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BORIS AND HIS FOUR FRIENDS' ADVENTURE TO PINEDALE: MEASURING NUTRIENT LOSSES FROM DAIRY FACTORY WASTEWATER APPLICATION ON LAND

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Introduction

It is widely documented that both nitrogen and phosphorus have been causing adverse effects on several New Zealand water bodies. Excessive quantities of either of these nutrients can lead to eutrophication (the nutrient enrichment of a water body resulting in excessive plant and algae growth). Nitrogen predominately enters water bodies through nitrate leaching down to soil profile and into ground water; while phosphorus is generally enters surface water bodies through surface runoff. Irrespective of how either nitrogen or phosphorus enters a water body they both play key roles in water quality degradation.

Fonterra Pinedale, an ex-forestry block has been under conversion for the past five years. As each rotation of mature pine trees is harvested these areas of land have been converted to a cropping system. The entire property is 1,250 ha of which 315 ha has been converted to a maize and ryegrass cut-and-carry system. Other areas of the property are solely ryegrass or legume crops while a large proportion of the property has been replanted in either pine trees or New Zealand native plants including manuka. Once land has been converted dairy factory waste products are now applied to that land.

Fonterra dairy factory waste products are applied to all ryegrass blocks at Pinedale at an annual nitrogen loading rate of 400 kg N/ha. Given the nature of this system - ex-forestry now a cut and carry system with a range of waste products being applied with varying composition - the Overseer model cannot realistically be expected to model nitrogen loss accurately. Therefore, a trial was established to measure leaching losses. A lysimeter trial has was installed on the property in May2018. Modifications to traditional lysimeters were required for the trial to function within a commercial farming situation.

Experimental Design

Site Description

Pinedale Fonterra is located in South Waikato with a Longitude: Latitude of -38.078810, 175.834721. The property has an average annual rainfall of 1,482 mm and an altitude of 210 m above sea level.

The soils on the property were mapped and identified as a mix of Horotiu and Te Kowhai soils. The split between the two soil types was approximately 90% of Horotiu to 10% Te Kowhai.

The Horotiu soils are free-draining, coarse-textured soils occurring in slightly elevated positions. They have deep, brown subsoils and exhibit the typical properties of volcanic loams and the phosphate-fixing clay, allophane, makes up around 10 percent of the B horizon. Their parent materials are coarse rhyolitic alluvium which are sufficiently weathered for them to exhibit the properties of volcanic loams.
The Te Kowhai soils are fine textured and poorly drained. Their parent materials are also rhyolitic alluvium but are finer and, being subject to high, fluctuating water tables, they have developed the pale grey subsoils and prominent mottles so characteristic of gleyed soils.

Trial site

A total of five lysimeters were fabricated and installed. All lysimeters were installed in Horotiu soils. At the time of installation, the site was coming out of maize crop and following installation ryegrass was sown.

Lysimeter Fabrication

Lysimeter design and fabrication followed the methodology of Lovett et al (2017). Each lysimeter was formed from 3 mm thick steel that was rolled and welded to produce a cylinder 700 mm high and 500 mm in diameter. A 95 mm wide circular plate was welded 100 mm below the top of the lysimeter to prevent soil consolidation around the outside of the lysimeter once installed. The ring was drilled with tapered holes to facilitate drainage. A sheet of 3 mm polyethylene plastic was cut, and plastic welded to produce a 400 mm deep x 500 mm wide riser. A steel clamp was fabricated from the 3 mm thick steel plate, and there was approximately 100 mm overlap of steel and polyethylene. The lysimeter base plate was manufactured to be slightly concave (c. 10 mm) to promote drainage from the lysimeter. Four steel rods (700 mm long with a 100 mm long threaded end) were provided to secure the base plate to the lysimeter casing following preparation of the lysimeter. Following fabrication, all lysimeter components were hot galvanised.

