Nitrogen budgeting for water quality improvement in pineapple production systems of south eastern Queensland, Australia.

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Abstract

The Glass House Mountains area was identified as a source of elevated nitrogen (N) which flows into the Pumicestone Passage and Moreton Bay. Elevated N causes decline in water quality and ecological function of these internationally important Ramsar wetlands, fisheries habitat, and recreational tourism natural amenities. Investigations into the origin of elevated aquatic N levels identified intensive horticultural activities were likely key contributors. A review of horticulture in the catchment was undertaken. The review determined that pineapple production systems in this area presented the largest opportunity for addressing aquatic N levels. Using a systems agronomy approach a partial N budget and review of nutrient management practices investigated nitrogen use efficiency (NUE). Findings identified N loading in waterways was impact by rainfall volume and frequency. Agronomic timing of N application to meet plant demand was imbalanced. Deep drainage is the predominant N loss pathway in major soil types of the catchment.

Keywords

Nitrogen use efficiency, deep drainage, farming systems, water quality, *Ananus comosus*

Introduction

The Coochin Creek and Back Creek catchments in the Beerwah – Glass House Mountains area have been identified as a source of elevated nitrogen (N) loads. The elevated N loads negatively impact upon the water quality of Pumicestone Passage and Moreton Bay (Wolkenhauer 2011). These freshwater catchments are tributaries of areas of high environmental significance. This includes internationally important Ramsar wetlands, vital fisheries habitat, and valuable recreational and tourism natural amenities.

Off-target movement of N from horticultural farming systems in the region were identified as a major contributor to the elevated N loads (Wolkenhauer 2011). An N budgeting approach was undertaken to understand the inputs and outputs of pineapple farming systems. Monitoring farming practices provided an understanding of how they influence nitrogen use efficiency (NUE). Farming practices with a high NUE maximise the profitability and sustainability of a farming enterprise while minimising ecologically harmful effects of elevated N in the waterways.

Findings identified include 1) deep drainage as predominant loss pathway in soil types studied. 2) Rainfall volume and frequency having major impacts on N loading to the environment. 3) Large applications of soil applied N have a very low NUE when applied to a young crop. 4) NUE varies with application method, timing, placement and nutrient form.

Methods

Site selection and crop details

Two trial sites were established at two sites near the township of Glass House Mountains, Qld adjacent to waterways identified in (Wolkenhauer 2011). Table 1 provides information relating to trial site and crop development at each site. Soil fertiliser inputs (shown in **Figure *3*** and **Figure *4***) were measured directly at application. Six drainage flux meters (DFMs) were installed on a transect at each site to capture leachate. At Pine1, DFMs were intentionally located on the upper slope of the block. At Pine2, DFMs were strategically placed along a ridge to optimise consistency of the soil profile.

Rainfall was monitored at Pine1 by a 6622AU Vantage Connect® wireless weather station maintained by a project collaborator. Pine2 was monitored by a Wild Eye brand rainfall gauge and Teros 10 brand soil moisture probe. Automated data logging and remote access supplied by Outpost Central Pty Ltd. The rain gauge measured in 0.2mm increments and the soil moisture probe was installed at a depth of 0.6m in the profile.

Table 1. Planting, crop timing and site details

	Pine1	**Pine2**
Planting Date	28th August 2017	20th September 2017
Target plants ha^{-1}	58,000	50,000
Bed spacing	1.22m centres	1.32m centres
Plant spacing	0.24m x 2 rows per bed	0.305m x 2 row per bed
First side-dress	1st December 2017	1st February 2017
Second side-dress	25th January 2018	4th April 2018
Induction	7th August 2018	14th February 2019
Harvest	14th March 2019	9th September 2019
Crop length	563 days	719 days
Soil type	Red kurosol	Red kandosol

Drainage flux meters

DFMs are used to capture and measure leachate and perform well in sandy soils (Gee, Newman et al. 2009). The DFMs were obtained from Tranzflo NZ Ltd based in Palmerston North, New Zealand. Figure 1 shows the specifications and installation prior to repacking. Leachate was collected by the wick at 0.6m depth indicating the base of the DFM was 1.5m below the bed surface and the top of the DFM was 0.45m below the bed surface. DFMs were installed in the middle of the growing bed. The augured hole and top 0.15m of DFM was repacked with depth appropriate soil and mimicked the target soil bulk density. Each DFM had 8mm diameter polyethylene tubing attached to the bottom of the DFM to allow the collection of leachate from the DFM via a vacuum air pump.

