Why is it hard to measure N leaching on-farm?

Nutrient loss limits are being progressively implemented by regional councils at farm and catchment level. Farmers will need to consider how to change their farm system to meet these limits. The tool that regional councils are using to estimate Nitrate (N) leaching from farms is Overseer. However, Overseer is acknowledged to have drawbacks for this use. The two that stand out most for farmers are

- 30% variation in the estimates,
- that each new version changes a farm estimated leaching.

This has meant farmers do not trust Overseer and some are planning to measure their own N leaching to prove the environmental viability of their farming operations.

Before even considering this approach, a farmer should check with their regional council as the regulations as written may not allow for an alternative other than Overseer.

In order to get a more accurate estimate than Overseer, a sampling plan will need to account for on-farm variation in the forms of

- the randomness of urine patches,
- physical variation, (land slope, soil water holding capacity, infiltration and preferential flow),
- farm management practices (cultivation, irrigation, crop and grazing rotations),
- annual variation in climate,
- sources of nitrate from outside the farm boundary.

For an individual farm to address the above research has shown that an impractical number of samples will need to be taken over several years at a significant cost.

Common problems that sampling needs to overcome

The problem with measuring N leaching across a whole farm is that there is variation in space, time, on farm activities, annual climate variation, and N sources outside the farm boundaries.

The solution to this is to find a representative area on the farm to measure and then scale up to estimate the farm’s impact. This, of course, means a series of assumptions, which lowers the accuracy of what is being measured. In order to get a representative area, a farmer will need to think about urine patch randomness, physical variation and variation in farming operations.

Urine patch randomness

The urine patch is the biggest driver of N leaching. Leaching occurs when the urine patch has more N than the plant can take up before a drainage event (rain or irrigation) moves the N down through the soil profile until it is flushed into ground or surface water.

Cows deposit urine patches randomly and at different concentrations (500 to 100 kgN/ha), creating a random pattern within the paddock. Research shows an annual urine patch coverage of 20% to 30%. Sampling then needs to have enough sampling points to represent the number of urine patches and spaces between patches in the chosen area.

Physical variation

As soil type changes so do the characterises of the soils and the speed at which N may leach out of the soil. The speed of leaching is determined by

- how quickly water infiltrates the soil,
- soils ability to hold on to the water and
- the size of soil's drainage pores. tThe greater the size of the drainage pores the greater the speed at which N can bypass the bulk of the soil and root zone to groundwater. The majority of soils under flat to rolling land in New Zealand have potential for preferential flow.

Variation in farming operations

Changing the farming activities will impact on the N available to leach I.E.

- Cropping changes like moving from chicory to summer turnips
- Different types of irrigator vary the amount of water applied, and thus drainage. A single paddock with a centre pivot and a moveable sprinkler system has areas receiving greatly different water depths, at different timings, and at different intensities, meaning there may be no one point that is representative of the paddock as a whole.
- How many times are cows on the paddock and at what stocking rate (impacts on number of urine patches).

Annual climate variation

- Climate variability will impact on how much water drains through the soils and at what time of the year, resulting in variations between years of N leaching. For example, annual drainage from lysimeters at the Lincoln University Dairy Farm show drainage volumes have ranged from 50 to 600 mm/y, depending on winter rainfall.

Pros and Cons of different sampling methods for measuring N leaching under grazed systems

When measuring N leaching, researchers have primarily used suction cups, barrel lysimeters or mole and tile drainage to measure N in soil solute, and then calculate the amount leaching out of the soil. Other options for farmers are to measure the N concentration in surface and ground water.

An alternative method being used by researchers in the horticulture industry is drainage flux meters (not discussed in this document).

Accounting for variation in sampling design

Research from the Forages for Reduced Nitrate leaching project has modelled two of the most common research samplers (suction cups and barrel lysimeters) for measuring N leaching to see if they can be practically used on the farm as an alternative to estimates from Overseer.

