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# Guidelines on data collection from lysimeter and small plot experiments for evaluating OVERSEER nitrogen leaching estimates

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## Report prepared for OVERSEER Ltd

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# 1. Purpose

The OVERSEER Team receives many requests from researchers on what information would be useful to enable the use of that experiment for further development of OVERSEER. Therefore, the aim of these guidelines is to describe the information that would be required from such experiments to provide additional data for evaluating and developing the Background and Urine patch sub-models within OVERSEER. These data can be considered in terms of:

- Data that describes the experiment set-up and conditions to enable the experiment to be represented as accurately as possible by the model (e.g. climate and soils data) - inputs.
- The results that the experiment produces, e.g. measured N losses as affected by the experiment treatments (outputs) that can be used to compare with OVERSEER or aid its development.

# 2. Introduction

For pastoral systems, OVERSEER nitrogen (N) leaching estimates have generally been evaluated against measurements of N leaching in grazing experiments that represent the block-scale model within OVERSEER. During the development of OVERSEER Version 6, the calculation of N leaching was separated into urine patch and non-patch ('background') sources. This separation has allowed development of a 'Lysimeter' block in the development version of OVERSEER. The lysimeter block allows lysimeter and small plot experiments to be modelled. This allows these two sub-models to be evaluated against experimental data, other than grazing trials, i.e. using data from lysimeter or small-plot trials that represent separate components of the grazed paddock:

- The urine patch
- Between urine patches
- Either of the above when fertiliser or effluent are also applied

The lysimeter block allows experiments that use a single primary event to be entered into a development version of OVERSEER. This facility enables such data to be used to evaluate and develop the Background and Urine Patch sub-models.

## 2.1 What type of experiments?

Typically, these would be lysimeter or small plot experiments where a treatment is applied and the effect of that treatment measured over a defined time. The main driver for evaluation and development of these models would be the treatment effect on N leaching, but supporting information on other processes that compete with leaching (denitrification, volatilisation, and uptake) would be of value. Thus, lysimeter experiments or small plot (with porous cups or tile drains) are probably the most appropriate types of experiment. Note that larger scale grazing experiments (equivalent to block-scale OVERSEER) are not covered by this document[1]. Criteria for small plot experiments include:

- Event based (application of N source)
- Sufficient duration that the effect of the event can be estimated
- No grazing animals
- Sufficient background (Section 4.1) and experiment data collected (Section 5) to enable model evaluation.
- Initial focus on N leaching but processes that compete with leaching (denitrification, volatilisation, and uptake) would be of value, in conjunction with N leaching.

## 2.2 Recommended use of guidelines

These guidelines should be used at the outset to inform experiment design AND/OR for retrospectively packaging information after the experiment so that it could be useful to OVERSEER. It is best to engage with OVERSEER Limited at the earliest opportunity to discuss the data and how the researchers and OVERSEER team would work together.

## 2.3 OVERSEER involvement

To facilitate updates to the model, OVERSEER technical involvement is recommended at an early stage; contact science@overseer.org.nz

Our aim is to work collaboratively with data providers to build data sets that are able to test and develop the model. OVERSEER Limited operates a quality process that would require reference to data sources. The use of data and scope of any data sharing approach can be confirmed through written agreement.

OVERSEER Limited will support preliminary discussions between the OVERSEER team and data providers. However, sources of funding to facilitate detailed collaboration will need to be considered at the outset.

[1] These grazing experiments are of course essential for the evaluation of OVERSEER and data collection for these type of experiments will be covered in a later document.

