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Field Scale Simulation of Nitrogen Dynamics Using LEACHN and OVERSEER® Models

Babar Mahmood

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Abstract

Computer models have been used extensively to study the dynamics of nitrogen (N) at effluent-irrigated land treatment systems (LTS). Nitrogen version of leaching estimation and chemistry (LEACHN) model and OVERSEER® are two such models that have the ability to simulate N movement through the soil-water-plant system. This chapter covers brief description of two models, that is, LEACHN and OVERSEER® that were used in this study. This is the third phase of previously conducted studies, and the focus of this third phase was (i) to use the LEACHN model (as optimised based on best N transformation rate constants in a previous study) to simulate N dynamics (under different irrigation scenarios, that is, natural rainfall only, rainfall and irrigation with no N, and rainfall with irrigation containing N) for the medium effluent irrigation treatment plot at an existing land disposal site and (ii) to use another model (i.e., OVERSEER®) to simulate N movement at the same land disposal site and compare its prediction with LEACHN model's predictions (for the low effluent irrigation treatment at the site). This study showed that the LEACHN model has the ability to simulate the fate and transport of N (under different irrigation scenarios) at field scale level. Also, OVERSEER® model could be used to simulate N dynamics at an effluent-irrigated land disposal site. The amount of N leached as predicted by OVERSEER® was reasonably close to LEACHN model predictions.

Keywords: LEACHN model, OVERSEER® model, N dynamics at field scale level, nitrate-N leaching

1. Introduction

As we know that it is impractical to directly measure the nutrient losses to the environment and therefore simulation models could be the best alternative to assess the potential loss of nutrients to the local environment. Over the past decade, the development and use

of simulation models for predicting nutrient and pesticide behaviour in the root zone of agricultural land systems, and in the underlying unsaturated zone, have received considerable attention. The models currently available for predicting the fate and transpiration of pesticides and nutrients in soils and groundwater have been critically reviewed and used, among others [1–7].

Cichota and Snow [1] presented an overview of some models used for nutrient loss estimation at farm scale (including OVERSEER®, NPLAS—nitrogen and phosphorus load assessment system, SPASMO—soil-plant-atmosphere system model, EcoMod, LUCI—land use change and intensification, and APSIM—agricultural production systems simulator), and at large scales, that is, catchment level (including NLE—nitrogen leaching estimation, SPARROW—spatial referenced regression on watershed attributes, ROTAN—rotorua and taupo nitrogen, CLUES—catchment land use and environmental sustainability, and AquiferSim).

They [1] also reviewed some soil process models such as groundwater loading effects of agriculture systems (GLEAMS), Leaching Estimation and Chemistry Mode (LEACHM) and HYDRUS. In their review, they said that most of the models have shown their usefulness to estimate nutrient losses in order to prevent environmental impacts at a small or larger scale levels. However, there is a *lack* of information about how these models work and what is their main focus, and therefore, it is important to know the main purpose, strengths and weaknesses of a model (before it is used to perform any kind of simulation) so that the most appropriate model could be selected.

It is well known that the simulation models are useful to understand the interaction between the transformation and transport of N in the field. The growing concern about the environmental impact of effluent-irrigated systems has increased the desire to predict the transport and transformation of N in the soil-plant system more accurately. Several models simulating N transformations and transport in the soil-plant system have been developed and tested over time [2–4, 8–13]. Evaluating N transformation and transport models under field conditions is a complex research challenge. A major difficulty in evaluating these models under field conditions results from the strong interaction between physical and biological factors, plant uptake and N cycling processes.

In recent studies [14, 24], the nitrogen version of leaching estimation and chemistry (LEACHN) model was optimised and an in-depth analysis of changing the N transformation rate constants (i.e., mineralisation—K_{min} – day^{-1}, nitrification—K_{nit} – day^{-1} and denitrification—K_{den} – day^{-1}) and bulk density on LEACHN model predictions was undertaken. The in-depth analysis (based on N transformation rate constants) (i.e., second phase of the study) provided an in-depth understanding of movement and distribution of effluent N down the profile at the studied land disposal site. The testing of the parameterised/optimised LEACHN model (as part of second phase of the study) showed that this model had the ability to predict the timing and amount of leachate nitrate-N (NO_3-N) concentrations at an effluent disposal site. The work reported here (i.e., *third* phase) is the continuation of a previous study [14]. The key research *questions* were: (i) Is LEACHN model able to simulate N dynamics (under different irrigation scenarios) at a land disposal site and (ii) Is it possible to use OVERSEER® model to simulate N movement at a land disposal site? Therefore, the *main* focus of this chapter was to use LEACHN model