Collection and Installation Procedure

Lysimeter removal

The collection of the lysimeters involved placing the metal cylinder casing on the soil surface and digging around the outside edge. Each lysimeter was gradually pushed down the soil profile without disturbing the soil structure inside the casing. Each lysimeter was driven down until the upper lip was approximately 15 mm above ground level. Once the casing reached the desired depth of 100 cm, the soil monolith was cut at the base of the casing with a cutting frame driven by a 10 tonne Porta Power. The cutting plate was secured to the bottom of each lysimeter using four long metal rods. The lysimeters were lifted out of the collection site by attaching chains and lifting them out with a digger. Each lysimeter was inverted to allow for preparation of the soil base.

Lysimeter preparation

The cutting plate was removed and the soil at the base of the lysimeter were levelled off allowing the base plate to be secured without any gaps. Prior to securing the base plate, a circular layer of shade cloth was cut and placed on the soil base to stop fine material flowing from the lysimeter following installation. A 32 mm right-angle fitting, coupler and 15 mm reducer was attached to each of the base plates prior to securing the plate onto the lysimeter. All pipe fittings were wrapped with thread tape prior to attachment, and sufficiently tightened with an adjustable spanner. The lysimeter were inverted and carefully lowered onto a timber platform. The lysimeter column were then cleaned of all soil and solvents in preparation for sealing.

A Sika 291 marine sealant was applied sparingly and left to set overnight. The following day a 20 L bucket of Petroleum Jelly was heated on a gas burner. A hand pump with a copper nozzle was used to pump the heated petroleum jelly inside the lysimeter casing to seal any gaps between the steel casing and soil column to prevent edge-flow.

Installation of lysimeters

Each lysimeter was lifted using a digger. An approximately 1 m length of 15 mm diameter alkathene pipe was attached to the reducer at the base of the lysimeter. The lysimeters were lowered into the pit using a digger. Each lysimeter sat on a timber platform of 1.5 m long, 125 mm x 125 mm treated house piles. During preparation of the platform, particular care was taken to ensure that the house piles were level and at a height that would allow the lysimeter casing to sit flush with the ground surface.

Collection enclosures

A 10 L plastic container sat at the base of each collection pit and a 12 V vacuum pump was used to transfer leachate from the container to the grounds surface for measuring. To secure each collection pit, 1.2 m of PVC with a dimeter of 37.5 cm were used to hold the walls of the pit. Once buried, there was no easy access to the drainage collection containers. At the 30 cm depth mark, the 37.5 cm PVC casing stops and a cap with a hole in for tubing is to be placed on top of PVC. Flexible tubing travelled from the bottom on the 10 L collection container up through its lid top the top of the PVC cap. The tubing then went through the cap and travel to the soil surface. To prevent any soil contamination to the tubing, a second smaller PVC pipe encased the tubing from 30 cm to the soil surface. A cap was also placed on top of this second PVC pipe.

Infilling and site completion

Infilling of the excavated area around the lysimeters was undertaken using a digger. Particular care was taken to ensure that the lysimeters are packed into the surrounding soil. The soil was re-instated as close to natural profile as possible.

Leachate collection

Leachate collection occurred every seven days when drainage is occurring. During leachate collection, all leachate was removed from the collection containers using a vacuum pump and measured for total volume using a 5 L measuring jug. Subsamples of the leachate were taken using a 100 ml plastic bottle for sample analysis.

Sample analysis

After collection, all samples were couriered on the same day as collection to Hill Laboratories in Hamilton. If there was a delay in getting the samples couriered, they were kept refrigerated at 4° C. Each sample was analysed for NO_3^--N, NO_2^--N, TKN, DRP, and DOP.

