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ROOTZONE REALITY – A NETWORK OF FLUXMETERS MEASURING NUTRIENT LOSSES UNDER CROPPING ROTATIONS. SUMMARY OF YEAR 1 AND YEAR 2 RESULTS

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Abstract

Between August 2014 and May 2015 a network of passive-wick drainage fluxmeters (DFMs) were installed on commercial cropping farms in the Canterbury, Manawatu, Hawke's Bay and Waikato/Auckland regions to quantify the amount of nitrogen (N) and phosphorus (P) in drainage water leaving the root zone. Results from this study are providing growers and regional authorities with measured nutrient losses from cropping farms across a range of sites and seasons and will provide a platform for the discussion and review of current management practices. The DFM network includes three monitoring sites in each of the four monitor regions, with 12 fluxmeters per site. Individual sites were chosen to provide a range of cropping systems, soil types, climatic conditions and management practices relevant to each region. Measured drainage ranged from 0 to 611 mm and from 0 to 411 mm over the respective Year 1 (October 2014 to September 2015) and Year 2 (October 2015 to September 2016) monitoring periods. Across the majority of sites, most drainage (84–100%) occurred over the winter and spring periods (June to November). Measured N losses ranged from 0 to 226 kg N/ha in Year 1 and from 0 to 118 kg N/ha in Year 2, while measured P losses ranged from 0 to 0.56 kg P/ha and from 0 to 0.27 kg P/ha respectively. Nitrate-N was the dominant form of N loss while most P was lost as dissolved reactive phosphate. Work is underway to explore the relationships between measured losses and site specific weather, soil and management factors now that several seasons of data have been collated.

Introduction

Optimising nutrient supply is a key management consideration for all farmers across New Zealand. Too little supply and crop productivity can be constrained; too much supply and grower profitability decreases and leaching risks increase. Despite the significance of this issue in New Zealand, there is limited information regarding measured inter-annual nitrogen (N) and phosphorus (P) losses from the root zone of commercial cropping fields. Such information is needed to inform policy decisions around nutrient losses and support the development and implementation of good management practice (GMP) to reduce risks.

Losses of N and P in drainage water from cropping systems depend on a range of factors including soil physical and chemical properties, site attributes (e.g. slope and surface hydrologic conditions), grower management practices (e.g. fertiliser use, irrigation, cover crops, cultivation techniques, crop sequences), crop uptake demands and weather conditions (especially rainfall). In previous studies under arable systems, measured N leaching losses have ranged from 35 to 110 kg N/ha/year (Adams & Pattinson 1985; Francis et al. 1994, 1995) and under vegetable production systems the measured losses have ranged from 63 to 292 kg/ha/year (Francis et al. 2003; Williams et al. 2003). In contrast with N losses, there is very little information on measured P leaching from these systems, the magnitude of which are likely to be closely linked to soil Olsen P levels and anion storage capacity (McDowell & Condron 2004).

Between August 2014 and May 2015 we established a network of passive-wick drainage fluxmeters (DFMs) on commercial cropping farms in the Canterbury, Manawatu, Hawke's Bay and Waikato/Auckland regions to directly quantify loads and concentrations of N and P in drainage water leaving the root zone. In this paper we summarise results from the twelve sites for the Year 1 (1 October 2014 to 30 September 2015) and Year 2 (1 October 2015 to 30 September 2016) monitoring periods.

Materials and Methods

Experimental design

The fluxmeter network includes four monitor regions, with three sites in each region and 12 DFM devices at each site. The four monitor regions are Canterbury, Manawatu, Hawke's Bay and Waikato/Auckland. All sites are located on commercial properties that were selected to provide a range of cropping systems, soil types, climatic conditions and management practices relevant to each region (Table 1). A summary of the crop rotations at each site from August 2014 to September 2016 is provided in Figure 1. A more detailed overview, including information on the installation process and design of the passive wick drainage fluxmeters (DFM) is provided in an earlier paper by Norris et al. (2016).

Measurements

Drainage sampling

Drainage samples were routinely collected from the fluxmeter units using a suction pump. A water balance model was used to assist in predicting the timing of sampling. At each sampling event, the volume of drainage was recorded and subsamples retained for analyses of inorganic N (nitrate-N and ammonium-N), dissolved reactive phosphorus (DRP) and total P.