(as optimised using the best N transformation rate constant values in the previous study [14]) to refine our understanding of the predicted fate of N at the existing effluent-irrigated land treatment site under different irrigation scenarios. Also, it was decided to use another model (i.e., OVERSEER®) to simulate N dynamics for the same site and then compare its predictions with LEACHN model's predictions for one of the effluent irrigation treatments (i.e., the low effluent irrigation treatment for pasture plot was chosen). The details of optimisation of LEACHN model are not given here, and can be found in [14] as recently published. Thus, the specific objectives of this study were to (i) undertake irrigation scenario analysis (i.e., rainfall alone with no effluent irrigation, rainfall and irrigation of effluent containing no N, and rainfall and irrigation with effluent containing N) using the optimised model in order to understand the predicted fate of N added in effluent at a land disposal site and (ii) explore the use of OVERSEER® model at land treatment systems (LTS), and then compare its predictions of the amount of N leached and average NO_3-N concentrations with optimised LEACHN model predictions. As we know that the movement of N through the soil-water matrix is a very complex process. Therefore, in terms of novelty, the work presented here in this chapter refines our knowledge and understanding of N dynamics movement at a land treatment facility. This work explores and compares the abilities of two different models (i.e., LEACHN—a process-based models, and OVERSEER®—a farm management tool), which has not been undertaken earlier. Further, the testing of OVERSEER® model for a LTS was challenging and it was done in an innovative way as this model is not designed to predict N leaching at a LTS (refer to section 2.4).

2. Material and methods

As noted above, the work described in this study (i.e., *third* phase) covers two main areas.

1. To use the optimised LEACHN model to gain a greater understanding of the dynamics of N within an existing effluent-irrigated land disposal site in Carterton District Council (CDC) of Wellington region, New Zealand.

2. To use the OVERSEER® model to simulate N movement at the CDC land disposal site.

2.1. Model descriptions

2.1.1. LEACHN

LEACHN is the nitrogen version of the LEACHM model, which has evolved from modelling efforts in the last 20 years and has successfully been used by several workers to describe nitrate and pesticide movement in the field [4, 14–19, 24]. It is a research model that can be used for management purposes. There are five modules of LEACHM. One of these modules, LEACHN, describes nitrogen transport and transformation and that was optimised in the second phase [14] of the study. The details of other modules and the soil hydrological properties, interactions, transport and transformation of N in LEACHN are *not* provided here, as it is covered in more detail in the second phase of this study [14, 24].

2.1.2. OVERSEER®

OVERSEER®is a decision support system (DSS) farm model used by farmers, advisors and policy makers. It estimates the nutrient budget for a farm taking into account all inputs and outputs (including internal cycling of nutrients around the farm) to and from the farm. This model is widely used in New Zealand as a decision support tool by consultants and regional councils. This model was based on the knowledge obtained primarily from New Zealand and in consultation with farmers and consultants, and therefore, it is well suited for handling management practices and environmental conditions specific to New Zealand. Initially, this model was used to examine the impacts of land use and management practices on nutrient losses as a way of estimating fertiliser requirements, but recently the model has been used to monitor farm nutrient losses as a tool for applying new environmental policies [20].

OVERSEER®has proved to be a very useful tool to examine nutrient use and flows within a farm (i.e., as products, fertiliser, effluent, supplements or transfer by animals) and to assess nutrient use efficiency and environmental impacts at the farm scale. It is an empirical model (i.e., based on observations or experiments) and empirical relationships, internal databases and readily available data from existing farms are used by the model to calculate nutrient budgets at a farm scale level [20, 21]. The overall model contains separate sub-models dealing with pastoral, cropping and horticulture enterprises. Of these various sub-models, the pastoral model is probably the most *robust* because of the large quantity of trial data that is available in New Zealand on grazed pasture systems.

The model is designed so that the input data required is meaningful to farmers and is easily available. This is in contrast to LEACHN, which is a data hungry model. For reliable performance, OVERSEER® requires that reasonable input data are given [21]. This means that the amount of fertiliser required to support the given level of production needs to be known. The model assumes that the system is in equilibrium (i.e., model does not account for transition during a change from one practice to another). The OVERSEER®model is designed to predict long-term average behaviour of the system (as compared to LEACHN that can predict on a daily, weekly and monthly basis), and therefore, it is not suitable for extreme case scenarios or a system in transition, or for estimating nutrient losses from particular years.

In OVERSEER®,a *dairy* farm can be divided into blocks that can include effluent disposal and non-effluent disposal blocks. This provided the opportunity to assess whether the OVERSEER® model could be used to simulate N leaching losses at a LTS by assuming that it was operating as an effluent-irrigated block on a dairy farm. If the OVERSEER® model could be *used* at a LTS, this would have considerable advantages as many regional councils already understand and accept the principals and predictions from the OVERSEER®model.