Soil characterisation

Soil characterisation of the two trial sites was undertaken. Characteristics such as landscape, profile morphology, basic field tests and laboratory mineral analysis were undertaken. Detailed methodology is described in (Walton and Finn 2020).

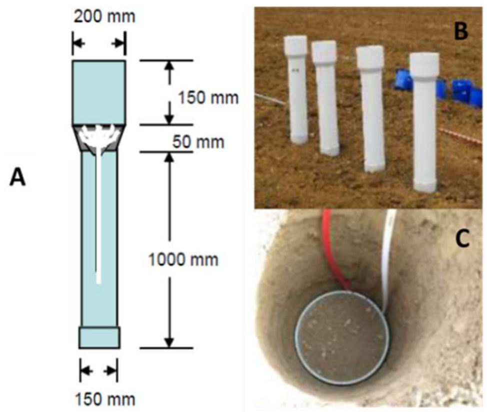

Figure 1: (A) Cross-section diagram of DFM. (B) DFMs in field prior to installation. (C) DFM installed prior to repacking augured hole.

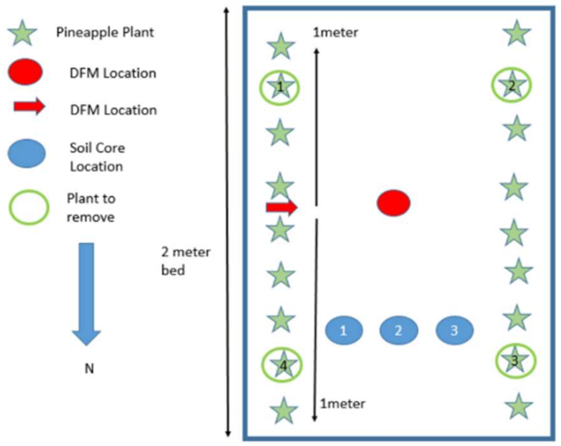

Figure 2: soil and plant collection at DFM

Sampling and analysis

Leachate samples were collected throughout the growing season post rainfall events. Collection generally occurred 2-5 days after rainfall events and volume from each drainage meter was recorded. The concentration of nitrate-N (NO_3^--N) and ammonium-N (NH_4^+-N) was measured. Testing was undertaken by Dr Fabio Manca from QUT. The samples were analysed using a Thermo-Fisher-Scientific Gallery™ Automated Photometric Analyser type 861.

Soil samples were collected at four separate occasions. Initially, at establishment of the trial, at the second fertiliser side-dress event, thirdly at floral induction, and finally immediately after harvest. Establishment and first sidedress were bulked samples from adjacent to the drainage meters. Induction and post harvest were taken as three soil cores, (see figure x), separated into three depths (0 - 0.3m, 0.3 - 0.6m, 0.6m - 0.8m). Samples were analysed at DES Chemistry Centre for total N in a Delta Advantage Isotope Ratio Mass Spectrometer made by Thermoline Scientific. This method was utilised as $^{15}N/^{14}N$ isotope work was undertaken as part of the project, but not presented here.

Whole plant samples were collected at induction and harvest. Pattern for induction collection shown in Figure 2. Plant samples were separated into leaf, stems and root, dried at 60°C for ten days. At harvest, fruit and clonal propagation plant material were grouped. DES Chemistry Centre destructed and analysed for total N in a Delta Advantage Isotope Ratio Mass Spectrometer made by Thermoline Scientific. Full methodology of sampling and analysis can be found in Abel et al. (2021).

Results

Soil characterisation

(Walton and Finn 2020) provide a detailed characterisation of the soil used for pineapple production in the Coochin Creek and Back Creek catchment area. Table 2 contains soil profile parameters for each site. Plant available water capacity (PAWC) is low to moderate for each of the sites. Pine1 for the 0.5m is 51mm and Pine2 is 53mm. At both sites the PAWC to 1m is 85mm and 1m is considered the effective rooting depth of pineapples. Both sites are moderately permeable with infiltration between 50-500mm / day. Pine1 is moderately well drained and Pine2 well drained.

