Deer and environment: Overseer® upgrade

R.W. MCDOWELL[1], D.M. WHEELER[2], C.A.M. DE KLEIN[1] AND A.J. RUTHERFORD[1]
[1]*AgResearch, Invermay Agricultural Centre, Private Bag 50034, Mosgiel*
[2]*AgResearch, Ruakura Research Centre, East Road, Hamilton*
richard.mcdowell@agresearch.co.nz

Abstract

Recent upgrades to the nutrient budgeting programme Overseer® that affect environmental outputs for deer farms include: the deer intake model, which can influence nitrogen leaching losses; phosphorus losses from areas affected by wallowing and fence-line pacing; and, the greenhouse gas emissions database. In addition, farm blocks within Overseer® are tested as sub-catchments (e.g. a group of paddocks 10-20 ha in size) within a farm as a "basic" spatial management tool to determine the likely areas at risk of contaminant losses (e.g. nutrient losses to water). Data were sourced from 10 deer-farmed sites in Otago and Southland representing the following scenarios: winter forage cropping, finishing and weaning blocks, fence-line pacing, wallowing and wetlands. Overall, the model predicted 87% of variation in phosphorus (P) losses ($P<0.05$), but this was based on limited data. Additional data will be incorporated when available. The recent upgrade of Overseer® gives farmers a tool to see how deer affect environmental outputs at a farm and possibly, sub-catchment, scale.

Keywords: fence-line pacing, nutrient budgeting, wallowing, water quality, soil quality

Introduction

Proven options to mitigate the detrimental effect of farming red deer (*Cervus elaphus*) on soil, air and water quality while maximising productivity are limited. Tools must incorporate a number of unique behavioural characteristics such as wallowing and seeking shelter during calving. One such tool is the OVERSEER® Nutrient Budget model (hereafter referred to as Overseer®) a nutrient budgeting programme that can determine nutrient (nitrogen and phosphorus) losses to water and greenhouse gas emissions (e.g. methane). A number of upgrades have occurred recently to Overseer® which include: the deer intake model, which can influence nitrogen leaching losses; phosphorus losses from areas affected by wallowing and fence-line pacing; and, the greenhouse gas emissions database.

While Overseer® can determine losses on a farm scale, mitigation of air and water quality contaminants requires management at a finer scale. Tools to mitigate contaminant losses within farms therefore should have a spatial component. Overseas, issues such as surface water contamination by phosphorus (P) inputs have been handled by ranking fields/paddocks by their potential for P loss according to a number of risk factors like slope, rainfall, and P inputs (Sharpley *et al.* 2000). Using a similar approach, farm blocks within Overseer® could be used to represent small sub-catchments (e.g. a group of fields 10-20 ha in size) within a farm as a "basic" spatial tool to determine the likely areas at risk of contaminant losses to water.

This paper presents the validation data and reasoning behind each of the upgrades for deer farmers to Overseer®. Furthermore, we use data from a number of trials over the past 5 years to test the efficacy of Overseer® at the sub-catchment scale (and one plot scale study). This is demonstrated by testing estimated versus actual P losses and, if used well, could help in identifying areas on a farm where contaminant loss to surface water should be mitigated.