2.2. Experimental site

A brief detail of experimental site is provided here. Further details can be found in Refs. [14, 15]. A diagram and the layout map of the existing CDC land disposal site are shown in **Figures 1** and **2**. The site was located close to the Carterton's wastewater land treatment facility. An irrigation system was designed to apply effluent at three rates, that is, 30 (Low),
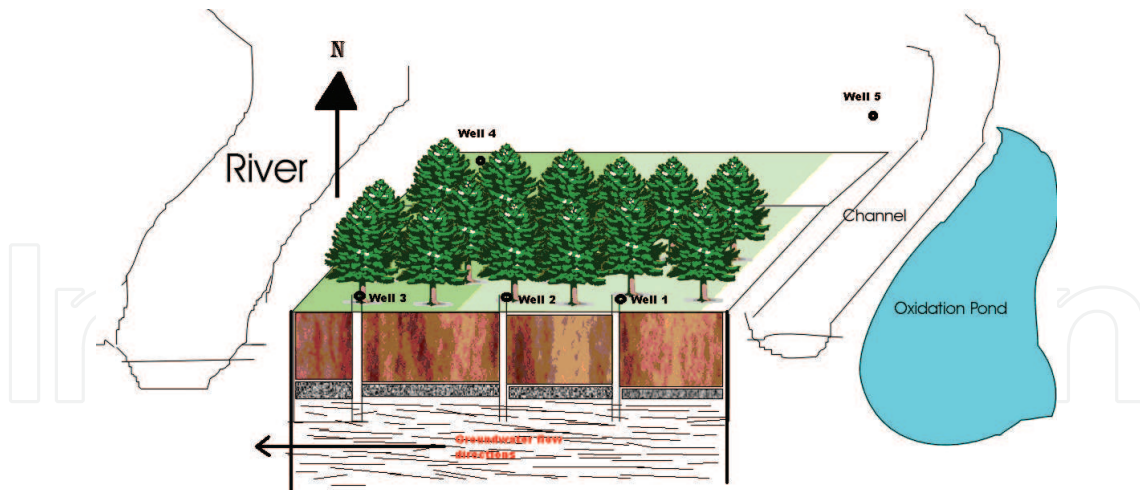
Figure 1. The CDC effluent-irrigated land disposal site.
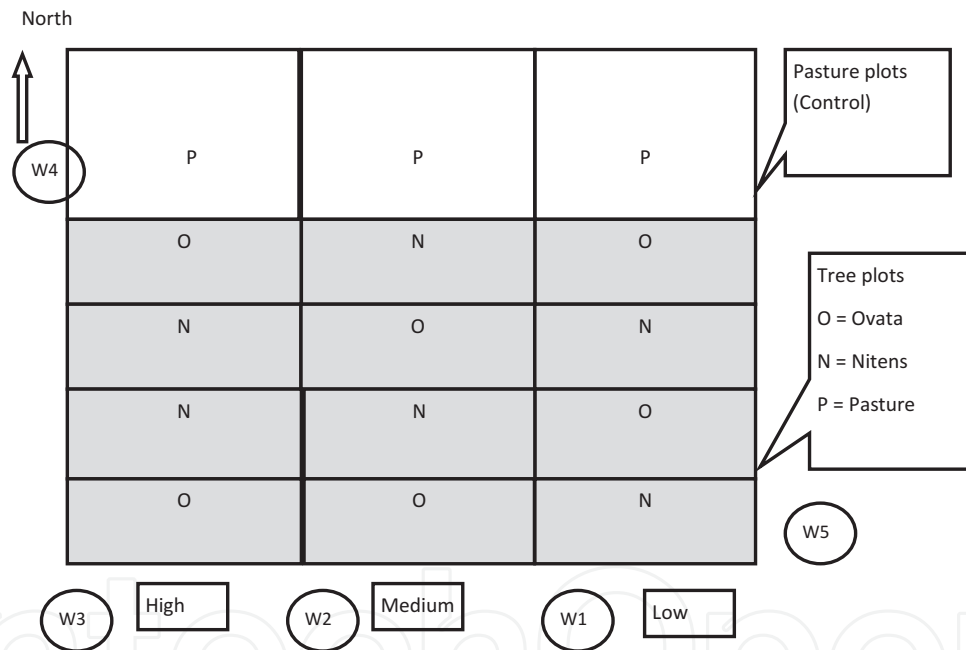

Figure 2. A layout map of the effluent-irrigated land treatment site planted with trees and pasture, showing low, medium and high irrigations areas, and the locations of monitoring wells (sourced from Ref. [14], and as modified from Refs. [15, 24]).

45 (Med) and 100 (High) mm per week. The site was planted with pasture and short rotation trees, that is, *Eucalyptus ovata* and *Eucalyptus nitens* (refer to **Figures 1** and **2**). The total study area was 540 m². There were three blocks (i.e., 180 m² per block) and each block has three plots (i.e., one control plot of pasture and two plots of randomly planted trees; **Figure 2**). The location of monitoring wells is also shown in **Figures 1** and **2**.

The experiment was conducted over the time period of 38 weeks (i.e., December 1997–August 1998). Soil moisture content (SMC) measurements were made using the time domain

reflectometry (TDR) machine (prior to irrigation and then fortnightly) at 0–150, 0–300, and 0–450 mm soil depths in all pasture and tree plots. Soil-water samples were collected using ceramic cups installed at 150, 300, and 450 mm depths before the first irrigation and then bi-weekly. The groundwater samples were also collected before starting effluent irrigation and then bi-weekly from the monitoring wells. All soil and water samples were analysed for NO_3-N and ammonium-N (NH_4-N) using the standard methods of water analysis [22]. Please *refer* to [14, 24] for more experimental details.

2.3. Use of the optimised LEACHN model to explore the effect of effluent irrigation on the dynamics of water and N at the CDC LTS

It was assumed that the values for K_{min}, K_{nit} and K_{den} (i.e., 0.02, 0.02 and 0.0000017 per day, respectively) *used* in the optimised LEACHN model [14] were adequate to describe the NO_3-N concentrations at the CDC's land disposal site. The optimised model was then used to investigate in more detail the effect of adding effluent to the soil at the land disposal site. The *medium* irrigation treatment of the tree plot (refer to **Figure 2**) was only used for this analysis, and this treatment was compared first with the model predictions of what would have occurred at the site under natural rainfall with no added effluent and second with the model predictions of what would have occurred if the medium irrigation strategy had been followed, but with pure water, rather than N-containing effluent. The chosen time period was 260 days (almost 38 weeks) to simulate N dynamics for the medium effluent irrigation treatment pasture plot at the land disposal site.