Weather

Weather data for each site (daily and long term) were collated using data from the nearest NIWA climate station. Key observations included daily air temperature (minimum, mean and maximum), solar radiation, rainfall, vapour pressure and wind run.

Data validation

To verify that measured drainage volumes were realistic, a water balance model was used that accounted for daily rainfall, irrigation, crop water use and soil hydraulic properties.

Table 1. Summary of key farm and site characteristics for the twelve fluxmeter sites. MC-LG = mixed cropping and livestock grazing, MC = mixed cropping, IVP = intensive vegetable production.

Site	Region	System	Soil type	Irrigation system	Fluxmeter Installation date
1	Canterbury	MC-LG	Mayfield silt loam	Centre pivot	26 Aug 2014
2	Canterbury	MC-LG	Barhill silt loam	Gun	22 Sept 2014
3	Canterbury	MC-LG	Templeton silt loam	Roto-rainer	24 Sept 2014
4	Manawatu	IVP	Shannon silt loam	Lateral	20 Oct 2014
5	Manawatu	MC-LG	Pukepuke sandy loam	Centre pivot	29 Sept 2014
6	Manawatu	MC	Ohakune brown loam	Travelling	20 Apr 2015
7	Hawke’s Bay	MC-LG	Waimakariri silt loam	Centre pivot	8 Sept 2014
8	Hawke’s Bay	MC-LG	Waimakariri silt loam	Gun	2 Oct 2014
9	Hawke’s Bay	MC-LG	Takapau silt loam	Centre pivot	4 Sept 2014
10	Waikato	MC	Waihou silt loam	Centre pivot	13 May 2015
11	Auckland	IVP	Patumahoe clay loam	Gun/lateral	10 Mar 2015
12	Waikato[1]	IVP	Patumahoe clay loam	Gun	14 June 2016

[1] Site was originally installed on 7 April 2015 but due to flooding of the fluxmeter units was subsequently reinstalled to a more suitable location.

Results and discussion

Drainage volumes

Across 10 of the sites, measured drainage for the respective Year 1 (1 October 2014 to 30 September 2015) and Year 2 (1 October 2015 to 30 September 2016) monitoring periods ranged from 0 to 611 mm and from 0 to 411 mm (Figure 2). The wide range in drainage volumes reflected the variability in climate, management and soil characteristics at each site and for Year 1, the different length of monitoring between sites (five to twelve months depending on installation date; Table 1). At Sites 11 and 12 (both located on Patumahoe clay loams) captured volumes were not consistent with outputs from the soil water balance models used to validate drainage volumes. Additional analyses are underway at Site 11 to understand soil drainage dynamics and at Site 12 to more fully assess drainage volumes from a new site which was established in June 2016 (Table 1).