# 3. Experiment design preferences

If designing a new experiment, the following inclusions would be of benefit for using the data to evaluate OVERSEER:

- If urine is applied,
  - Currently no preference whether natural or synthetic urine is used.
  - The rate of urine applied should be consistent with the experiment aims, and provided other data is supplied, would have little effect on the evaluation process. If in doubt, consider rates in the range 300-700 kg N/ha.
  - Nitrogen additions (fertiliser, effluent) on top of the urine: the additive effect of urine and fertiliser complicates interpretation, hence a non-N addition treatment must be included.
- Nitrogen additions in non-urine studies (fertiliser, effluent)
  - Use a rate consistent with the experiment aims.
  - Single or multiple applications over time can be modelled.
  - If slow release fertilisers are applied, then some detail on expected release rates would be beneficial.
  - If effluents are applied, then chemical composition should be defined (minimum: inorganic N ($NO_3$, $NH_4$, both required), total N as % DM, DM content (optional).
- No flood irrigation – less likely these days as this practice is becoming increasingly redundant.
- Inclusion of a nil-N control with experiments – because the model estimates net effects on the fate of urinary N (i.e. after subtracting control values)
- Data collection on a minimum of a monthly time step so that we can learn about the time course of N leaching or pasture N uptake as well as the total amounts

# 4. Data input fields to describe the experiment

This section describes the information about the experiment that need to be collected if the experiment and its data are to be of value for OVERSEER evaluation and/or calibration.

## 4.1 Description data

Table 1 summarises the data input fields that are available for describing the experiment – and that are therefore required as a part of the data package for evaluating OVERSEER. Many are the same as for the full OVERSEER model but a few are unique to the lysimeter/small plot sub-model (e.g. lysimeter depth). Most have been assessed as essential, a few fall into the category 'nice to have' but aren't essential.

***Table 1.*** *Input data fields available for data entry when evaluating the lysimeter/small plot scale facility within OVERSEER, and comments on which data are essential for using the data to evaluate OVERSEER.*

| Information | Need | Comments |
|---|---|---|
| **Site data** | | |
| Experiment location | Essential | Region/nearest town of experiment – helps set some of the default climate patterns. A GPS or map reference may be useful for upgrading future data sources. |
| Climate | Essential | The bare minimum is the annual rainfall for the experiment site, but preferably much more site specific detail can be provided. Further guidance on climate data input requirements is provided below. |
| Soil-type description | Essential | Different levels of input data can be used, varying in detail. Essentially, a reliable estimate of soil water holding characteristics is required and there are a number of ways that his information can be obtained – see detailed discussion below. |
| Pasture type | Essential | Currently assumes that the pasture is established, i.e. it does not account for establishment of the crop within the 12 month experiment period. |
| **Trial setup** | | |
| Depth of drainage measurement | Essential | Depth of lysimeters or porous cups: The model can cope with depths to 120 cm, although the default depth is 60 cm. |
| Rooting depth | Optional | This would be of use when evaluating new crops. |

| Information | Need | Comments |
|---|---|---|
| Date of start and end of experiment | Essential | Usually the month of the first treatment application. |
| Experiment pre-treatment | Essential | Not a data input field, but essential information to be able to best represent the experiment. Any information that might help understand the response of the site, e.g.:<br>• Wetting up the lysimeter: often done in practice e.g. to elute the profile, but not always recorded. This will start drainage earlier.<br>• Sward from where lysimeters were taken: years in dairying or drystock, etc.<br>• Whether re-sowing or cultivation has occurred. |
| **Material applied** | | |
| Urine N inputs | Essential | Rate (kg N/ha), month(s) applied and type (synthetic, natural). |
| Fertiliser N inputs | Essential | Rate (kg N/ha), month(s) applied and type (urea, DAP, etc.).<br>If slow release fertilisers are applied, then some detail on expected release rates would be beneficial. |
| Organic N inputs | Essential | Rate (kg N/ha), month(s) applied, type and chemical composition.<br>Chemical composition should be defined (minimum: inorganic N ($NO_3$, $NH_4$, both required), total N as % DM, DM content (optional). |
| Treatment water | Essential | Water applications (mm/month) associated with N applications, particularly effluent. |
| Irrigation | Essential | Amount (mm/month), application method and date applied.<br>Reason for application (e.g. to mimic rainfall, substitute as unusually dry year, or as a treatment).<br>N content in irrigation water. |

While most of the input fields are easy to understand, information is provided below on some of the challenges in setting up the model to best represent the experiment.

### 4.1.1 Climate data

There are a number of methods for inputting the climate data:

- Best option is the actual weather for the site by month: rainfall (mm), PET (mm) and average air temperature ($^0$C). For rainfall in particularly, it would be useful to collect data prior to the treatments been applied.

