OVERCOMING CHALLENGES IN MODELLING NUTRIENT LOSSES FROM A NON-TRADITIONAL INDOOR DAIRY PRODUCTION UNIT

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Abstract

A non-traditional indoor dairy production unit is being developed in South Canterbury. The farm was previously a dryland farm. A barn will be constructed, to accommodate cows 24 hours/day (no pasture grazing during milking). For most of the year, cows will be housed within the barn and milked using a robotic-based milking platform. The cows will be fed within the barn, from crops grown on-farm (pasture, maize, lucerne) with additional feeding of imported supplementary feed.

The excreta from the barn will be scraped off floors (using automated scrapers) into a slurry storage facility and applied to land using a slurry tanker. Combined washdown water and milking area excreta will be applied to other parts of the farm using a travelling irrigator. The farm will not be irrigated with clean water.

Consents for various farm activities have been applied for. The regional council requires an Overseer based nutrient model to be produced for land use intensification. Modelling of the proposed farming operation highlighted several issues inconsistent with the assumptions and calculated outputs of Overseer®.

Despite having a model output that produced a 'realistic' leaching number for the total farm, it was considered the components within the modelled farm were not realistic. The solution was to develop an Overseer® model which treats the farm as a cropping farm receiving external organic fertiliser, keeping the barn operation separate to the land area used to generate feed for the barn. The revised model examined just the paddocks, with excreta from the sheds calculated separately and applied to the cropped areas as an organic fertiliser. This strategy is consistent with other housed animal enterprises (poultry, piggeries). Development of fertiliser inputs was the key to this revised assessment.

This revised approach produced a nitrogen leaching rate which was very low when compared to typical Overseer® model outputs. When the nitrogen dynamics and flows within the proposed farming system are considered, the Overseer® output achieved appears reasonable and realistic. Utilising a very basic and conservative mass balance approach also supports the view that nitrogen leaching will be limited.

Key words: nitrogen, leaching, modelling, consenting.

Background

A property in South Canterbury is currently operated as a dryland farm (sheep/beef/deer). It is proposed to convert the farm into an indoor-based dairy operation. The farm will be divided into four management areas and will not be irrigated with clean water.

A barn will be constructed to accommodate 1,500 cows 24 hours/day i.e. no pasture grazing during milking. There is a 25 ha pasture area next to the barn, where cows will be grazed during calving. For the remainder of the year, the cows will be housed within the barn or when not milking, they will be grazed off-farm. The cows will be divided into four herds, with calving of each herd spaced about three months ahead of the next herd. The cows will be milked using a robotic-based milking platform, with a 305 day lactation length.

The cows will be fed within the barn with crops grown on the farm (pasture, maize, lucerne – area 536 ha), provided as silage. The cows will also receive limited amounts of imported supplements.

The barn excreta will be scraped off the floors (using automated scrapers) into a 12,000 m^3 slurry storage facility. This material will be undiluted solid material capable of being pumped, and will be applied to part of the farm using a slurry tanker.

The milking area will be periodically washed down with water (during a typical day) using a maximum of 50 m^3/day. The combined washdown water and excreta (that was deposited in the milking area) will drain to a separate sump, and will be applied to part of the farm using a travelling irrigator. At times when application is not possible, this liquid effluent will be discharged into the slurry tank.

Consents for various farm activities have been applied for. The proposed conversion requires a consent to be obtained from Environment Canterbury to permit the change in land-use (intensification). The regional council requires an Overseer®-based nutrient model to be produced to support such an application.

Initial Modelling

Input Details

In order to assess leaching losses from the proposed development, an Overseer® file was set up by an external party, and subsequently revised by Lowe Environmental Impact staff.

Key inputs into the initial Overseer file are shown in Table 1.

Table 1: Key Inputs

Input	Value	Details
Estimated Production	1.2 M kg MS/year	Value provided by client.
Lactation length	305 days	Longer than traditional length (270 days).
Effluent Application	Various combinations of liquid and solid effluent to be applied to each block.	Some blocks receive only liquid effluent, others receive solid + liquid effluent.
Fertiliser application	No fertiliser applications	No fertiliser will be used anywhere on the farm.

The block areas used in the initial post-conversion model are shown in Table 2.