2.4. The ability of the OVERSEER® nutrient budget model to predict N dynamics at the CDC LTS

The OVERSEER® model was used to compare the amount of N applied and leached for the low application rate of effluent irrigation treatment on pasture plot (refer to **Figure 2**) at the CDC LTS. This part was interesting, innovative and bit *challenging* as the OVERSEER® model was not originally designed to predict N leaching from a LTS. But, as mentioned earlier that the OVERSEER® model does have the ability to simulate N leaching from effluent disposal areas on *dairy* farms. In doing this, the OVERSEER® model (version 6 that was used for the study) does not have a facility to enter the application rate of effluent N directly into the model. Instead, the OVERSEER® model calculates the application rate of effluent N from the number of dairy cows in the herd on the dairy farm and the area of the effluent disposal area. For a given number of cows, if the size of the effluent area is large, the application rate of effluent N per hectare will be low, and if the area of the effluent area is very small, then the application rate will be correspondingly high.

This feature of OVERSEER® provided the opportunity to use the model to simulate N leaching on an LTS (for the low effluent irrigation pasture plot) such as that at Carterton. This was done in the OVERSEER® model by setting up the CDC LTS as the effluent disposal block of a *notional* dairy farm. The notional "size" of the effluent block was adjusted so that the application rate of effluent organic N corresponded with the application rate of organic N in the low

irrigation treatment on the pasture plot at the CDC LTS. The reason for matching the application rates of organic N in this way is explained below.

Although by manipulating the size of the notional effluent area, it was possible in OVERSEER® to adjust the rate of N application on the effluent block to a value similar to that was applied at the land disposal site for the low effluent irrigation pasture plot, there are differences between farm dairy effluent (FDE) and municipal sewage effluent in the concentration of total N (which affects the amount of water added per kg of N) and the ratio of organic to inorganic N. Fortunately, the OVERSEER® model can account for these differences through its capacity to apply irrigation water containing inorganic N, as well as applying FDE.

FDE is more concentrated than the municipal sewage effluent at the CDC LTS. Its N concentration, on average, varies between 200 and 500 mg/L [23]. Also, it has been reported that organic N is the main component of total N in FDE (up to approximately 80% [23]). In this analysis, it was assumed that OVERSEER® would use an average total N concentration for FDE of 250 mg/L, of which 80% would be in organic form.

As noted above, the OVERSEER® model (version 6) has the capacity to specify an amount of irrigation on a monthly basis, and also to specify the nutrient concentration in that irrigation water. If a N concentration in the irrigation water is specified, the OVERSEER® model assumes that this N is in the inorganic form. By using this feature of the OVERSEER® model, it was possible to mimic the N application regime in the *low* effluent treatment at the CDC LTS exactly, in terms of the depth of water applied, the total N applied and the ratio of organic to inorganic N. This was done as follows:

1. The quantities of water, organic N and inorganic N applied in the low effluent treatment at the CDC LTS were calculated.

2. The application rate of FDE needed to apply the same amount of organic N as at the CDC LTS was then calculated (assuming that 80% of total N in FDE was organic N) and the "size" of the notional effluent area was adjusted so that quantity of organic N was being applied.

3. This application rate of FDE was then supplying the correct amount of organic N, but the quantities of water and inorganic N applied were much less than at the CDC LTS. These shortfalls were then added in the OVERSEER® model through irrigation.

4. The amount of additional irrigation water required to match the total water applied in the low effluent treatment at the CDC LTS was then calculated.

5. The inorganic N concentration in this irrigation water needed to ensure that the same quantities of inorganic N were applied as in the low effluent treatment at the CDC LTS was then calculated.

When setting up the notional effluent block in the OVERSEER® model, it was specified in the model that all the pasture grown on the effluent-irrigated block was taken off as supplements in order to mimic the "cut & carry" system at the CDC LTS.

The behaviour of N predicted by OVERSEER® for this farm scenario was then compared with the predictions of the LEACHN model. The annual rainfall data for the Carterton land treatment site were used in the scenarios.

3. Results and discussion

3.1. The ability of the LEACHN model to predict N dynamics at the CDC LTS

This study used the optimised LEACHN model to investigate the fate of the added water and N in the effluent at the CTC LTS (**Table 1**). The model predicted that under natural rainfall and with no effluent irrigation (Scenario S1 in **Table 1**), there would be very little accumulated leachate from day 1 to 196. However, there was some leaching from day 210 onwards (a total of 177 mm during winter). The predicted leachate NO_3-N concentrations were very low (<1 mg/L) and the cumulative mass of NO_3-N leached for this scenario was <1 kg/ha (**Figure 3**) for the simulation period (260 days). The reason for these low predicted NO_3-N concentrations in the drainage water is discussed later in this section. The predicted net N mineralised in scenario S1 was 6 kg/ha.

