IRRIGATION IN OVERSEER®

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Introduction

In New Zealand, there were approximately 620,000 ha of irrigated land in 2013, with 38% on dairy farms and 26% on sheep/beef farms. About 84% of the total irrigated area was in the South Island (Irrigation New Zealand, 2014). The irrigation sub-model within OVERSEER® Nutrient Budgets (hereafter referred to as *Overseer*) has come under increasing scrutiny, particular in the Canterbury and Hawkes Bay regions. Although there have been no formal surveys, concerns about the Overseer irrigation model have centred on:

- The 'method only' option maintains soil moisture in a narrow range and thus does not reflect irrigation as it is commonly practised. Hence the 'method only' option, typically results in under-estimation of the applied irrigation;
- The 'method only' option does not have sufficient range in management options to reflect changes in nutrient losses when irrigation management practices are changed;
- Confusion over whether the 'method plus depth' or 'method only' option should be used to enter irrigation;
- Difficulty in determining the correct irrigation depths to align with climate inputs if the 'method plus depth' option is used;

In pastoral systems, irrigation increases pasture production and hence animal production. The resulted increase in pasture production results in higher nitrogen (N) intake by stock and hence higher amounts of N excreta as urine, the major source of N leached from pastoral systems. The amount of N leached is determined from the amount of N deposited and drainage (Wheeler *et al*., 2011). Within *Overseer*, there is a daily single layer water balance model (Wheeler and Rutherford, 2014) which has the generalised form:

$$SM_t = SM_{t-1} + DailyRain + DailyIrrigation - AET – ROsurface – ROdrain$$

where SM_t is the soil water content (mm) to 600 mm on day t, DailyRain is the daily rainfall, DailyIrrigation is estimated daily irrigation (mm/day), AET is the actual evapotransipation (mm/day), ROsurface is the surface runoff (mm/day) and ROdrain is the drainage from root zone (mm/day). Daily rainfall and potential evapotranspiration, used in the estimation of AET, are derived from climate data (Wheeler, 2014). Drainage occurs when soil water content (SM) exceeds field capacity (Wheeler and Rutherford, 2014). Daily irrigation is estimated within the model using irrigation management rules.

The above equation shows that the addition of irrigation can increase soil water contents, and if this is larger enough results in drainage. For a given irrigation event, the likelihood of drainage occurring increases as the amount of storage available decreases, that is the difference between soil water content and field capacity. Thus, the amount and timing of irrigation can affect the amount of drainage. Irrigation also increases AET due to increased soil water availability.

Therefore, a project to improve the irrigation sub-model was instigated so that irrigation management rules within the model reflected the range used within New Zealand, and allowed a fair reflection of the impact of irrigation management practices on drainage and resultant estimates of N leaching.

Process

The upgrade was initiated by implementing irrigation management rules into *Overseer* that are in IrriCalc (Bright, 2009), a standard model used for irrigation planning. The irrigation management rules in IrriCalc are based on a matrix of whether depth per application and return period is fixed, or determined by soil water content. This gives four basic systems, FF, VF, FV, and VV as shown in Table 1.

Table 1. Matrix of irrigation management rules used in IrriCalc.

		Return period	
		Fixed	Variable
Depth of application	Fixed	FF	VF
	Variable	FV	VV

The irrigation management rules in Table 1 where implemented in a development version of *Overseer*. A comparison between IrriCalc and *Overseer* outputs of annual actual evapotranspiration, irrigation and depths was undertaken based on four climate regimes, seven soil types and nine irrigation scenarios. Site-specific monthly climate data was used, which consisted. IrriCalc used 30 year daily data set (IrriCalc), and the outputs where average annual outputs. *Overseer* used average monthly climate data using the IrricClac climate data set, and the outputs where annual. This comparison indicated that:

- In the absence of irrigation, IrriCalc and *Overseer* estimates of drainage were similar,
- *Overseer* predicted similar irrigation and drainage depths to IrriCalc. There were small differences between the models in estimated irrigation depths for the variable management options,
- *Overseer* predicted AET was 100 mm higher than IrriCalc for the non-irrigated scenarios, and about 45 mm higher for the irrigation scenarios.

Hence, it was concluded that the irrigation management rules used in IrriCalc could be used within Overseer as the approaches were compatible with Overseer and the results were similar, and it provided the increase in range of management options required.

Two workshops where then conducted with an Industry group, facilitated by Irrigation New Zealand, to provide feedback on the model design. The development version of the model with the updated irrigation sub-model was upgraded for testing. The development model has now then been integrated into the main *Overseer* model in preparation for an April 2015 release.