Materials and Methods

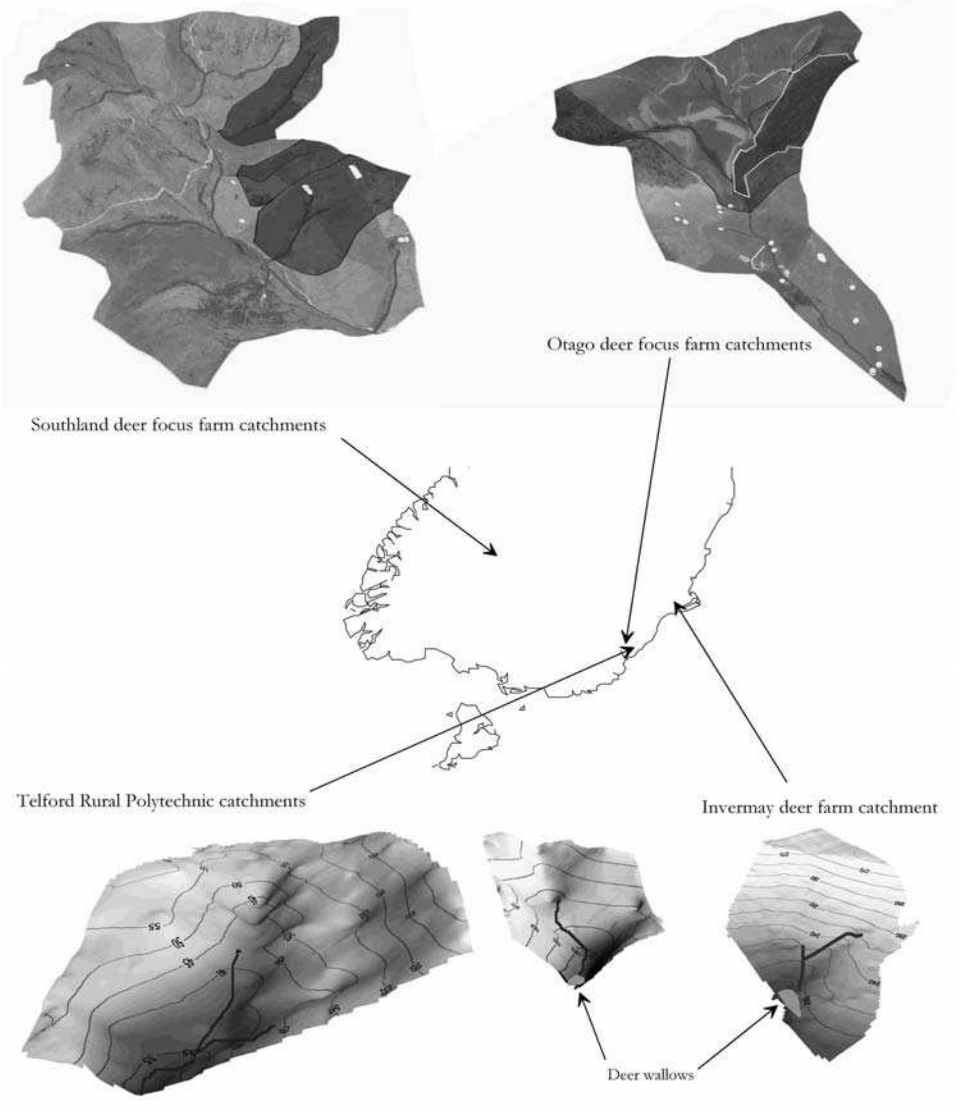
Data for contaminant losses to water and air have come from a variety of literature sources. Each will be dealt with below. Data for Overseer® testing came from trials conducted in catchment at AgResearch-Invermay (Invermay), Telford Rural Polytechnic (Telford) and the Southland and Otago deer focus farms (DFF). A full description of the DFF can be found in McDowell *et al*. (2006a), while the trials conducted at Telford and Invermay are outlined in McDowell (2007) and McDowell & Stevens (2006), respectively. Some input data for Overseer® are given in Table 1. In 2006, soil samples were taken (0-75 mm) from each catchment on a 50-m grid in October and analysed for typical soils tests including Olsen P. With the requirement to get a fine spatial scale, water quality was monitored at sub-catchments within the Southland (4) and Otago (3) DFF and at the outlet of the two small Telford and one Invermay catchments. All are referred to from now on as sub-catchments. The Otago DFF and Telford sub-catchments were monitored for 2 years, while the Southland DFF sub-catchments were monitored for 3 years and the Invermay sub-catchment for 5 years (2 of which were after fencing-off and riparian planting an old wallow). At locations within each, gauges were installed to determine flow. Water samples were taken on a monthly and occasional event basis and measured for several water quality parameters. However, only loads of total P (TP)

Table 1 Examples of sub-catchment characteristics used for input into Overseer®.