When LEACHN was used to simulate the addition of irrigation water containing no N at the medium effluent application rate (Scenario S2 in **Figure 3**), the irrigation caused drainage from day 28 onward (i.e., during summer). The accumulated drainage for scenario S2 was 1080 mm as compared to 177 mm for S1. The amount of water added (as rainfall and irrigation water) in scenario S2 was 2256 mm as compared to 681 mm added in scenario S1 as rainfall only. In Scenario S2, the predicted leachate NO_3-N concentrations were high (up to 32.0 mg/L) at the start of the drainage period but then dropped away to much lower concentrations (1 mg/L) towards the end of the simulation period (**Figure 3**). The cumulative mass of NO_3-N leached was 20 kg/ha (refer to **Tables 1** and **2**; **Figures 3** and **4**), and net N mineralised was 9 kg/ha (i.e., 3 kg/ha more than when no irrigation water was applied).

Irrigation scenarios	Cumulative mass of NO_3-N leached	Cumulative drainage	Net N mineralised
	(kg/ha)	(mm)	(kg/ha)
S1—Just rainfall and no effluent	<1	177	6
S2—Rainfall and effluent with no N	20	1080	9
S3—Rainfall and effluent with N	92	1080	9

Table 1. The amount drainage, NO_3-N leached, and net N mineralised in response to three different irrigation scenarios, as calculated by LEACHN.
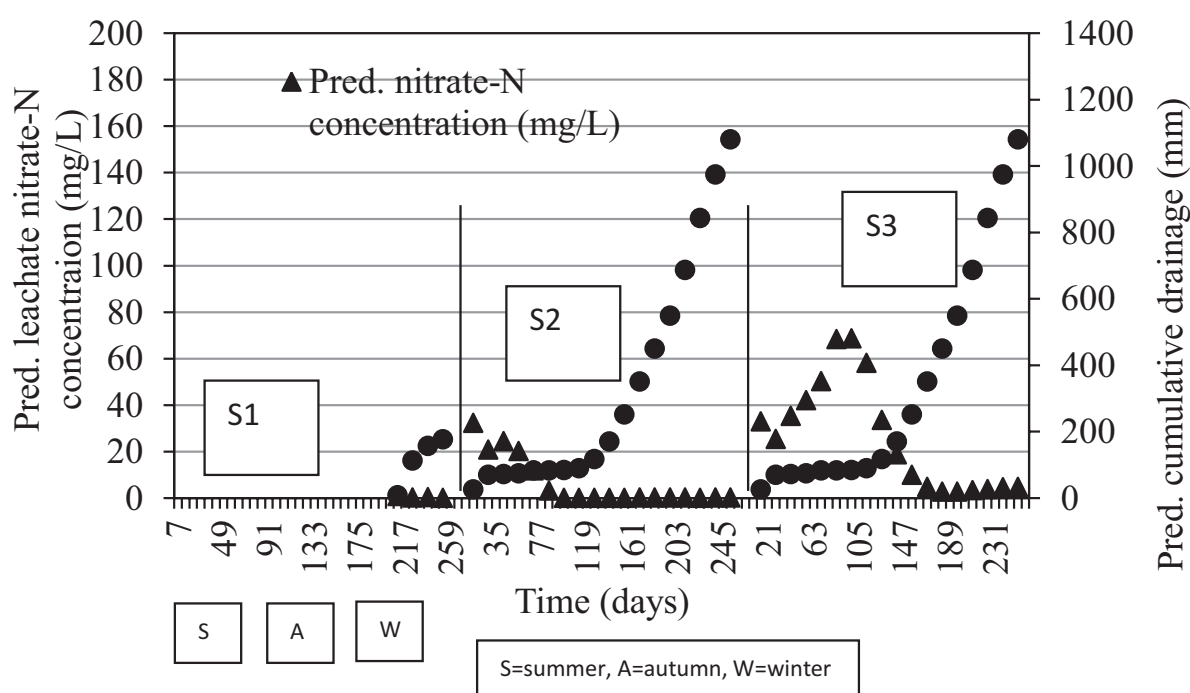
Figure 3. The predicted leachate NO_3-N concentrations and cumulative drainage volume for three irrigation scenarios (S1—rainfall alone and no effluent irrigation, S2—rainfall and irrigation with effluent containing no N, and S3—rainfall and irrigation with effluent that contains N) using the LEACHN model.

When the normal N-containing effluent was added (Scenario S3 in **Figure 3**) LEACHN predicted that the cumulative drainage would be 1080 mm (the same as in scenario S2). The NO_3-N concentrations at the commencement of drainage were similar to those at the start of scenario S2 (32 mg/L) but then increased to a maximum of 68.6 mg/L after about 90 days. From then on, the NO_3-N concentrations dropped steadily to a minimum value of 2.75 mg/L. The net N mineralised was the same as in scenario 2 (i.e., 9 kg/ha) but the cumulative mass of NO_3-N leached was greater (i.e., 92 kg/ha—**Tables 1** and **2**; **Figure 4**) than that in scenario 2 (20 kg/ha; **Figure 4**). The pattern of NO_3-N concentrations over time was reflected in the cumulative loads of NO_3-N which were similar to those in scenario S2 until about day 115. After this date, however, the cumulative load of leached NO_3-N in scenario S3 increased rapidly—presumably reflecting the arrival of the first of the effluent N at the drainage depth, that is, 500 mm.