Irrigation system types
Overseer now aligns with commonly accepted irrigation systems types used in New Zealand, as described by Irrigation New Zealand (Irrigation New Zealand, 2014). The irrigation system type options are:

- Linear and centre pivot
- Travelling irrigator
- Spraylines
- Micro-irrigation (drip and sprinkler)
- Solid set
- Controlled flood
- Border dyke

Irrigation system types are primarily used to set default data for management options and to estimate additional drainage associated with the delivery system and spay drift. Management rules were required that covered the range of irrigation system types typically used in New Zealand.

Management rules
The management rules in IrriCalc (Table 1) where translated into four management options:

- Fixed depth and return period (FF)
- Trigger point; fixed depth applied (FV)
- Depth applied to achieve target; fixed return period (VF)
- Trigger point and depth applied to achieve target (VV)

with the input parameters that the user can enter for each option shown in Table 2. The first letter in the code in parenthesises is whether depth is fixed or variable, and the second whether return period is fixed of variable. Trigger point is the soil water content that triggers an irrigation event. Target is the soil water content that irrigation is applied to achieve. Both are dependent on profile available water (PAW) to 600 mm.

Table 2. Parameters for management options that use soil moisture data

Management option	Parameters
Fixed depth; fixed return period (FF)	Depth per application (mm/application) Return period (days)
Trigger point; fixed depth applied (FV)	Depth per application (mm/application) Minimum return period (days)* Trigger point[1]
Depth applied to achieve target; fixed return period (VF)	Minimum application depth (mm/application)* Maximum application depth (mm/application)* Return period (days) Target[1]
Trigger point and depth applied to achieve target (VV)	Trigger point[1] Target[1]

*optional input.
[1]units of % of PAW or mm deficit.

Border dyke and controlled flood irrigation only have the fixed depth and return period option. For border dyke, an option for management of border dyke outwash is included, with options of ‘Outwash occurs’ (the default) and ‘No outwash’. Outwash results in loss of water and nutrients from the block, but these can be recycled within the farm.

The depth of application and return period vary with the irrigation system type (Irrigation New Zealand, 2014). For example, border dyke usually has higher depths per application and longer return periods than centre pivots.

The management rules define the depth per application and frequency of application, and whether these are fixed or vary with soil water content. The rules for determining when irrigation is applied and for determining the depth of applications are common to all systems. These are summarised as:

1. For controlled flood and border dyke systems the fixed depth and return period’ option is only available. Therefore, if time since irrigation equals the return period then the irrigation depth applied to the crop or pasture (mm/day) is estimated as the entered depth per application (mm/application).
2. If the 'Trigger point; fixed depth applied', option is selected then an irrigation event is triggered when the soil water deficit reaches the trigger point, and if a minimum return period is entered or default option is selected, then the time since irrigation is equal to or greater than the minimum return period. If an irrigation event is triggered, then the entered application per depth is added as irrigation.
3. For the ‘Depth applied to achieve target; fixed return period' an irrigation event is triggered when the time since irrigation is equal to the return period. The application depth is estimated as the amount of water to bring the soil up to the target soil water content. The application depth is constrained by minimum application depth (if entered or if default option is selected) and the maximum application depth (if entered or if default option is selected).
4. If the option ‘Depth applied to achieve target; fixed return period’, then an irrigation event is triggered as in point 2, and the application depth is estimated as in point 3. There are no constraints on the application depth or the return periods.

Data requirements

The minimum data requirement is for the user to select the irrigation system type, the management options, and whether default values are used or the user enters parameter shown in Table 2. Most systems have only one set of default parameters. The exception is for Travelling irrigator and Sprayline irrigation system types which have two options, ‘1 shift per day’ and ‘2 shifts per day’. The default values are available from the *Overseer* website.

A schematic representation of data decision tree is shown in Figure 1.