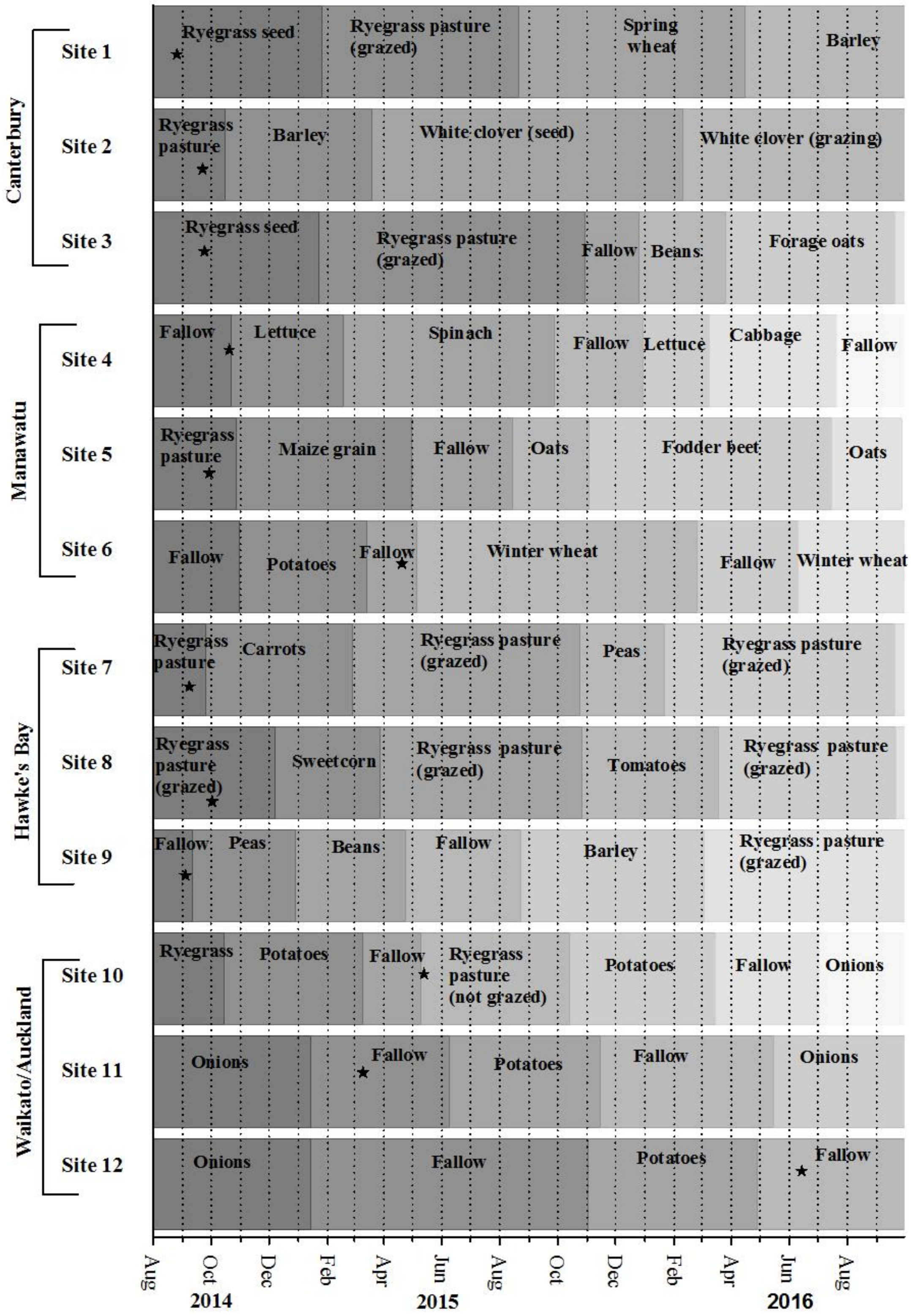

Figure 1. Crop sequences at the twelve experimental sites for the Year 1 (1 October 2014 to 30 September 2015) and Year 2 (1 October 2015 to 30 September 2016) monitoring periods. Fluxmeter installation dates (★) are shown for reference.

Over both the Year 1 and Year 2 monitoring periods, measured drainage volumes were consistently lower at the Canterbury (range was 1–101 mm) and Hawke's Bay (range was 0–66 mm) sites than the Manawatu (range was 196–611 mm) and Waikato (Range was 112–150 mm) sites. Regional differences in drainage volumes were consistent with rainfall patterns (generally lower on the eastern side of both islands in both years). At the Canterbury and Hawke's Bay sites, respective rainfall totals for the Year 1 and Year 2 monitoring periods were 20–36% and 9–19% below the long-term average for these regions. By comparison, rainfall at the Manawatu and Waikato/Auckland sites was higher than respective long-term averages (1–14%), except at Site 10 where rainfall totals over both years of monitoring were 7% below the annual long-term average (Figure 2).

At the majority of sites in both years, most drainage (84–100%) occurred during the winter and spring periods (June to November). However, at a few sites, drainage volumes over the summer and autumn periods (December to May) relative to total drainage were elevated including at Site 3 in Year 2 (85%), Site 4 in Year 1 (44%) and Site 5 in both Year 1 and Year 2 (48% and 37% respectively). Irrigation application volumes provided by the collaborating growers ranged from 22 mm to 450 mm in Year 1 and from 40 to 410 mm in Year 2 (Figure 2).

