NITROGEN LEACHING FROM CUT-AND-CARRY LUCERNE

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Abstract
Water in Lake Taupō is deteriorating due to increasing nitrogen levels. To maintain water quality, the Waikato Regional Council's Regional Plan (which outlines the nitrogen discharge allowance for each farm in this region) has adopted a catchment-wide target of a 20% reduction in manageable-N entering the lake. The target is challenging and farmers are now looking for economically viable, low N-loss options for land use.

Overseer® V5 is the model used to obtain nitrogen discharge from farming platforms. When the N reduction target was established, however, Overseer® did not contain a module for cut-and-carry lucerne, in which the crop is not grazed on site but the herbage is cut and carried off site where it is subsequently fed to the animal. With published data for N-leaching under cut-and-carry lucerne ranging between 5 and 26 kg/N/ha/y, Waikato Regional Council set the N leaching under cut-and-carry lucerne at 19 kg/N/ha/y. This disadvantages uptake of this option and constrains use of lucerne if the actual leaching values are in fact lower. The relatively high N leaching value chosen by the Council reflected uncertainty both in the availability of data on N leaching under lucerne.

As a consequence, Lake Taupō Protection Trust is currently funding a 3-year trial on N-leaching under cut-and-carry lucerne. Since lucerne is a deep-rooting plant, leachate needs to be collected at a 1500 mm depth and the size of lucerne plants means large diameter barrels are required. Twelve barrel lysimeters (950 mm diameter × 1500 mm high) of intact soil were collected and installed around an underground collection facility. The lysimeters have 500-mm-long hanging fibreglass wick installed at the base of the soil to maintain a soil suction on the base of the lysimeter. The lysimeters were not grazed and therefore urine and dung returns are absent, and as clover and lucerne are legumes (fix nitrogen) no nitrogen fertiliser has been applied. For comparison purposes four replicates of ryegrass/clover were included and harvested on a similar rotation to a farm grazing rotation, while the eight replicates of lucerne were harvested at 10% flowering. Four of the lucerne replicates have been amended with biochar incorporated into the topsoil at a rate of 10 t/ha. Fertiliser (without nitrogen) is applied to all lysimeters based on soil and foliage tests. As expected, N leaching from the ryegrass/clover is low – less than about 5 kg/N/ha/y. As a result of cultivation, there was a spike in N leached under lucerne, which started and finished in the year following cultivation. Nitrogen leaching from the lucerne is now at a low and similar rate to that of the ryegrass/clover treatment.

Introduction

Water in Lake Taupo is deteriorating due to increasing N levels (approx. 1250 tonnes/yr). To maintain water quality, Waikato Regional Council has adopted a target of reducing manageable N entering the lake by 20%. Lake Taupo Protection Trust (LTPT) has a fund of $81M (including GST) to reduce manageable N from the Lake Taupo Catchment by 20% or

100 tonnes over the next 15 years. Much of the reduction is achieved by land purchase and resale for forestry, or low N land use. Ngati Tuwharetoa have also agreed not to develop large tracts of their land currently under native forest – which is a low-N discharge land use.

Modelling of farm economics indicates that farms could become uneconomic within 7 to 11 years if current management practices continue (M. Barton, Statement of Evidence to Environment Waikato, 2006). Cut-and-carry lucerne may be an economically viable, low-N loss agricultural option for land use. However, current predictions of N leaching losses for lucerne range between 5 and 26 kg/N/ha/y (Bergström 1987; Thorrold & Betteridge 2006). Due to this large range and uncertainty farmers cannot participate effectively in the nitrogen trading market, i.e. change farming operations to achieve accurate, quantifiable reductions and hence receive appropriate payments from the Lake Taupo Protection Trust. Nitrogen leaching losses from farming operations are calculated by LTPT using the Overseer® V5 model.