Table 2: soil profile parameters

Site	Depth (m)	Coarse sand (%)	Fine sand (%)	Silt (%)	Clay (%)	Description	pH water	ECEC meq/100g
Pine1	0.00-0.20	38.1	48.7	6.3	9.6	Loamy sand	4	1.75
	0.20-0.45	32.8	35.3	6.3	28.2	Sandy light clay	4	2.79
	0.50-0.80	30.2	28.4	4.6	36.7	Light medium clay	4.1	3.1
	0.90-1.20	28.1	24.3	4.5	43.5	Light medium clay	5.1	2.89
Pine2	0.00-0.30	41.5	32	5.7	21.7	Sandy clay loam	4.2	1.96
	0.4-0.6	35.5	24.2	4.4	38.6	Clay loam	4.3	2.19
	0.70-1.00	36.6	24.6	4.4	36.9	Light clay	4.7	1.67

The soil type which characterises pineapple production is high permeability and low fertility. This has implications for the management of N fertilisers. Soil bound applications of N are susceptible to leaching losses, particularly in sustained periods of rainfall. Further evidence of this is the high concentrations of ammonium captured at Pine1 after the side-dress of 136 kg N ha^{-1} in the form of ammonium sulphate. The small cation exchange capacity was unable to retain the N, which was subsequently leached.

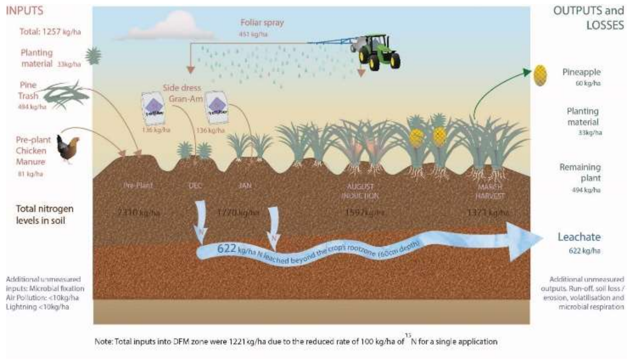

Figure 3: Pine1 inputs, outputs and losses

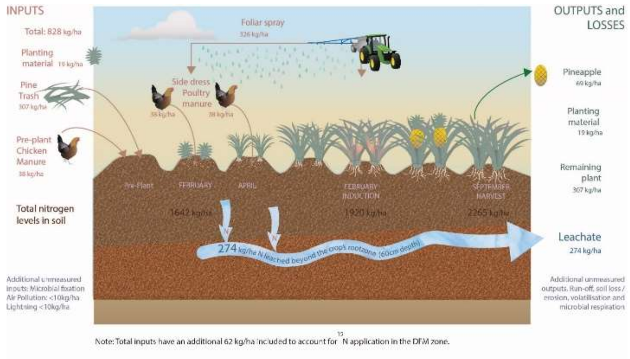

Figure 4: Pine2 inputs, outputs and losses

Pineapple plant development characteristics

From planting to induction the pineapple growth can be broken into two phases. Initially the establishment phase which is the two months posts planting, followed by the main growth phases from 3 months to induction (Sinclair 1993). The plant demand for nitrogen reflects the plant size and rate dry matter production until floral initiation. N demand in the establishment period and post induction is low. Dry matter production is greatest in the summer/autumn (0.40±0.32 g g^{-1} day^{-1}) and lowest in the winter/spring (0.08±0.12 g g^{-1} day^{-1})(Sinclair 1993). Current practice of high rates of N in pre-plant and side-dress applied to the soil does not reflect the match the agronomic demands of the pineapple plant. Figure 3 and Figure 4 show the timing of inputs in relation to crop growth for Pine1 and Pine2 respectively.