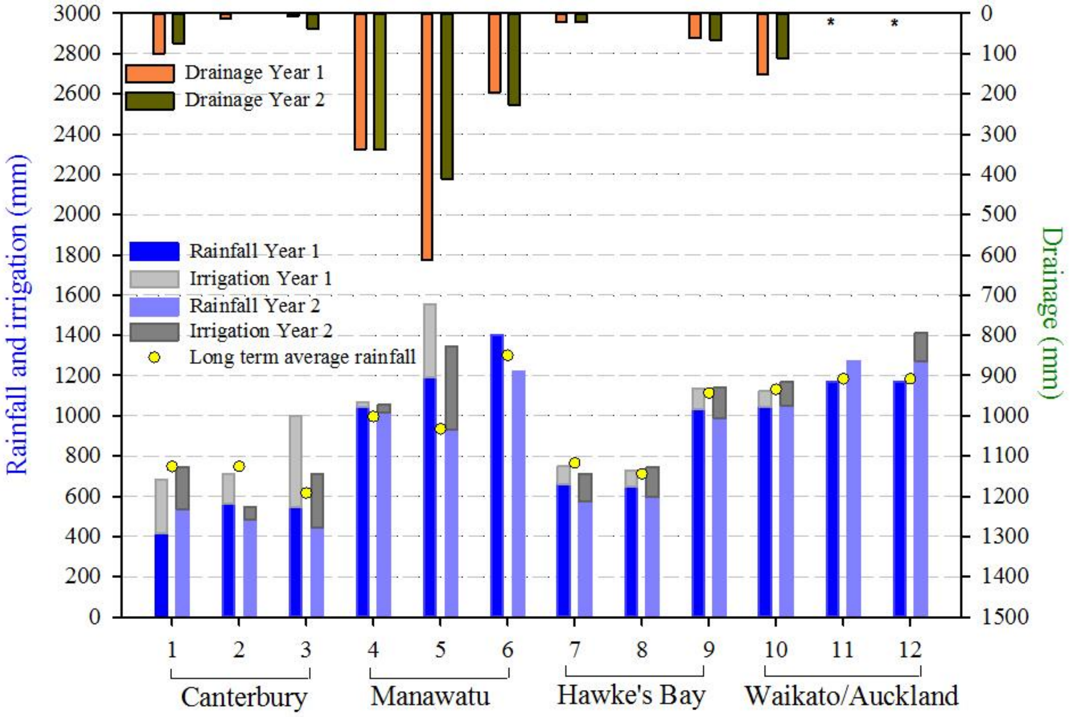

Figure 2. Rainfall (actual and long term average), irrigation and measured drainage at the twelve fluxmeter sites for the Year 1 (1 October 2014 to 30 September 2015) and Year 2 (1 October 2015 to 30 September 2016) monitoring periods. Fluxmeters were installed between August 2014 and May 2015. Updated drainage results from Sites 11 and 12 (*) are not presented.

Losses of N via drainage

Measured losses of mineral nitrogen (nitrate-N + ammonium-N) in the drainage water for the respective Year 1 and Year 2 monitoring periods ranged from 0.2 kg N/ha to 226 kg N/ha and from 0 to 118 kg N/ha (Figure 3). Across sites and years, 94% of mineral N losses occurred as nitrate-N. In Year 1, losses were less than 25 kg N/ha at five of the sites, between 25 and 50 kg N/ha at three sites and greater than 50 kg N/ha at two sites. By comparison, in Year 2 losses were less than 25 kg N/ha at seven sites, between 25 and 50 kg N/ha at one site and greater than 50 kg/ha at two sites. These losses were lower than or comparable with those observed in previous studies, which have ranged from 35 to 110 kg N/ha/year in arable systems (Adams & Pattinson 1985; Francis et al. 1994, 1995) and from 63 to 292 kg/ha/year in intensive vegetable production systems (Francis et al. 2003; Williams et al. 2003). N losses generally followed expected seasonal trends with the greatest loses occurring over the winter-spring period (Figure 3) as a consequence of increased drainage and high residual mineral N levels in the soil during this time.

Overall, Year 2 losses were lower or comparable with those observed in Year 1, despite the longer Year 2 monitoring durations for some of the sites (e.g. Sites 6 and 10; Table 1). The one exception was at Site 9 where losses increased from 7 kg N/ha in Year 1 to 17 kg N/ha in Year 2 due primarily to increased nitrate-N concentrations in drainage (Table 2). Similarly at Site 1 where nitrate-N concentrations were increased in Year 2, losses remained elevated (44 kg N/ha) despite 27% less drainage than Year 1. At Sites 2, 3, 7 and 8 drainage volumes were low over both years and consequently losses remained low (< 4 kg N/ha) while at Sites 4, 5, 6 and 10 lower Year 2 losses were related to a combination of less drainage and lower nitrate-N concentrations in drainage (Table 2).