Table 2: Block Areas Inputted into Initial Post-Conversion Overseer File

Block	Total Area	Calving Area (grazed pasture)	C&C Lucerne	C&C Pasture	C&C Maize	Headland, setback, riparian, buildings (non-productive)
Total farm	**536**	25	150	121	232	8.0

Initial Results

The nutrient budget nitrogen summary values from the initial Overseer® modelling are shown in Table 3.

Initial Modelling Issues

The initial modelling highlighted several issues inconsistent with Overseer® assumptions and calculated outputs. They are:

- The standard Overseer® pastoral module has a limit of 25% of the farm area able to be used as a fodder crop. In this case, the fodder area is the majority of the farm, so a combination of using pastoral, cut and carry and cropping options had to be used to allow a realistic output to be produced. The maize operation also uses "back to back" maize production, which cannot be modelled in the pastoral module;
- The management of excreta from the barn operation requires distribution around the farm based on crop needs and the ability to apply the material at an appropriate stage of growth/harvest. The ability to apply this discretion in Overseer® is limited, meaning that due to the internal workings of Overseer®, some areas receive more or less than desired (as shown in Table 3);
- Excessive urine leaching is predicted to occur, as shown by the values given in Table 3;
- The known animal production and import of supplements determines the pasture production. The determination of pasture production relies on standard feed conversion matrices (i.e. kg DM to kg MS). If the conversion is more efficient, then there can be an over-estimation of pasture production, as is the case here (see predicted dry matter production figures in Table 3);
- Based on the suggested input parameters by the property owners, if the pasture silage area is set up as a cut and carry operation (which is intended), Overseer® highlights an error being to too much supplementary feeding. The result is this area has to be set up as a grazed pastoral area; and
- Per cow production expected in this operation is significantly higher (8 kg DM/kg MS) than that observed in 'typical' pastoral farming operations around New Zealand (12 kg DM/kg MS). This means that the feed conversion rate is a lot more efficient in the barn operation when compared to a grazed pastoral setting.

Table 3: Nutrient Budget Nitrogen Summary Values – Initial Modelling

Item		Pre-conversion		Post- conversion				
				A to B - CC Pasture	C to D - CC Lucerne	A to B Maize	B – Grazed pasture	Total
N fertiliser	kg/ha	60		0	0	0	0	0
N fixation	kg/ha	150		520	344	2	264	227
N effluent	kg/ha			310	407	123	310	
N leaching	**kg/ha**	**13**		**18**	**6**	**5**	**41**	**12**
urine	kg/ha			4	0	0	37	3
other	kg/ha			12	4	4	2	8
Organic pool	kg/ha	98		184	216	-39	313	128
N concentration	ppm			13.1	20.9	2.5	32.3	
Total P lost	kg/ha	0.2		0.7	0.8	0.2	0.7	0.7
Drainage	mm/yr			120	18	177	120	
Dry matter production	kg DM/ha			25,913	14,147	9,500	25,834	
Farmer anticipated dry matter production	kg DM/ha			10,000	12,000	15,000	10,000	

Consenting Implications

Environment Canterbury (ECan) require an Overseer®-based nutrient model to be produced for any farming-based change in land use. The predictions made suggested that the proposed land use would decrease leaching from 13 kg N/ha/year to 12 kg N/ha/year. This is a relatively minor decrease and likely to be within the margin of error of the modelling.

Despite having a model output that produced a 'realistic' number for the total farm, it was considered that the components within the modelled farm were unrealistic. It was considered that ECan would be likely to notice this and ask for clarification. This clarification would be to highlight the limitations of Overseer® for modelling this farming operation, as outlined above. This still leaves the issue of having to produce a sensible nutrient budget, preferably using Overseer® (as required by ECan rules).

Next Step

Modelling the farm as a single entity did not produce sensible results. The proposed operation is a feeding operation producing excreta which is applied to farms removed from the barn (i.e. no dependent connection), and produce supplementary feed which is consumed in the barn operation.

As a nutrient budget was needed, the solution was to produce an Overseer® model based around a larger cropping farm that receives external organic fertiliser. The model keeps the barn operation separate to the land area used to generate feed for the barn. This strategy is consistent with other housed animal enterprises (poultry, piggeries etc).

Revised Modelling

Revised Inputs

The Overseer® model was revised using previous farm characteristics.