- Next option is monthly rainfall, and annual PET (mm) and average air temperature ($^0$C).
- Of less value is an annual rainfall (the minimum required) plus annual average air temp (optional) and annual PET (optional). This is of less value when trying to represent a single year because the default climate patterns that distribute annuals to monthly and daily values are based on long-term averages for the climate variables. These rarely fit accurately with a single (experiment) year.

It is desirable to have climate data for the 12 month period before start end of the experiment for the reason outlined in Section 6.

### 4.1.2 Soil-type data

There are a number of methods for entering a soil description within OVERSEER. For N leaching estimation, the main properties of interest are:

- Soil water characteristics (wilting point, field capacity and saturation) as this determines profile available water (PAW), an important as this drives the leaching model.
- Soil %N and %C
- Clay content (optional)
- General visual description – whether there are stony or sandy layers, degree of cracking or macropores, structure.

Apart from direct measurement of the soil properties during the experiment, the preferred option is the SMap sibling, which will then allow population of all of the above parameters within OVERSEER. However, these characteristics can also be estimated from OVERSEER databases using soil series, soil order or soil group, and soil descriptors (topsoil texture, depth to a non-standard layer – and what that layer is (stony, stony matrix, sandy)). In all cases, good measurements of drainage are essential to determine whether the soil properties descriptions are adequate for the site or soil in the lysimeter. In summary, the more detailed the soil data available for the experiment the better.

# 5. Experimental data outputs

This section describes the measurements that need to be considered at the outset if the experiment and its data, are to be of value to OVERSEER. Additionally, when providing data, the following would also be useful:

- Experiment type – Lysimeter or small plot. For small plot, plot size, collector method (ceramic cups, drains, isolated plots). If hydrologically isolated plots, estimate of drainage efficiency of the drainage system. For lysimeter: diameter
- Trial design - Description of trial design
- Any associated experiment report

Table 2 lists data that the experimenter might capture that would be of value for evaluating and developing the Background or Urine patch models within OVERSEER. Not all of these measurements might be captured in a single experiment but we have marked as 'Essential' those that are the minimum requirement for evaluating/developing the N leaching model.

***Table 2.*** *Experiment data that could be collected to aid evaluation of the OVERSEER Urine Patch or Background models.*

| Information | Need | Comments |
|---|---|---|
| Drainage with its monthly distribution (mm) | Essential | Key data for understanding the experiment and OVERSEER's performance against the data. |
| Inorganic N leached with its monthly distribution (kg N/ha) | Essential | Key data for understanding the experiment and OVERSEER's performance against the data. $NO_3^-$N plus $NH_4$-N. |
| Pasture DM production and N concentration | (Essential) | Used to estimate pasture net N uptake (kg N/ha). |
| Organic N leached (kg N/ha) | Optional | Currently not accounted for in OVERSEER due to insufficient information. |
| Other N loss pathways | Optional | kg N/month – $N_2O$, $N_2$ or $NH_3$ if available. |
| Soil moisture contents | Optional | Used to benchmark drainage model. |
| Soil N transformations | Optional | e.g. soil sampling of $NH_4$-N and $NO_3^-$N |

OVERSEER runs on a monthly time step so results need to be aggregated to a monthly basis, and by individual year for multi-year experiments (i.e. not averaged). This is particularly important for the N leaching data. In particular, we need to know if the profile was completely eluted in the drainage period, so providing concentration profiles plotted against cumulative drainage for each year of the experiment would be of great value. Similarly, cumulative N leached vs cumulative drainage allows us to assess if the OVERSEER description of the N leaching curve fits with measured: all aid the diagnostics of model performance.

Reported data should be for the duration of the experiment. OVERSEER estimates inorganic N leaching and data on organic N leaching would help us to extend the model.

For urine treatments, definitely in the 'nice to have' category would be soil sampling at regular intervals to measure soil $NH_4$-N and $NO_3$-N (say 3, 7, 15, 21, 30 days after application). This would give an indication of the initial losses, how fast $NH_4^+$ is nitrified and hence where we need to look at adjusting these in the model.