Losses of P via drainage

Measured losses of total P in the drainage water ranged from 0.01 to 0.56 kg P/ha in Year 1 and from 0 to 0.27 kg P/ha in Year 2. Across sites and years, P was lost predominantly in the dissolved reactive form (61–92%), except at Site 9 where DRP accounted for an average of 46% of total P. On the whole, P losses over the two-year monitoring period were minimal in an agronomic context and similar to those reported under grassland systems (< 2 kg/ha/year; (Condron 2004; Houlbrooke et al. 2003; Toor et al. 2004). Year 1 losses were less than 0.10 kg P/ha at five sites, between 0.10 and 0.30 kg P/ha at three sites and greater than 0.30 kg P/ha at two sites, while in Year 2 total P losses were less than 0.10 kg P/ha at eight sites and between 0.10 and 0.30 kg P/ha at two sites. Low losses in drainage reflect primarily P retention by the soil matrix which, in arable and vegetable production contexts, may be increased by management practices such as cultivation (Dodd et al. 2014). Overland flow processes have the potential to make a greater contribution to P losses from these sites, but are beyond the scope of this study.

Across sites total P concentrations were highest in the three months following fluxmeter installation (up to 1.18 mg/L) and were consistent with disturbance of the soil profile and subsequently resettling effects. Over subsequent months, P concentrations were observed to decrease considerably, as did the concentration difference between total P and DRP indicating a reduction in the transfer of particulate forms of P (data not presented). The two exceptions were at Sites 3 and 7 where total P concentrations remained at elevated levels in Year 2 (Table 2). Initial observations indicate that P concentrations in drainage are related to soil P retention and Olsen P concentrations as demonstrated by McDowell and Condron (2004). In general average total P concentrations in drainage were lower at sites located on allophonic soils with high P retention (Sites 6, 9 and 10) than sites located on Pallic (e.g. Site 3) or Recent (e.g. Site 7) soils with low P retention or where soil Olsen P concentrations were high (e.g. Site 4). These relationships will be examined further as additional soil testing is carried out.