Although LEACHN predicted that more NO_3-N would be leached in scenario S3 (92 kg/ha) than in scenario S2 (20 kg/ha), the difference (i.e., 72 kg/ha) was much less than the amount of N added in the effluent (184 kg/ha; **Table 2**). The net mineralisation was predicted to be the same in both scenarios and so the remainder of the added N was divided between increased volatilisation and plant uptake, and a greater amount of inorganic N remaining in the soil profile (**Table 2**).

The predicted differences in plant N uptake and soil mineral N concentrations are interesting. It is apparent from **Tables 2** and **3**, and **Figure 5** that the LEACHN model predicts that the quantities of inorganic N in the profile will decrease during the period of the simulation— particularly in scenarios S1 and S2. This is a result of plant uptake being greater than the

	Units	Irrigation scenarios		
		Rainfall alone (S1)	Rainfall and irrigation without N (S2)	Rainfall and effluent irrigation with N (S3)
Total N applied	(kg/ha)	0	0	184
Humus-N_i	(kg/ha)	17,922	17,922	17,922
Humus-N_f	(kg/ha)	17,916	17,913	17,913
Initial NH_4-N	(kg/ha)	19	19	19
Initial NO_3-N	(kg/ha)	31	31	31
NH_4-N in the soil profile	(kg/ha)	0.4	0.6	19
NO_3-N in the soil profile	(kg/ha)	0.00	0.05	5
NH_4-N leached	(kg/ha)	0.2	1	3
NO_3-N leached	(kg/ha)	<1	20	92
Plant uptake of NH_4-N	(kg/ha)	8	8	25
Plant uptake of NO_3-N	(kg/ha)	47	30	66
Volatilised	(kg/ha)	<1	<1	34
Denitrified	(kg/ha)	0.00	0.05	0.22
Cumulative leachate	(mm)	177	1080	1080

Table 2. A quantitative N balance for day 252 for three irrigation scenarios, as calculated by LEACHN.
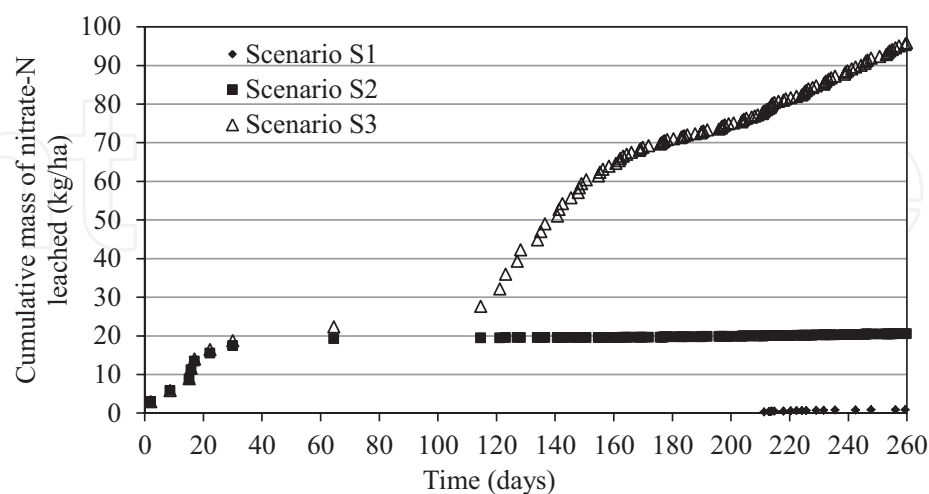

Figure 4. The cumulative mass of NO_3-N leached over the simulation time period of 260 days for the three irrigation scenarios.

Day no.	Soil depth	Soil NO$_3$-N for scenario S1	Soil NO$_3$-N for scenario S2	Soil NO$_3$-N for scenario S3
	(mm)	(mg/dm³)	(mg/dm³)	(mg/dm³)
0	100	6.63	6.63	6.63
	200	7.02	7.02	7.02
	300	5.31	5.31	5.31
	400	5.31	5.31	5.31
	500	7.03	7.03	7.03
56	100	1.44	0.12	4.16
	200	2.94	0.47	4.85
	300	4.97	1.50	6.56
	400	5.71	2.94	7.90
	500	6.61	4.36	9.09
126	100	0.00	0.00	2.90
	200	0.00	0.00	3.82
	300	0.02	0.00	5.75
	400	0.10	0.00	7.29
	500	0.18	0.00	8.11
252	100	0.00	0.00	0.68
	200	0.00	0.00	0.81
	300	0.00	0.00	1.10
	400	0.00	0.03	1.18
	500	0.00	0.05	1.21

Table 3. The distribution of NO$_3$-N in the soil profile (mg/dm³) on day 0, 56, 126 and 252 for the three irrigation scenarios (i.e., S1—just rainfall and no effluent irrigation, S2—rainfall and irrigation without N, and S3—rainfall and irrigation with effluent that contains N).

supply of inorganic N through mineralisation. By day 56 in scenario S1 (**Table 3**), the amount of inorganic N in the upper layers of the soil had been depleted but most of the inorganic N in the lower layers remained. In contrast, by day 56 in scenario S2, irrigation had moved inorganic N down the soil profile and some had leached beyond the root zone. As a result, inorganic N levels were low throughout the soil profile and plants were unable to access sufficient N for maximum growth. As a result, plant uptake by day 56 was predicted to be lower in scenario S2 than in scenario S1 (data not presented).