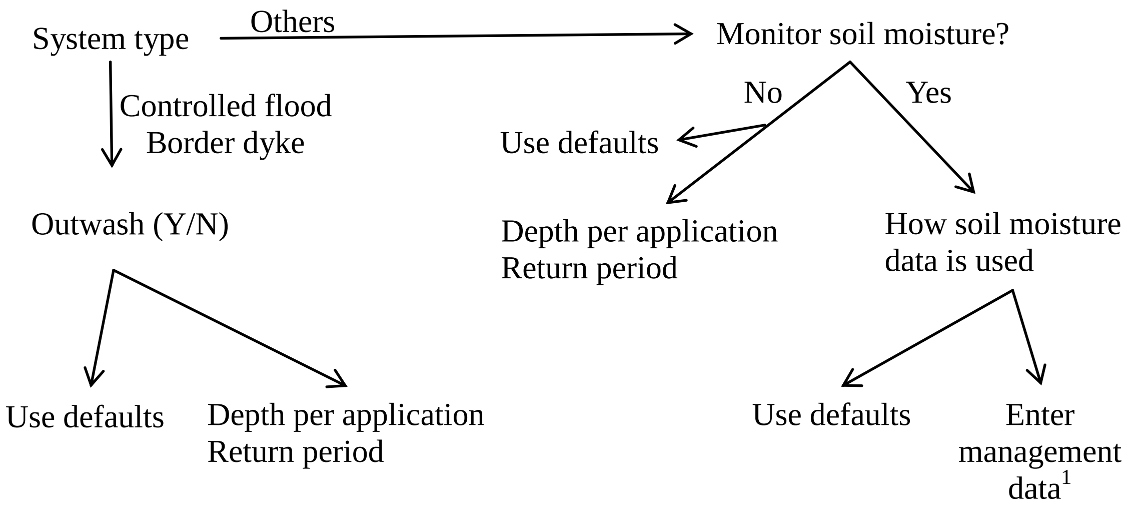

Figure 1. Schematic representation of decision tree for modelling irrigation using management options. [1]The data management options are shown in Table 2.

Example outputs
Estimated irrigation rate, drainage rate and N leached for a range of management options are shown in Table 3 for a block receiving 600 mm rainfall, irrigated between October and March, on a light soil (PAW = 49 mm to 600 mm) or a heavy soil (PAW = 103 mm to 600 mm), using the default options. This analysis was undertaken using the development (pre-release) version of the model and hence values may change by the time of release. It is also important to note that these examples have been set for illustrative purposes only. The effects of management rules will depend on climate and soil characteristics, and only a small subset of possible options is shown in Table 3. However, Table 3 does illustrate several points:

1) Different management options give a large range of annual irrigation depths; for example, for light soils 350-1465 mm irrigation with a resultant drainage 197-1288 mm and N leaching of 40 to 147 kg N/ha/year.
2) High irrigation inputs lead to high drainage and hence high N leaching.
3) Irrigation management practices can be changed to reduce the effect on drainage and N leaching. In this example, adjusting the frequency of application so that water was only applied when a trigger point soil water content was reached (FV, VV options) resulted in lower N leaching.
4) For the travelling irrigator, even though a fixed depth and return period where used, the different annual depths are due to the default values being dependent on PAW for this system.

These examples also indicate that lower irrigation depth, drainage, and N leaching occur when applications are controlled by soil moisture monitoring (FV, VF, and VV options).

Table 3. Estimated irrigation rate, drainage rate and N leached for a range of default management options for a block receiving 600 mm rainfall, irrigated between October to March on a light soil (PAW = 49) and heavy soil (PAW = 103 mm).

	Light soil			Heavy soil		
	Irrigation (mm/yr)	**Drainage (mm/yr)**	**N leached (kg N/ha/yr)**	**Irrigation (mm/yr)**	**Drainage (mm/yr)**	**N leached (kg N/ha/yr)**
Border dyke	1337	852	147	1337	834	108
FF – centre pivot	970	777	107	971	794	87
FF – travelling irrigation	1465	1288	106	1097	1045	97
FV – centre pivot	350	197	40	315	157	16
VF – centre pivot	965	788	105	956	779	82
VV – centre pivot	365	227	40	328	170	16
FF – 25 mm 5 day return	981	804	106	971	794	87
FF – 50 mm 10 day return	1007	829	111	998	820	90

In pastoral systems, urine leaching losses are dependent on the amount of urine N added, which is a function of stock numbers, their diet and their location (whether they are on pasture), and the proportion of that N that leaches (Wheeler *et al*., 2011). The proportion of that urine N that leaches is dependent on soil properties, drainage, and the rate at which N is removed from the urine patch, for example, by pasture uptake, volatilisation, and denitrification. The process that determined the proportion of N that is leached has been encapsulated in a unitless urine risk indicator, which is based on the current urine patch model. An example of urine risk indicators for non-irrigated and irrigated FF centre pivot option is shown in Figure 2.