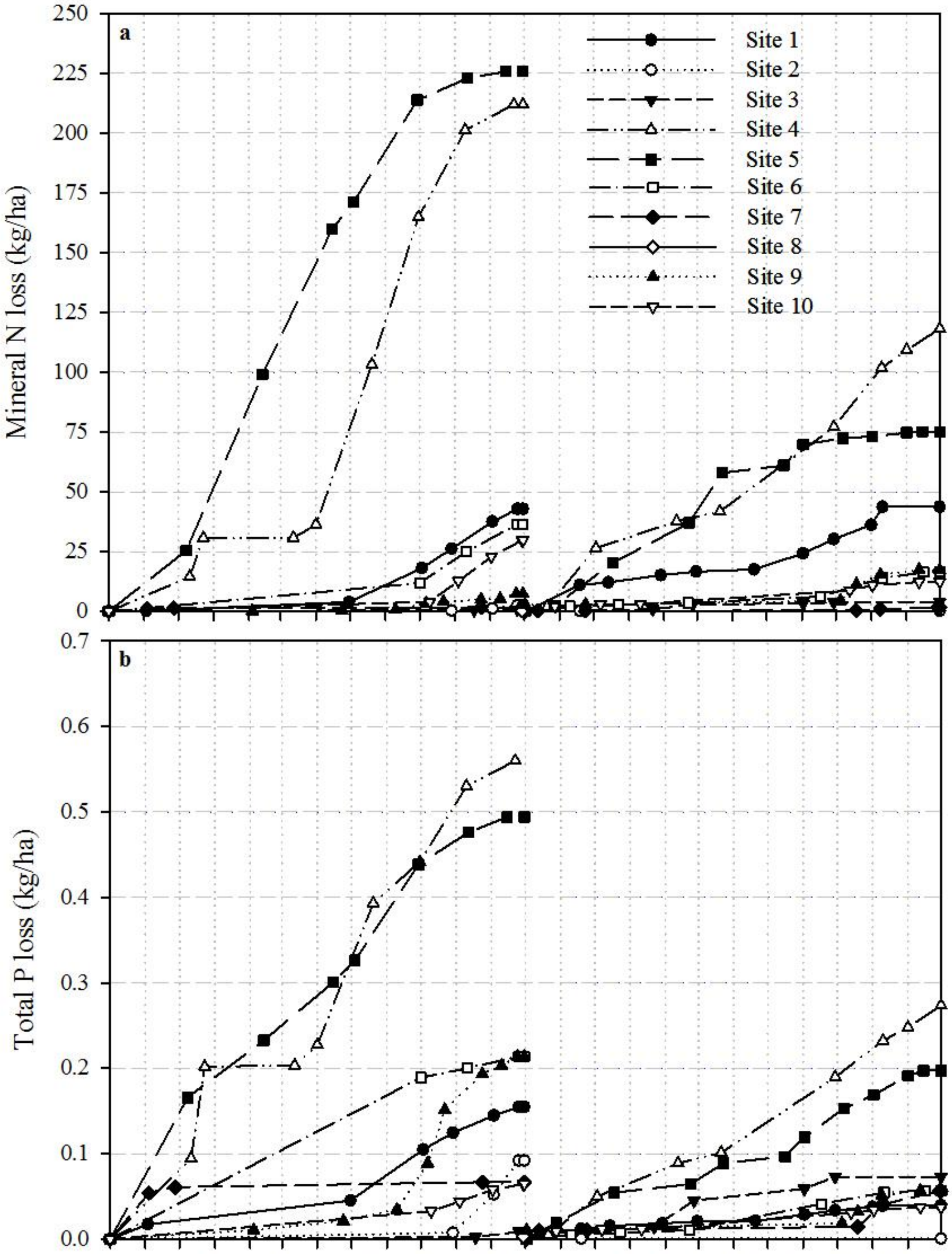

Figure 3. Measured (a) mineral N and (b) total P losses in drainage at fluxmeter Sites 1 to 10 for the Year 1 (1 October 2014 to 30 September 2015) and Year 2 (1 October 2015 to 30 September 2016) monitoring periods.

Table 2. Number of sampling events and average concentrations of nitrate-N and total P in fluxmeter drainage samples collected over the Year 1 (1 October 2014 to 30 September 2015) and Year 2 (1 October 2015 to 30 September 2016) monitoring periods.

Site	Region	Year 1			Year 2		
		Number of sampling events	Average Nitrate-N mg/L [1]	Average Total P mg/L [1]	Number of sampling events	Average Nitrate-N mg/L [1]	Average Total P mg/L [1]
1	Canterbury	6	26.2 (5.9 – 36.6)	0.39 (0.09 – 0.86)	9	43.4 (17.8 – 63.0)	0.06 (0.01 – 0.13)
2	Canterbury	3	22.3 (14.2 – 36.4)	0.96 (0.72 – 1.18)	1	18.6	0.30
3	Canterbury	2	7.8 (5.7 – 9.9)	0.22 (0.02 – 0.41)	4	10.5 (3.9 – 17.6)	0.20 (0.08 – 0.32)
4	Manawatu	8	49.9 (9.5 – 75.0)	0.29 (0.13 – 0.62)	8	37.7 (19.9 – 56.1)	0.14 (0.08 – 0.23)
5	Manawatu	7	33.7 (10.1 – 80.1)	0.14 (0.06 – 0.49)	10	27.6 (4.6 – 70.1)	0.06 (0.04 – 0.09)
6	Manawatu	3	17.5 (11.9 – 20.4)	0.11 (0.02 – 0.28)	6	8.3 (5.1 – 19.4)	0.03 (0.01 – 0.06)
7	Hawke’s Bay	3	4.2 (3.1 – 5.1)	0.22 (0.08 – 0.44)	5	12.3 (3.1 – 23.6)	0.38 (0.13 – 0.77)
8	Hawke’s Bay	1	21.5	0.38	0	–	–
9	Hawke’s Bay	8	9.5 (1.5 – 21.2)	0.43 (0.17 – 0.64)	6	21.7 (16.4 – 27.4)	0.10 (0.05 – 0.16)
10	Waikato	4	17.2 (15.9 – 19.1)	0.08 (0.02 – 0.20)	6	14.5 (10.4 – 18.2)	0.04 (0.01 – 0.10)

[1] The range of nutrient concentrations is presented in parenthesis.

Conclusions

The Rootzone Reality fluxmeter network has now been established for two years and is generating valuable data on N and P losses in drainage from cropping systems. Overall, losses have been lower than or comparable with those seen in previous studies and have occurred predominantly over the winter through to spring period when drainage volumes have been elevated. Initial observations indicate that concentrations of N in drainage are closely linked to soil mineral N content while drainage P concentration are related to a combination of soil Olsen P concentrations and anion storage capacity. Work is underway to explore the relationships between measured losses and site specific weather, soil and management factors now that several seasons of data have been collated.

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