By day 126, virtually all the inorganic N in the profile in scenarios S1 and S2 had been exhausted by a combination of plant uptake (S1 and S2) and leaching (S2). As a result, the predicted plant
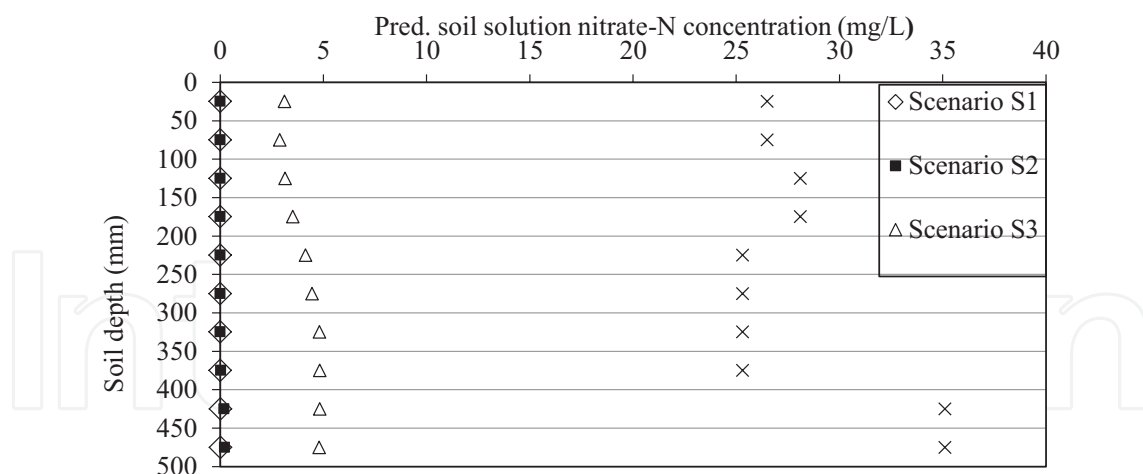
Figure 5. Predicted soil solution NO_3-N concentrations down the soil profile on the starting day and day 252 for the three irrigation scenarios (i.e., S1—just rainfall and no effluent irrigation, S2—rainfall and irrigation without N, and S3—rainfall and irrigation with effluent that contains N).

N uptake in scenarios S1 and S2 was considerably less than in scenario S3 in which effluent containing N was irrigated on to the soil. Such a plant response to added N is commonly observed in New Zealand agricultural systems.

3.2. The ability of the OVERSEER® nutrient budget model to predict N dynamics at the CDC LTS

The focus of this exercise was to explore if it is possible to use the OVERSEER® model (with some modifications to input parameters) to simulate N dynamics at an effluent-irrigated LTS (similar to CDC). As described in methodology section, the amounts of water, organic N and inorganic N applied in the low irrigation treatment of the pasture plot at CDC land disposal site (refer to **Table 4**) were entered into the OVERSEER® model as a notional combination of FDE and irrigation water containing a low concentration of inorganic N.

The outputs from the OVERSEER® model were compared (**Table 5**) with the outputs from the LEACHN model optimised as described in the previous section. Both models predicted similar annual total leachate (1629 mm and 1682 mm for the LEACHN and OVERSEER®models, respectively). The inputs of inorganic N in the applied effluent (and irrigation) were as measured at the CDC LTS and were therefore the same for both models. Similarly, in both models, the plant uptake of N was set at 132 kg N/ha, which was measured at the CDC site. Given these similar inputs, the OVERSEER®model predicted a leaching loss of 69 kg N/ha, which was reasonably similar to the 85 kg N/ha predicted by the LEACHN model. The OVERSEER®model predicted very small emissions of N to the atmosphere (4 kg N/ha), whereas the LEACHN model predicted that 32 kg N/ha would be lost to the atmosphere. Most of the predicted emissions in the LEACHN model were as ammonia volatilisation.

Input	Unit	CDC low effluent irrigation treatment		OVERSEER® model	
Water	mm/year	Effluent application	1560	FDE application	67
				Irrigation	1493
Total water	mm/year		**1560**		**1560**
Organic N	kg/ha/year	Effluent application	131	FDE application	132
Total organic N	kg/ha/year		**131**		**132**
Inorganic N	kg/ha/year	Effluent application	180	FDE application	34
				Irrigation	146
Total inorganic N	kg/ha/year		**180**		**180**

Table 4. The amounts of water, inorganic and organic N that were applied as FDE and irrigation in the OVERSEER® model to create a notional effluent disposal site similar to the low irrigation treatment pasture plot at CDC.