Results

Rainfall at Pinedale

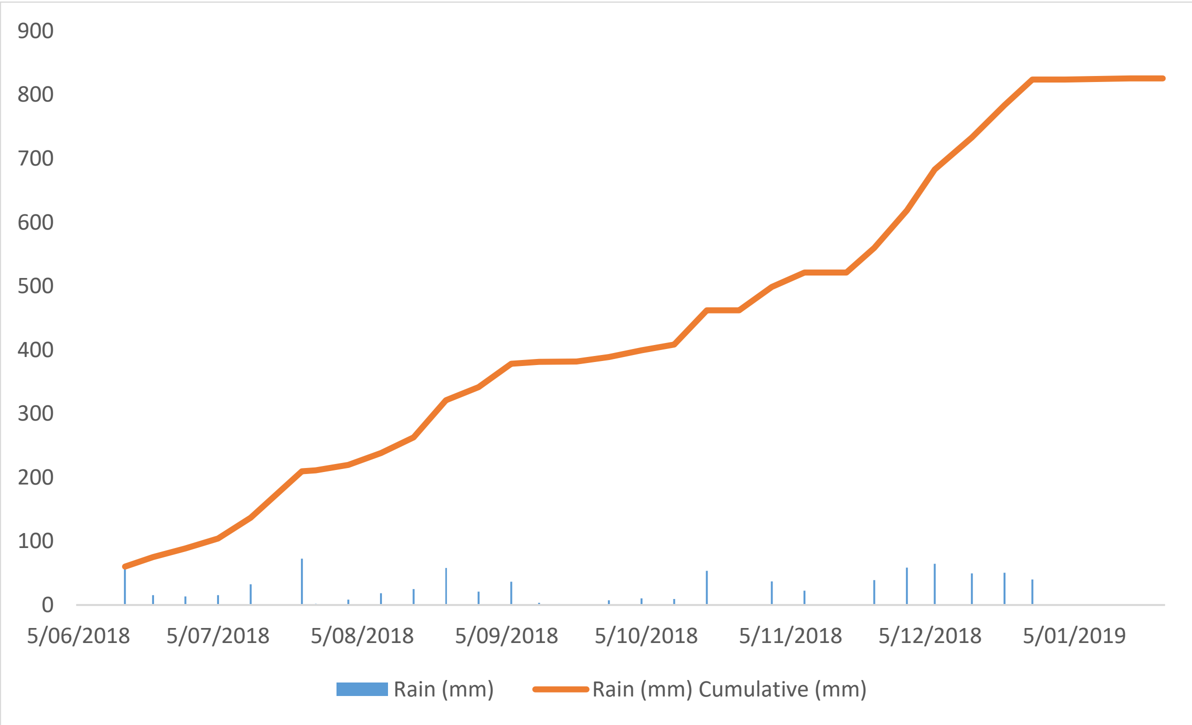

Figure 1 Rainfall per day and cumulative rainfall to date

Between the 1st of June 2018 and 31st January 2019, a total of 826 mm of rainfall was recorded at the on-farm weather station (Figure 1). For the months of September and October minimal rainfall occurred resulting in the lysimeters becoming dry and no drainage events occurred therefore no leachate collected. Rainfall occurred in late spring and early summer before the lysimeters drying up again in January 2019.