A trial measuring N leaching from cut-and-carry lucerne using suction cup lysimeters installed at a depth of 600 mm in Pumice Soils was conducted near Kuratau in the Taupo Catchment (Thorrold & Betteridge 2006). This trial reported N leaching losses of up to 26 kg/N/ha/y, though this included the pulse of N as a result of the cultivation associated with the planting of lucerne (S. Ledgard, AgResearch, pers. comm.). Additionally, up to 20 kg N/ha as fertiliser N was added to kick-start growth in spring. The aim of this study was to examine the economics of lucerne as an alternative crop rather than specifically determing N leaching under the crop.

Considering the range in N leaching values reported in the literature under lucerne, Waikato Regional Council set the N leaching value for lucerne under a cut-and-carry in the Lake Taupo catchment at 19 kg/N/ha/y, while acknowledging the need for further research.

To defensibly determine N leaching losses from lucerne, this work used large barrel lysimeters (950 mm diameter × 1500 mm high) with fibreglass wicks on the soil bases to providing a 500-mm hanging water column or –5 kPa tension. This tension overcomes saturation conditions at the base of the soil core, inducing possible anaerobic conditions and consequent N transformation and losses.

Methodology

Site and soil

The site is located approximately 6 km southeast of Tihoi on the western side of Lake Taupō at S38.66415 E175.74545, with elevation of approximately 560 m above sea level. Annual rainfall is approximately 1400 mm. The New Zealand Soil Classification (Hewitt 1992) of the soil is a Typic Orthic Pumice Soil with 700–900 mm of Taupo Pumice on older, finer, allophanic tephric soil material to at least 1500 mm.

Lysimeters and leachate analysis

Lysimeters were collected in autumn from a nearby farmed paddock grazed by non-lactating cattle. The ryegrass/clover paddock was grazed approximately 2 weeks before lysimeter collection.

The method for lysimeter collection has been described in detail elsewhere. Briefly, undisturbed barrel lysimeters (950 mm diameter × 1500 mm high) were hand carved in situ and the edges sealed with petroleum jelly at the soil-casing interface to prevent preferential flow (Cameron et al. 1992). Fibreglass wicks (Catalogue No. 1381, Pepperell Braiding Co., East Pepperell, MA, USA) were decontaminated by kiln drying at 400°C for 3 h (Knutson et al. 1993) then spread evenly and radially out on the lysimeter base and hung 50 cm below to provide a suction of –5 kPa to the bottom face of the soil. This suction was similar to that measured during late summer under adjacent field condition at soil depth of 1500 mm.

Wicks were placed at the base of the lysimeters to overcome the artefact of the free-water lower boundary at 1500 mm. Without wicks, soil at the base of the lysimeter becomes saturated, to overcome the air-entry potential, before drainge can occur at the base of the lysimeter. Without wicks, lysimeters also stop draining earlier than the in situ soil. This has the effect of underestimating leachate volume and is more apparent in fine-textured soils such as the allophanic soil material encountered on site. Furthermore, altered redox conditions at the base of the lysimeter may induce changes in N form and compromise data quality (Clothier et al. 2009).

The completed lysimeters (Fig. 1) were installed into the ground around a central collection facility where each lysimeters leachate is collected into a 200-L barrel. On an approximately monthly basis leachate volume from each lysimeter was measured, subsampled, and analysed for total nitrogen (Lachat Instruments, Milwaukee, WI, USA; 1998d Quik Chem Method 12-107-04-1-B). Total nitrogen concentration (mg/l) was converted to the leached mass (kg/ha/period) using the leachate volume and surface area of the lysimeter.

Stastical differences in total nitrogen leached between treatments was established using ANOVA (Genstat 14th ed.).