Two major changes were made:

1) The dairy farm was removed. Cows were only added for four one-month periods prior to calving; and
2) The expected mass of material produced in the shed operation was calculated, and applied to paddocks as an imported organic fertiliser. Overseer allows for off farm dairy effluent to be applied as an effluent/slurry. This is a **key** component to the revised assessment.

The effluent parameters developed are shown in Table 4.

Table 4: Barn Excreta (parameters based on Vanderholm 1984)

	Units	Total	Barn	Milking shed
Cow numbers		1,500		
Hours spent		24	22	2
Days milking		305		
Cow excreta per day	L/cow/d	40	36.7	3.3
Total excreta	L/d	60,000	55,000	5,000
	m3/y	18,300	16,775	1,525
Shed water use	L/cow/d			30
	m^3/d			45
	m^3/y			13,725
Material to discharge	m^3/y	18,300	16,775	15,250
N production	kg/cow/d	0.164	0.15	0.014
	kg/d	246	225.5	20.5
	kg/y	75,030	68,778	6,253

Revised Results

The revised Overseer modelling results are presented in Table 5.

Table 5: Revised Nutrient Budget Nitrogen Summary Values (separated barn)

Item		Pre-conversion		Post- conversion				
				A to B - CC Pasture	C to D - CC Lucerne	A to B Maize	B – Grazed pasture	Total
N fertiliser	kg/ha	60		155	35	218	16	140
N fixation	kg/ha	150		83	324	2	48	113
N effluent	kg/ha			0	0	0	0	
N leaching	**kg/ha**	**13**		**9**	**3**	**4**	**8**	**5**
urine	kg/ha						6	
other	kg/ha			9	3	4	2	5
Organic pool	kg/ha	98		0	-87	-55	-339	-64
N concentration	ppm			7.6	14.4	2.5	6.4	
Total P lost	kg/ha	0.2		0	0	0.1	0	0
Drymatter production	kg DM/ha			9,917	11,973	15,000	9,874	
Farmer anticipated drymatter production	kg DM/ha			10,000	12,000	15,000	10,000	

The revised assessment uses logical data, with less questionable variables compared to the previous model, as the grazing dynamics of the earlier version are removed. The leaching values appear to be extremely low, but the modelling approach can be checked using a very crude mass balance, with the output shown in Table 6.

Table 6: Revised Nutrient Budget Nitrogen Summary Values (separated barn)

Item		A to B - CC Pasture	C to D - CC Lucerne	A to B Maize	B – Grazed pasture	Total
Area	ha	121	150	232	25	528
N applied	kg N/ha	155	35	218	16	
Clover fixation	kg N/ha	125	200	0	150	
Total N in	kg N/ha	280	235	218	166	
Dry matter	kg DM/ha	10,000	12,000	15,000	10,000	
N concentration	%	2.5%	2.5%	2.0%	2.5%	
N uptake	kg N/ha	250	300	300	250	
N removal	%	90%	90%	90%	15%	
Total N removal	kg N/ha	225	270	270	38	
Surplus	kg N/ha	55	-35	-52	129	-14

Table 6 shows that the nitrogen status over the farm area is a deficit (shortage of nitrogen).

In reality:

- Crop growth would be limited by not having enough nitrogen (either greater fixation occurring, soil nitrogen resources being mineralised or a lesser crop yield produced) or
- Fertiliser could be applied to correct the lack of nitrogen.

The "So What"

After undertaking this project, we arrived at the following conclusions:

Overseer® has limitations for non-traditional pastoral systems when used in a traditional way.

- Overseer® allows for shed feeding and wintering barns, but is not set up to model barn systems, and has limitations as highlighted above.

Getting input parameters right is critical

- The predicted leaching rate has taken some time to determine, with much time spent clarifying input parameters. Experience has shown us this is essential, and in this case even more critical as the farming operation is unique.

Non-traditional systems are likely to be closely examined

- As this farming situation was non-traditional, any nutrient balance was likely to be very closely scrutinised by the regulator, especially if it is in a sensitive water quality zone.

Modelling outputs need to be closely scrutinised

- When modelling any farming system using Overseer®, check the outputs produced to ensure they are realistic, and consider carefully what the outputs mean.

There is more than one way to skin a cat

- If traditional modelling approaches are not giving realistic answers, then explore alternative assessment methods for the system you wish to model.

Reference

Vanderholm D (1994): *Agricultural Waste Manual.* New Zealand Agricultural Engineering Institute project report no. 32