The urine patch is the biggest driver of N leaching in a grazed paddock, it is also causes the greatest variability in estimating N leaching. A recent research project modelled four different sampling methods to see if accuracy greater than 20% could be achieved. Suction cups, barrel lysimeters, and liner lysimeters were modelled against, 1000, 3000 and 6000 annual urine patches per hectare. This document only reports on three of the results. For more information refer to Lilburne et al (2012).

The true result was 43.4 kg N/ha leached, at +/-20% the tolerance range is 34.7 to 52 kg N/Ha.

Table 1 shows that with 50 sampling devices per hectare, none of the samplers achieved the +/- 20% goal.

Table 1: Range of estimates of nitrate leached (kg N/ha), from 6000.

Sampler type	Range of estimates of nitrate leached (kg N/ ha)
Suction cup	23.8–86.9
20-cm lysimeter	23.8–87.0
50-cm lysimeter	25.7–77.9

Range of estimates of nitrate leached derived from 50 samplers

Therefore the question is to achieve an accuracy of +/- 20%, how many samplers would be needed per hectare to reduce the "failure rate" (number of samples outside +/- 20%). Lilburne et al. (2012) showed that even with 80 barrel lysimeters the poor interception of urine patches will mean that 23% of the time the estimate of leaching will not be within ±20% of the true value (Figure 1).

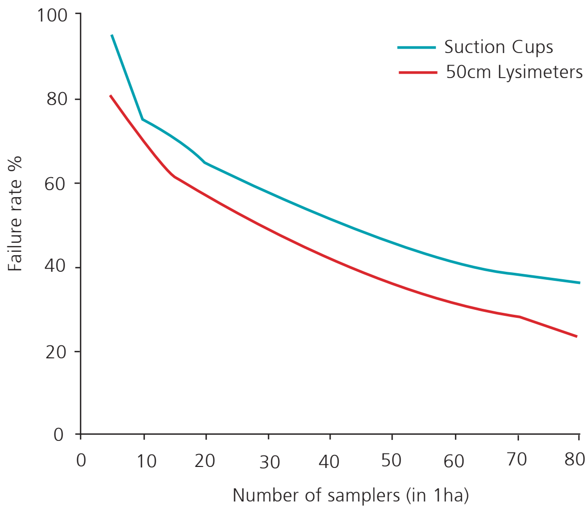

Figure 1 The accuracy of using suction cups or barrel lysimeters to measure nitrate leaching from urine patches on grazed pasture (redrawn from Lilburne et al. 2012). The failure rate is the percentage of times that the estimate of nitrate leaching fails to be within ±20% of the true value.

Pros and Cons of different samplers

Lysimeters

A lysimiter is a device for measuring the percolation of water through soils, and for determining the soluble constituents removed in the drainage. These can take many shapes and sizes. The most common research lysimeter in NZ is a barrel lysimeter, typically 50cm diameter by 70cm depth, though they can vary by 20cm to 120cm diameter by 120cm depth (figure 2). They normally contain an undisturbed soil monolith (slug) and can either be used in the ground within a paddock or, more commonly in research, they are in a pit and have N applied in concentrations similar to urinary N.

Figure 2 Research lysimeters Pastoral 21 research trial Ashley Dene near Lincoln

The pros of lysimeters are that they are large enough to account for soil pore variability, leachate can be measured from a known soil volume, and they control irrigation applications and exposure to ambient climate conditions.

The research drawbacks of lysimeters are that side walls can restrict lateral flow, they are not suitable for areas with high ground water table, and they can have a saturated zone at the base, if not used with suction, which can artificially reduce N leached through denitrification.

For measuring on-farm, the biggest drawback is that in order achieve robust data the number of lysimeters needs to account for urine patch, soil variation and farm management variation, increasing the number required. i.e. one hundred 50 cm barrel lysimeters installed in 1 ha paddock will only cover 2% of the paddock area.