In this example, irrigation is increasing the risk of N leaching in spring and summer, partly due to extra drainage in October (not shown) due to excess irrigation allowing urine N deposited in June to September to be susceptible to leaching losses. The susceptible is enhanced by low temperatures reducing N removal from the urine patch. Using a VV management system in October decreases drainage and thus reduces this impact. In the January to April period, the increased drainage due to the March irrigation has been offset by higher N removal by the pasture as the soils are moist and temperatures encourage the removal of N. This suggests that the shoulder periods (spring and autumn) are an important time to manage irrigation systems. In the examples in Table 3, no attempt was made to do this. Figure 2 also indicates that there are complex interactions between timing of drainage and urine deposition and N removal from the urine patch. Further work on N cycling in irrigated pasture systems is required to understand these interactions.

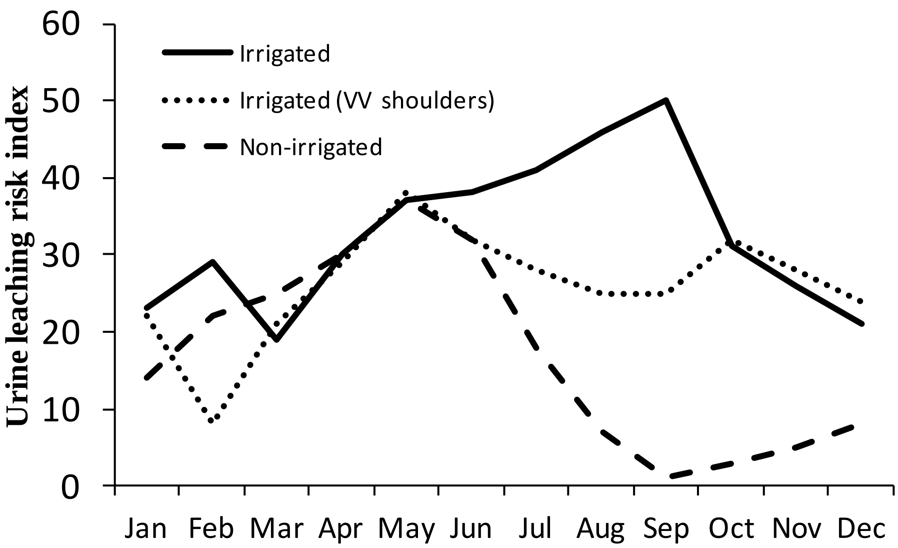

Figure 2. Urine leaching risk indicator for unirrigated, irrigated using centre pivot and default depth per application and return period, and the irrigation option except a VV option is applied in October and March (Irrigated VV shoulders).

Comparison with Overseer 6.1.3

Results from the earlier version of the model when the 'Method only' is used are similar to those for the new VV system for non-border dyke systems, and about 10% higher than VV for border dyke systems. The VV system is currently not widespread in New Zealand. Hence, N leaching rates are likely to be higher than the previous model when actual management systems are added, and in some cases considerable higher. The technology to monitor soil water contents and the results to adjust the irrigation applications depths or frequency are available.

As in the previous version, when adding irrigation to a farm file that was previously unirrigated, it is still important that stock production be also increased. The block relativity input option within the model can be used to indicate production differences between dryland and irrigated blocks.

Conclusions

The implemented sub-model reflects a wider range of irrigation management practices than the current *Overseer* version. This will be reflected in a wider range of drainage and N leaching estimates and is better able to capture the effects of improved irrigation management. From the test runs undertake, the impact on drainage and N leaching is less when soil water contents are monitored and used to adjust irrigation management practice.

Acknowledgments

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References

Bright, J. C. (2009). Estimation of seasonal irrigation water use – Method development. Aqualinc Report C08000/1, prepared for Irrigation New Zealand.

Irrigation New Zealand (2014). New Zealand Irrigation Overview, Book 1. Irrigation New Zealand, Christchurch.

Wheeler, D., Cichota, R., Snow, V. and Shepherd, M. (2011). A revised leaching model for OVERSEER® Nutrient Budgets. In: Adding to the knowledge base for the nutrient manager. (Eds L.D. Currie and C L. Christensen). http://flrc.massey.ac.nz/publications.html. Occasional Report No. 24. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. 6 pages.

Wheeler, D. M. (2014). Climate. OVERSEER® Technical manual. ISSN: 2253-461X. 45 p. Retrieved 10 February 2015, from http://www.overseer.org.nz/OVERSEERModel/Information/Technicalmanual.aspx.

Wheeler, D. M. and Rutherford, K. (2014). Hydrology. OVERSEER® Technical manual. ISSN: 2253-461X. 51 p. Retrieved 10 February 2015, from http://www.overseer.org.nz/OVERSEERModel/Information/Technicalmanual.aspx.