## 6. Matching experiment duration to the model time frame

This section briefly describes one of the main issues when setting up an OVERSEER file to represent a lysimeter/small plot experiment. The aim is to provide background and context. It is strongly recommended that an OVERSEER expert who is familiar with setting up these type of files is involved in file set-up and evaluation.

The major consideration is setting up a file so that the weather conditions before and during the experiment are accurately represented in OVERSEER. This is because OVERSEER operates on a 12 month cycle (Figure 1) and assumes a steady state (i.e. repeat treatments year on year). This has implications for entering some of the data to best represent a single experiment year and make a fair comparison with OVERSEER. Most critically, this relates to climate data.

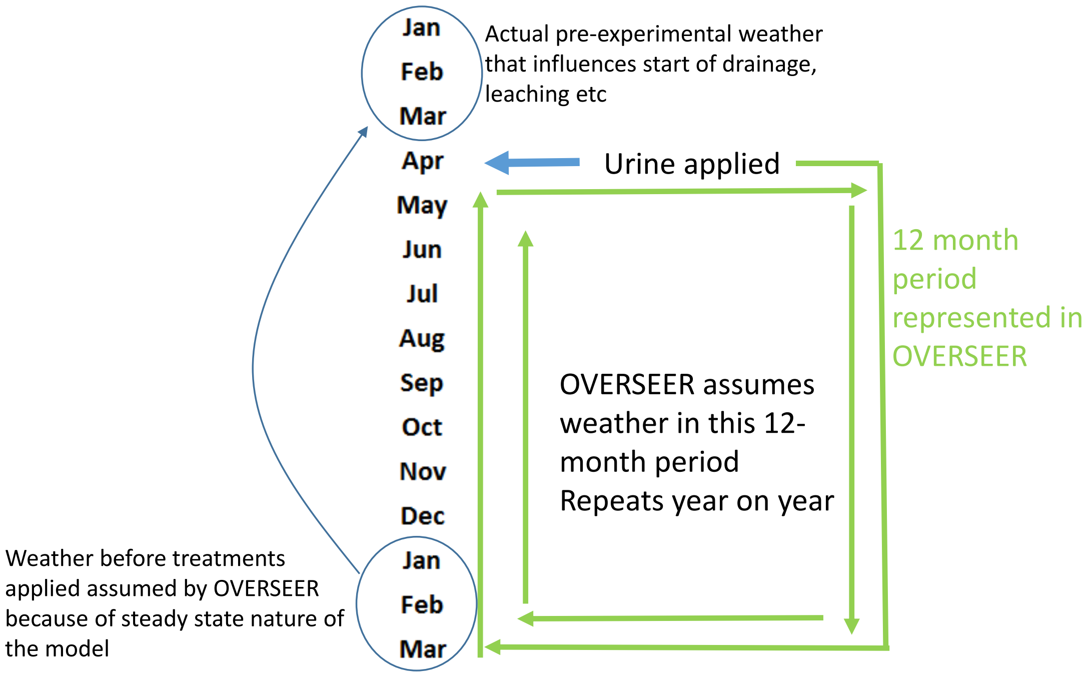


***Figure 1**. Diagram explaining the challenge in matching climate input data with a 12-month experiment to best represent reality. The OVERSEER assumption is that the 12 month Weather repeats year on year*

**Theoretical example of the importance of matching climate and experiment timescale:**

Treatments were applied in the lysimeter experiment in April: OVERSEER will model the period April-March. In the months preceding the experiment, January-March were exceptionally dry, which delayed the onset of drainage (and N leaching in the experiment until June). However, January-March at the end of the experiment were exceptionally wet. The OVERSEER model would use this wet January-March in its water balance calculation at the start of the experiment (assuming steady state); the result would be a calculated much earlier start to drainage than was measured. The water balance and N leaching models are not necessarily wrong because the cause could be an artefact of the mismatch between climate input and experiment period. There is no simple solution to this and it is best dealt with on a case-by-case basis by OVERSEER expert users. These issues require expert judgement when setting up the file, so the more information that is provided, the better – or expect a discussion with the OVERSEER team when they are setting up the model.