Nitrogen movement throughout the crop cycle

The main losses of N through leachate are at the beginning of the crop cycle as shown in Figure 5. This coincides with a period of low demand due to plant size and high application rates of N to the soil. Post canopy closure, pineapple crops are fed through broadacre boom spray of nutrients. Foliar application of nutrients in pineapples can match plant demand (Sanewski, Bartholomew et al. 2018) have likely have a high NUE due to the plant physiology. Post induction, during the wet season, N losses are negligible due to the primarily foliar program in the lead up to the wet season and the lack of N applications post induction.

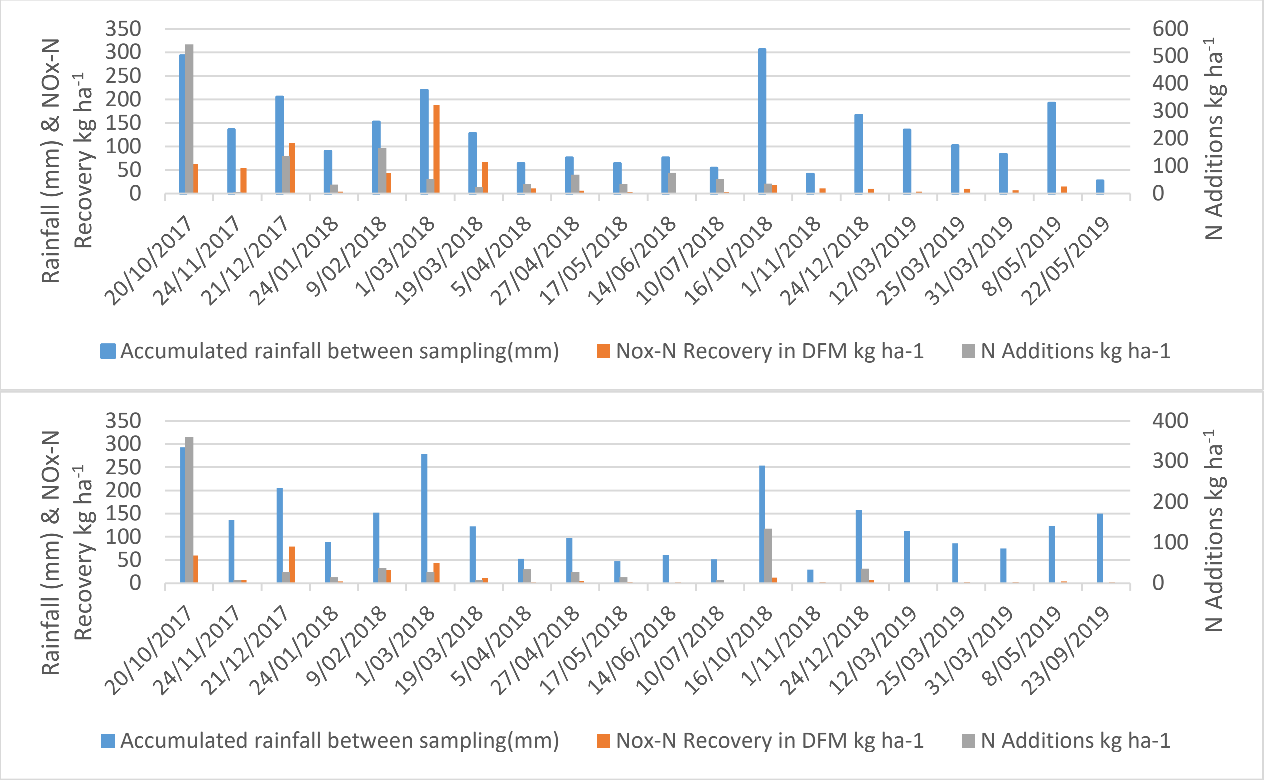

Figure 5: Pine1 (top) and Pine2 (bottom) measures of rainfall, NOx-N recovery and N additions

Conclusions

The main soil types present in the Pumicestone catchment have inherent low fertility and are susceptible to nutrient losses via leaching. N losses would be expected even under the most conservative of nutritional programs. The N budget was undertaken to improve understanding of soil nutrient dynamics relative to crop plant growth. Using a farming system approach in conjunction with the N budget and focus on NUE should improve overall agronomic performance and environmental outcomes.

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