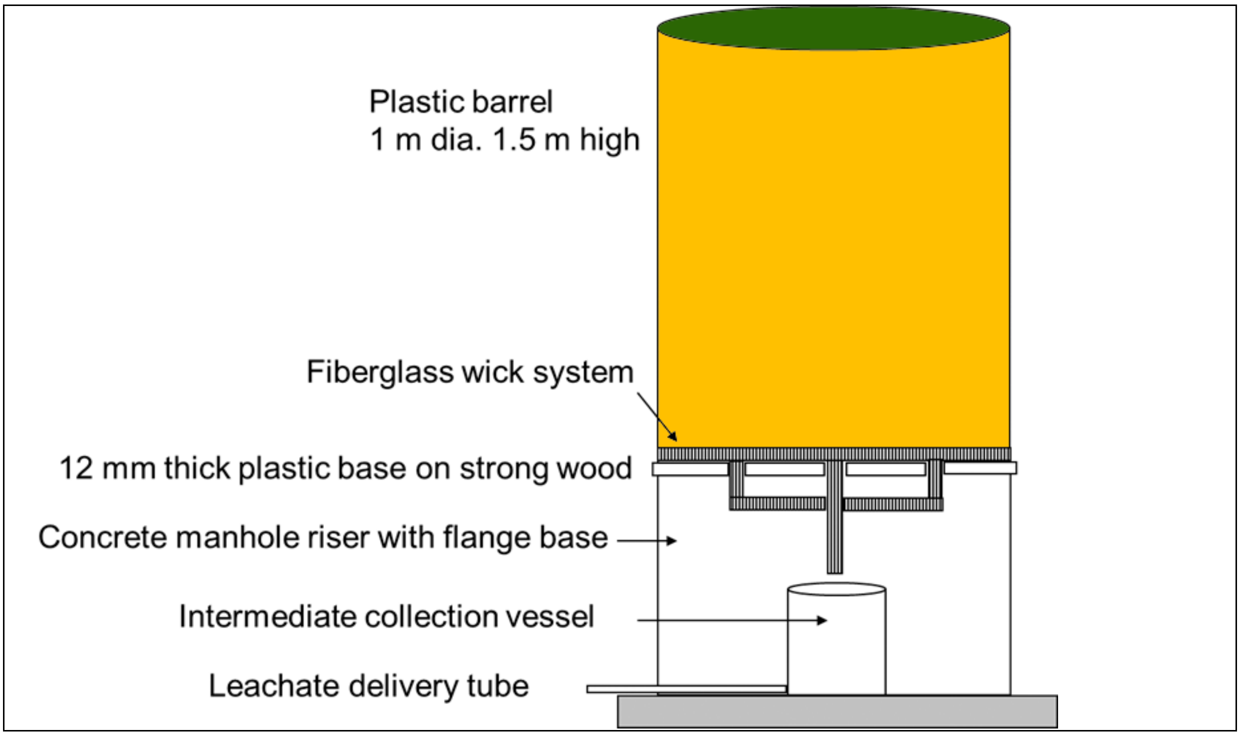

Figure 1. Layout of individual lysimeters.

Treatments
There were four replicates for each of the three treatments. The treatments were:

1. Ryegrass/clover. These lysimeters were not cultivated.
2. Lucerne. The lysimeters were sprayed with glyphosate, deep ripped to 500 mm, cultivated to 150 mm, and lucerne planted at a rate of 120 seeds per square metre.
3. Lucerne with biochar. The lysimeters were sprayed, cultivated, and planted in the same manner as the lucerne treatment but with biochar incorporated at a rate of 10 t/ha into the top 150 mm. The biochar was developed from *Pinus radiata* sawdust by Lakeland Steel Ltd, Rotorua.

Results and discussion
Cultivation of lysimeters to establish lucerne occurred in Spring 2011. Figure 2 shows the amount of total nitrogen leached from each treatment with measured drainage (mm). Error bars show standard error associated with each plotted value. Over four years lucerne has leached approximately 18 kg/N/ha while ryegrass clover has leached approximately 6.5 kg/N/ha.

There was no significant difference in N leached between the lucerne lysimeters with and without the addition of biochar. This could be because no nitrogen fertiliser or urine is being applied to the soil surface where biochar can possibly affect nitrogen dynamics and leaching. Since there was no significant difference between the two treatments, results from both lucerne treatments have been amalgamated.