Inputs	Units	LEACHN model	OVERSEER® model
Inorganic N applied	kg/ha	180	180
Organic N applied	kg/ha	(131)	132
N fixation	kg/ha	-	2
Total N inputs	kg/ha	311	313
Outputs			
N leached	kg/ha	85	69
Plant N uptake	kg/ha	132	133
Loss to atmosphere	kg/ha	32	4
Total N outputs	kg/ha	249	206
Change in soil N			
Soil inorganic N	kg/ha	−39	0
Soil organic N	kg/ha	(101)	107
Total change in soil N	kg/ha	(62)	107
Water			
Rainfall	mm		
Effluent and irrigation	mm	1560	1560
Cumulative leachate	mm	1629	1682
Average NO_3-N concentration	mg/L	5.2	4.1

Table 5. Comparison of the predictions from the LEACHN and OVERSEER® models in terms of N leached (kg/ha/year) and average NO_3-N concentrations (mg/L) when the amount of N applied is the same.

The OVERSEER® model predicted that there would be no change in soil inorganic N over the year but that the organic N would increase by 107 kg N/ha. The LEACHN model predicted a decrease in inorganic N, but prediction of changes in organic N by the LEACHN model is difficult. At the CDC LTS, the effluent applied contained both inorganic and organic N (**Table 4**) and the organic N was included in the inputs to the OVERSEER® model. It is, however, not easy to include inputs of organic N in the LEACHN model, and therefore only the inorganic N content of the CDC effluent was included in the LEACHN simulations described throughout the study.

In **Table 5**, a notional N balance was calculated for the LEACHN model by adding the input of organic N (number in brackets) and then calculating the final increase or decrease in organic N by difference. When this was done, the predicted increase in organic N was less than predicted by the OVERSEER® model—reflecting the greater losses by leaching and volatilisation.

It would therefore appear that the existing OVERSEER® model can be adapted to simulate a LTS and gives a similar prediction to a more detailed process-based model such as LEACHN. This could be of value because regional councils are increasingly recognising the use of OVERSEER® as a monitoring tool to demonstrate compliance with environmental regulations.

4. Summary and conclusions

This study was about the application of two models (i.e., OVERSEER® and LEACHN) to predict the fate of water and N dynamics at an effluent-irrigated land disposal facility, and therefore the following conclusions could be drawn from this piece of work.

1. The irrigation scenario analysis showed that the LEACHN model is able to build up a very detailed picture of what is happening to soil N in the soil profile in response to three irrigation scenarios, that is, no effluent application (i.e., just natural rainfall—S1), application of pure water (i.e., rainfall and effluent without N—S2) and effluent application with N composition (S3). This is very useful piece of information to understand the fate of water and N added to a land disposal site.

2. The irrigation scenario (using the optimised LEACHN model) showed that the accumulated leachate was almost nil from day 1 to 196 under natural rainfall (with no N effluent irrigation). There was a total of 177 mm leaching during winter from day 210 onwards and leachate NO_3-N concentration were quite low (<1 mg/L) during that time. The accumulated mass of NO_3-N leached in the first 177 mm of S1 and S2 was <1 and 20 kg/ha, respectively.

3. The predicted soil solution NO_3-N concentrations did not change greatly in the top 500 mm soil depth when more water (i.e., rainfall and irrigation with water containing no N) was added to the system and consequently the soil N was leached and therefore there was a lack of available soil N for plants uptake in irrigation scenario 2. The LEACHN model predicted that more nitrate would be in the soil profile and the soil solution NO_3-N concentration would be significantly increased (up to 5.0 mg/L) in irrigation scenario 3 (i.e., rainfall and irrigation with effluent containing N).

4. The comparison of two different models showed the amount of N leached, as predicted by OVERSEER® model, was 69 kg/ha/year which was reasonably close to that of predicted by LEACHN model (85 kg/ha/year). The comparison showed that, depending on the level of precision required, the OVERSEER® model could be used to simulate N dynamics at a LTS similar to CDC.

5. The strength of LEACHN lies in its ability to predict what would happen to soil N down the profile when irrigation with or without N is added at a LTS and when, where and how much NO_3-N is going to leach. It can be concluded that LEACHN model provides more accurate useful information on how much NO_3-N is going to leach and when this is likely to happen. At the same time, it provides useful insights into the movements and transformation of soil and effluent N down the profile, which could be very helpful for the operators/managers of effluent land disposal facilities. Therefore, a LEACHN model could be a useful decision-making tool to design effluent loading rates that minimise the risk of groundwater NO_3-N contamination at the effluent land disposal sites.

4.1. Recommendations

(a) In the simulations reported in this study, the focus in the LEACHN model was on the fate of inorganic N added in effluent. There is, however, the capacity within the LEACHN model to include the addition of plant residues, manure and urea. It would be useful in future studies to explore ways in which the ability of LEACHN to include different types of N input could be used to mimic more exactly the management regimes at LTSs.

(b) The study demonstrated that when using the LEACHN-based DSS to explore the consequences of different effluent application strategies care must be taken to ensure that realistic rainfall patterns are input into the model—rather than estimates of long-term averages.

4.2. Practicality

Overall, the findings of this chapter suggest that LEACHN model has the ability to simulate N dynamics (i.e., movement and transformation down the soil profile) at effluent-irrigated land disposal sites. In future, LEACHN-based DSS could be used by LTS managers/environmental engineers/scientists to monitor and manage effluent-irrigated land treatment sites in a way that reduces the risk of groundwater nitrate-N contamination at the sites.

Acknowledgements

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