Also, there may be a delay in getting all of the N through the lysimeter. Some of the experiments at Ashley Dene at 70cm depth from a urine application take about 350 – 500 mm of drainage for the pulse to come through.

Lysimeters are not cheap, with researchers indicating that the cost to install three 50-cm diameter lysimeters is $30,000, plus the ongoing cost of samples.

Suction cups

Suction cups are a cylindrical porous ceramic cup sealed to a tube, with a smaller tube inside to collect the soil solution. A hole slightly smaller than the diameter of the suction cup is made in the soil at a 45-degree angle down to 70cm, and the sampler inserted.

After each rain or irrigation event, the suction cup has a vacuum applied and water containing N is pulled out of the surrounding soil. A suction cup with a 0.05 m diameter will sample an area of 0.12m when vacuum is applied.

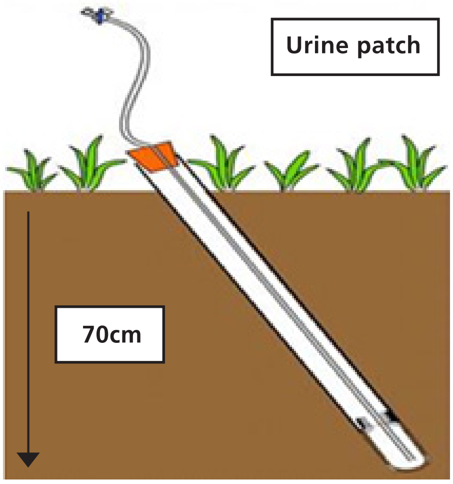

Figure 3 porous ceramic suction cup

The advantages of suction cups are that they are comparatively cheap and easy to install.

However, there are drawbacks:

- They have a small sampling area so can miss urine patches or areas of preferential flow.
- They don't work well in stony soils.
- They need to be emptied each time there is a drainage event, reported as 10 to 12 times in the Waikato
- Suction cups only measure leachate concentrations, not drainage. This means drainage will need to be measured (lysimeter) or estimated (mass balance calculations) to be able to calculate mass lost (kg ha) and then scaled up to a farm level.
- Cost is high. To get robust data the recommendation is to install approximately 100 cups per paddock at $300 a cup plus installation plus annual sampling costs. A researcher has estimated that the cost of monitoring a site with 60 suction cups per year is $50,000.

Mole and Tile drainage

This method is limited to soils with a hard subsoil pan and sufficient land slope for the drains to work well, both of which are uncommon in alluvial soils.

Other methods to measure N leaching under grazed systems

Another approach to measuring N leaching is to measure the receiving environment, ground water, and surface water.

These options are much cheaper with less capital outlay. The Southern Dairy Hub will undertake groundwater and surface water sampling. The cost to install a ground water well is approximately $300/m of 50mm uPVC, to a depth of 6m. Therefore, the cost per bore is $1,800. They will sample their surface and groundwater once quarter at a cost per site of $210.00 per sample X 4 samples = $840.

However, this type of sampling has its limitations.

Ground water

- Catchment effect: if an aquifer is big enough it may have several farms contributing to the N in the ground water, making it very difficult to separate one property's impact.
- Can you determine the flow direction of all of the groundwater entering the property, so only the farm's impact can be measured?
- Do you have areas of preferential flow occurring on the farm, and are the wells capturing this?
- Seasonal variation will have an impact on drainage and thus how much N is leaching into the groundwater, as shown in the lysimeter work at Lincoln University demonstration farm.

All of the above would mean that in order to prove farm's impact a significant number of bores and samples may be needed.

Surface water

- Source effect; can all sources be accounted for?
  - surface water entering the property from neighbours
  - groundwater flowing down gradient from the neighbours
  - some surface water is impacted due to upwelling from aquifers underneath the property
- To account for seasonal variation it is recommended that for surface water, 60 samples need to be taken over five years.