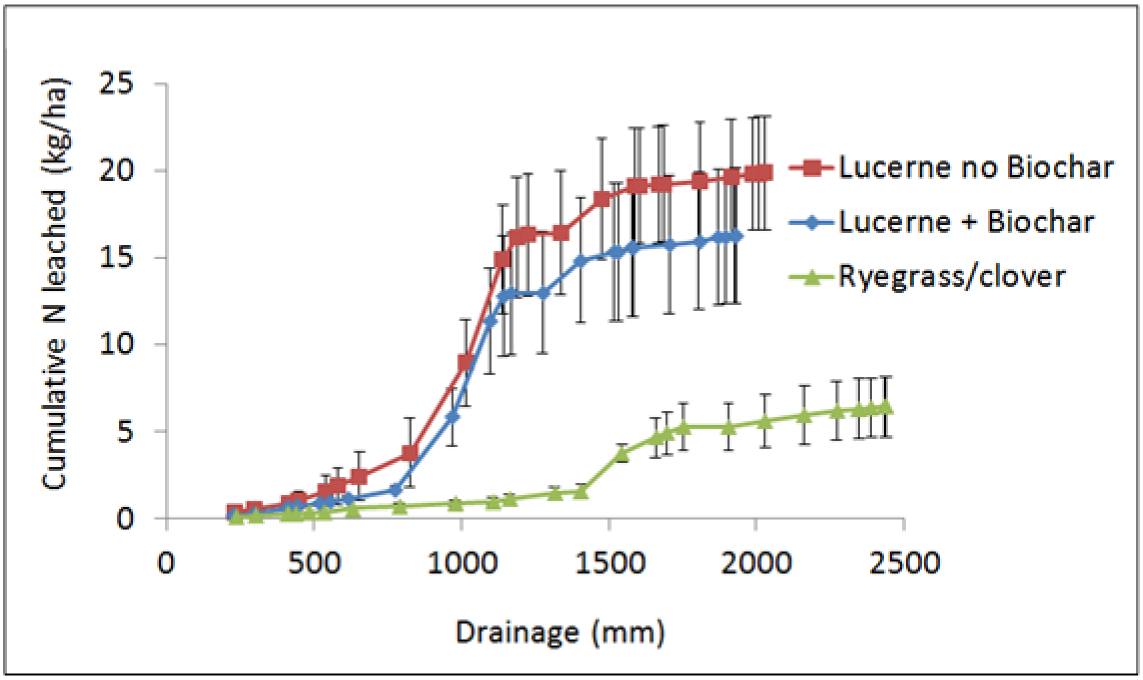

Figure 2. Cumulative nitrogen leached (kg N/ha) from lucerne ± biochar and ryegrass/clover lysimeters.

Figure 3 shows the amount of total N leached on a temporal basis, and annual amounts for the lucerne and ryegrass/clover treatments. L = lucerne, G = ryegrass/clover. Letters show significant differences in the treatments (*P*<0.005).

There was no significant difference between the amount of total N leached from lucerne or ryegrass/clover in Years 3 and 4 at less than about 5 kg/N/ha/y. However, over the four years lucerne leached significantly more total N than ryegrass/clover, but this is due to the spike in N leaching due to cultivation prior to sowing. The ryegrass/clover N leaching loss values are consistent with those reported by Shepherd (2009).