Loss of nitrogen through soil profile

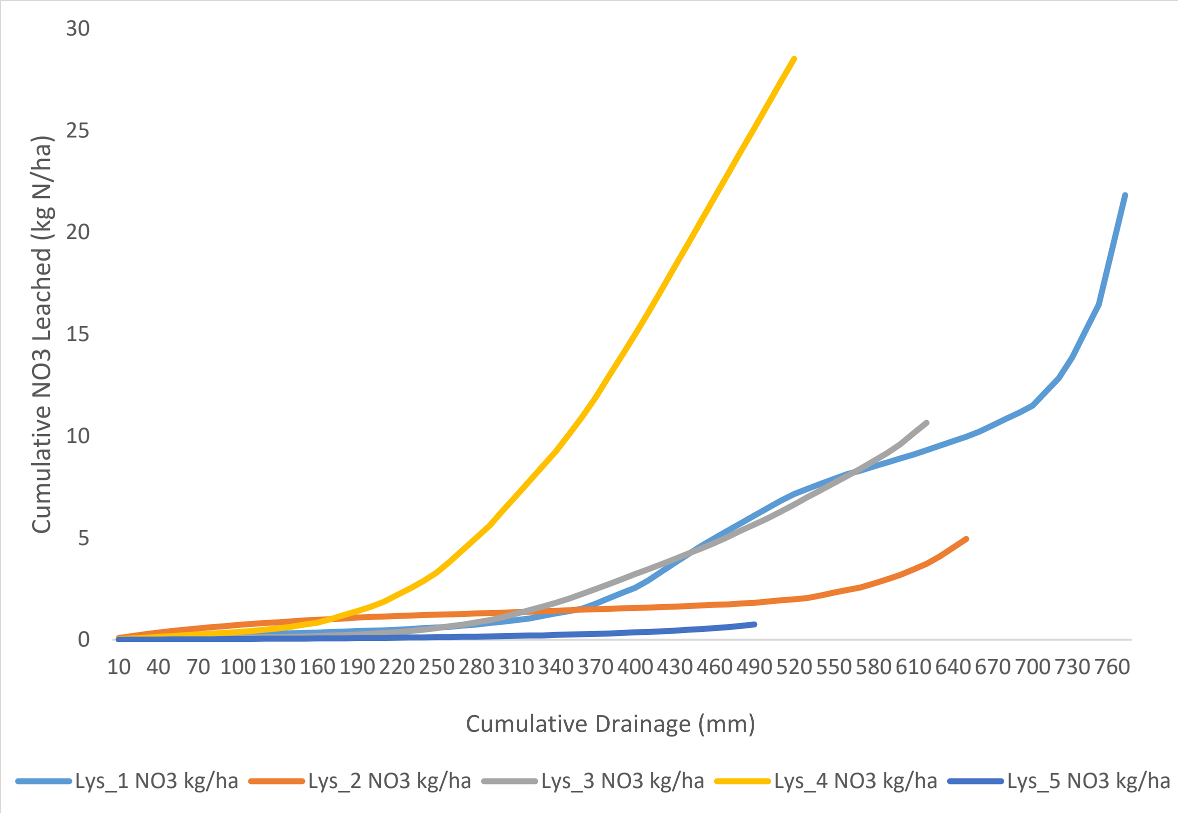

Figure 2 Total nitrogen leached to date

Total nitrogen leached ranged between 0.8 kg N/ha and 22.0 kg N/ha with the average concentration of 13.0 kg N/ha (Figure 2).

The average nitrogen loss per hectare is lower than expected to date because the project site has recently been developed from pine trees thus high mineralisation rates were expected. In addition, high nitrogen loading has occurred through factory waste being applied over the wet winter months. Even though ryegrass is present nitrate uptake between June to August is low due to slow plant growth rates over the winter period. Thus, high nitrate losses expected.

Issues to contend with

Taking a methodology which has traditionally only been used in a research setting and placing it into a commercial farming suitable creates several challenges. The greatest challenge being, being able to design a trial that fits within the farm's health and safety requirements. A key issue that was faced during trial design was that a large collection pit of 5 m x 5m could not be present within the paddock due to farm machinery driving the paddocks often. Thus, a redesign was required.

A second redesign was required due to the barrel lysimeters being a metal casing which sit within this soil profile. This is not suitable in a system where cultivation occurs twice a year. Therefore, the modified lysimeter design of Lovett et al 2017 was used. However, during lysimeter collection and installation it became apparent that the removable plastic top was not as functional as planned a and a redesign was required.

References

Lovett, A., Gordon D., Srinivasan, M.S., White, P. and Cook, R. (2017) Fabrication and installation of an arable lysimeter for measuring groundwater recharge in New Zealand. Gumpensteiner Lysimetertagung, 223 – 226