become approx. 15 - 20 kg N/ha for conventional orchards. These values were obtained using version 6.1.3 of OVERSEER®.

Figure 2. The influence of region on the annual average (April to April) nitrate-nitrogen load leaving the rootzone per canopy ha of New Zealand Zespri® Green Kiwifruit orchards. The bars denote ± one standard deviation, and represent only the variation caused by the different soil properties within each region. Source:[2].



In summary, N losses from kiwifruit orchards in the Bay of Plenty (where most orchards are located) are modelled to be 10 – 20 kg NO_3-/ha/y on average; the losses are typically even less for other regions. Such losses are low relative to those from other land uses (see Table 1).

Table 1. Recently reported nitrogen loss values for New Zealand farming systems (kg N/ha/y).

	Range in mean values	**References**
Dairy	14 – 81^	[4,5,6,7,8,9]
Market gardening	39 – 73	[10,11]
Mixed cropping & arable	1 – 65	[9,10,11,12,13]
Sheep/Beef	5 – 39[+]	[7,9,13,14,15]
Forestry	0 – 28*	[8,9,16]

^ Excludes border dyke farms in Canterbury, which have modelled losses of up to 195 kg N/ha/y.
* Excludes fertilised coastal sand, which can be much higher.
[+] Non-irrigated farms i.e. excludes non-irrigated farms.

Measured N losses

In a preliminary study, N losses were directly measured over two seasons on five kiwifruit orchards in a PlusGroup and Plant & Food Research project[17]. The average losses were approximately 30 kg NO_3-N/ha in the first season and 10 kg NO_3-N/ha in the second[B]. Of note, included in this study were 'Hort16A' orchards, which are now few and far between especially in the Bay of Plenty, because of Psa disease[C]. Given this and the variability between seasons, further direct measurements are planned in a new Zespri and Plant & Food Research initiative starting in 2016 to clarify losses from orchards and the impacts of different factors on these. The goal is to show how good orchard management practices can eco-verify kiwifruit production, and to confirm compliance with the NPS-FM. Measurements will be supported by modelling with both SPASMO and OVERSEER® to ensure these tools can reliably estimate losses associated with different orchard variables e.g. climate, soil type, management.

Figure 3. Fluxmeter being installed in a kiwifruit orchard. Source:[17].

Nitrate concentration

Human health and ecological concerns are framed in terms of concentration (mg-N/L or ppm), not loading (kg-N/ha/y). The maximum acceptable value (MAV) of nitrate-nitrogen in drinking water is 11.3 ppm[D] while a median value of 6.9 ppm[18] has been set as a national bottom line for ecosystem health[19]. In one study, the average concentration of nitrate-N in the leachate modelled to be leaving the root zone of Bay of Plenty kiwifruit orchards was found to be approximately 4 ppm, according to SPASMO[2]. Other regions had similar or lower values, with the exception of Hawke's Bay, which had higher values (approx. 6 ppm on average). Similarly, the concentration of N in water lost from orchards in the ARGOS project was modelled on average to be approx. 2 ppm (according to OVERSEER® v6.1.3). The concentrations for kiwifruit orchards are less than those measured and modelled previously for pastoral farming operations, of around 7 to 14 ppm[20].

In summary, the concentrations of nitrates estimated to be typically leaving the root zones of kiwifruit orchards are below national guidelines. Also, processes like attenuation and dilution will reduce the concentrations reaching waterways. The loading (i.e. kg/ha) of nitrates is important too. For example, if a receiving water body receives a small load then the nitrate is probably diluted even further.

[B] These averages exclude one orchard, which had high values because of unusual flooding.

[C] *Pseudomonas syringae* pv. *actinidiae* (Psa) is a bacterium that can result in the death of kiwifruit vines.

[D] The NZ Ministry of Health has set the MAV at 50 mg/L for the concentration of the nitrate ion[23], which is equal to a concentration of 11.3 mg/L (ppm) of nitrate-nitrogen.

Industry growth

In recent years the average yields for kiwifruit have increased significantly because of improved orchard practices and favourable climatic conditions. The N loss results in this report are based on lower yields (20%+ lower). The N loss values associated with the higher yields are not yet known and should be determined.

Phosphorus (P)

P loss values for kiwifruit

In kiwifruit orchards, an annual average of around 50 kg/ha of P is typically applied[24]. According to the ARGOS project, the corresponding modelled average P loss was around 0.5 kg/ha/y. In contrast, direct measurements of annual P losses in run-off from sheep- and cattle-grazed pastureland range from 0.11 to 1.60 kg P/ha/y, while forestry systems, which make the least contribution of P to waterways, lose only 0.01 – 0.10 kg P/ha/y[25]. It appears that P losses from kiwifruit orchards have not been directly measured.

Like nitrogen, over-fertilisation of aquatic plants with P can lead to excessive plant growth, algal blooms and the depletion of oxygen dissolved in water. But unlike nitrogen, the main pathway for P entering our waterways is via soil-attached P in surface run-off, unless the soils are coarse pumice or sandy, in which case leaching of dissolved reactive P might be larger. For surface runoff to be a significant issue, there needs to be sufficient P and slope, unstable soil, and a pathway to vulnerable waterways.

The risk of P losses for kiwifruit is thought to be low generally because orchards are relatively flat and permeable, so runoff is expected to be low. Also, features like shelterbelts will impede and minimise runoff.

Other pollutants

The concentrations and loads of other pollutants in drainage water leaving kiwifruit orchards, such as pesticides, have been calculated to be negligibly small, and their concentrations were even below the detection limit of currently available analytical methods[2]. Despite their high concentrations, other major inorganic constituents (e.g. Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, and SO_4) have rather minor significance for water quality. That is, these major constituents do not usually constrain water uses, at least not in New Zealand, in contrast to semi-arid or arid areas like parts of Australia with salinised soils[21].

Summary

There is evidence mainly in the form of modelling results that indicates nutrient losses from kiwifruit orchards on average are typically lower than from other land-uses. This should be taken into consideration when setting limits. But the current imperative, both for eco-verification in the market place and for compliance with regulatory processes, requires the dualism of measurement and modelling to demonstrate the value of good orchard management practices. Measurements are needed to ensure baseline observations are obtained. From these reference values, modelling using tools like SPASMO and OVERSEER® can provide regional assurances that kiwifruit orcharding is sustainable and is protecting the quantity and quality of our most valuable natural capital asset – water.

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