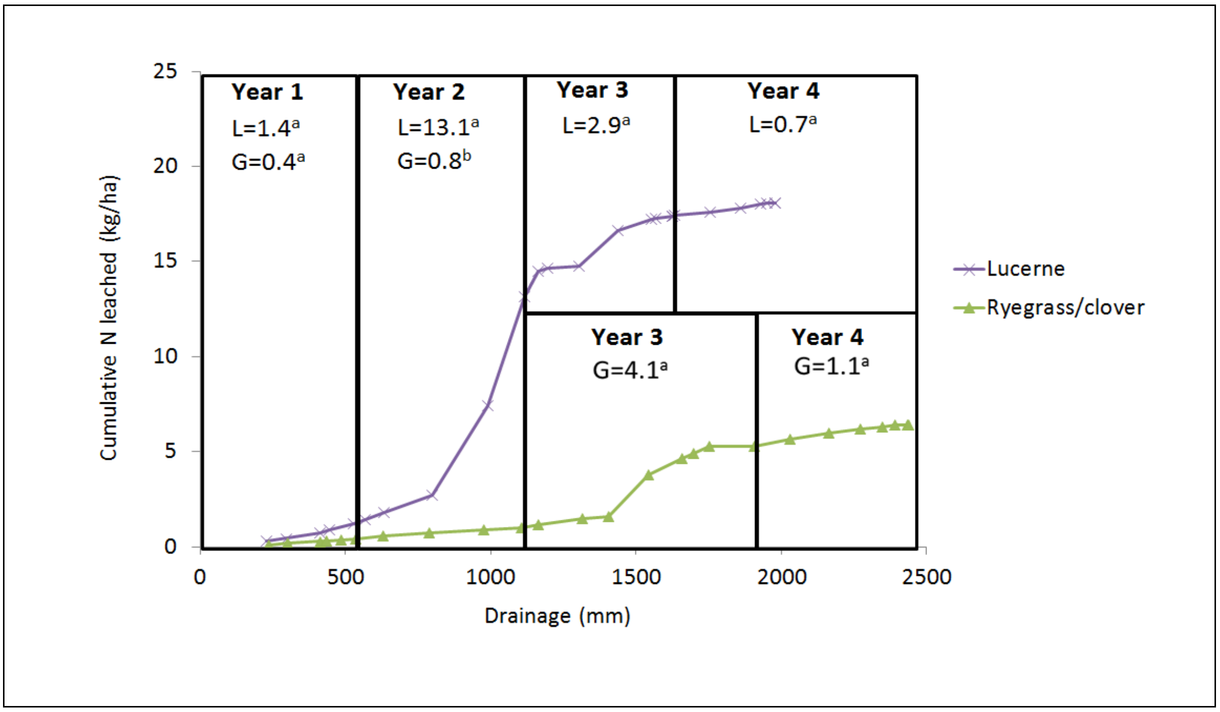

Figure 3. Cumulative nitrogen leached from lucerne and ryegrass/clover lysimeters in each year of the experiment. L = lucerne (combined ± biochar) , G = ryegrass/clover. Letters show significant differences in the treatments (*P*<0.005).

In Year 1 of the experiment there was no significant difference in total N leached between the lucerne and ryegrass/clover lysimeters, although in absolute terms the lucerne did leach more total N than the ryegrass/clover lysimeters.

Cultivation of the lucerne lysimeters produced a significant increase in N leached in Year 2, under both treatments, compared with the ryegrass/clover lysimeters that were not cultivated. The cultivation spike being measured at the base of the lysimeter at a depth of 1500 mm in Year 2 reflects the drainage volume needed for the leachate to move from the surface to the base of the lysimeter. The N spike was essentially confined to Year 2 of the experiment but elevated levels of total N were measured in the first sampling of Year 3.

Most of the N leached is as nitrate-N with very little ammonium-N (data not presented). This result is consistent with no stock urine or nitrogenous fertiliser being applied. Nitrogen is being supplied to the plants in the lysimeters by the nitrogen-fixing bacteria associated with clover and lucerne treatments.

Figure 3 also shows less drainage under the lucerne compared to ryegrass/clover. Although constrained by the volume of the lysimeters the lucerne crop has extracted more soil water than the ryegrass/clover. Similarly, Dunin et al. (2001) showed that, compared with wheat, lucerne removed an additional 125 mm soil water and attributed the greater uptake to greater root extension in the lucerne. While accepting greater soil water usage by lucerne compared with ryegrass/clover because of greater rooting depth, it is unknown how the lysimeter depth of 1500 mm constrains the rooting pattern and water uptake of lucerne.

Conclusions

After cultivation and establishment, there is no significant difference in the amount of total nitrogen leached by lucerne or by ryegrass/clover. On average this is less than about 5 kg N/ha/yr under a management system of no N fertiliser or urine applied and cut-and-carry. Cultivation can cause a one off spike of approximatley 10–15 kg N/ha.

Lucerne produced a lower volume of leachate than ryegrass/clover.

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