Catchment	Size (ha)	Rainfall (mm)	Soil class	Stock (su/ha)	Olsen P(mg/kg)	Fert. P (kg/ha/y)	Wallow[1]	Fence-line pacing[2]	Wetland
Southland DFF 1	290	850	Brown	10.2	33	10	No	No	Yes
Southland DFF 2	26	850	Brown	10.2	29	10	Yes	Yes	Yes
Southland DFF 3	11	850	Brown	10.2	30	10	No	Yes	No
Southland DFF 4	25	850	Brown	10.2	31	10	No	Yes	No
Southland crop	<1	850	Brown	10.2	25	60	No	No	No
Otago Flat DFF	140	950	Brown	11.8	37	38	No	Yes	No
Otago Steep DFF	50	1130	Brown	10.8	27	23	Yes	Yes	No
Telford 1	6	944	Pallic	12.9	27	35	Yes	Yes	No
Telford 2	36	944	Pallic	13.2	28	35	No	No	Yes
Invermay	9	687	Pallic	13.0	26	30	Yes	Yes	Yes

[1] Wallowing input into Overseer® if wallows were seen to be connected to a receiving stream.
[2] Fence-line pacing was deemed as < 40% coverage within 2 m of the fence-line.

Figure 1 Digital elevation models showing the location of each sub-catchment and notable streams and wallows (filled spots).



are presented in this paper and were calculated via interpolation techniques (Robertson & Roerish 1999). Where flow was not measured (three sites at the Southland DFF), it was estimated as proportional to the area of the sub-catchment relative to that occupied by the overall (gauged) catchment. This estimate was improved by a regression relationship generated between sub-catchment flow measured during sampling (by gauging the main channel before and after the confluence) and continuous flow measurements at the overall catchment outlet.

In addition to sub-catchments, 1 year's data were included for surface runoff losses from hydrologically isolated plots of winter-grazed forage crops at the Southland DFF (McDowell & Stevens 2007).

Soil sampling data were combined with a digital elevation model (DEM) and farm survey data for stock and pasture management within a geographic information system (Fig. 1). This was used to determine, in each sub-catchment, mean slope and soil test values for input into Overseer® (see Table 1). The presence of significant fence-line pacing or wallows connected to streams was also entered into Overseer®. The annual loss of TP (kg P/ha) was compared to the load predicted by Overseer® at each site.

Results and Discussion

Overseer® changes

Changes to Overseer® centre on accounting for behavioural characteristics of deer, feed and associated gaseous emissions. Much research and anecdotal evidence has identified that red deer will pace fence-lines when under stress such as during calving or when feed is low (Pollard & Stevens 2003). This can result in soil erosion losses of up to 20 tonnes/ha/yr (Thorrold & Trolove 1996). It is also recognised that red deer tend to wallow - even going to the extent of causing wallows in wet depressions in the landscape (Webb *et al*. 2006). The exact reason for this is unknown, but recent research has highlighted their role in contaminant loss due to the direct deposition of faeces and urine into wallows that are often connected to a stream or form the headwaters of a stream (McDowell 2007). As a consequence of fence-line pacing and wallowing, the following changes have been made:

- Work by McDowell & Paton (2004) McDowell *et al*. (2004) and McDowell *et al*. (2006b) has quantified nutrient, faecal bacteria and suspended sediment loss in deer grazed paddocks and fence-lines with Brown and Pallic soils. The loss of P from soil is influenced by soil P concentrations (e.g. Olsen P). Given the large variation of Olsen P within deer-grazed paddocks due to faecal returns along fence-lines (e.g. 53 mg/kg at fence-line compared to 30 mg/kg in rest of paddock), losses were calculated via sediment losses. Without any noticeable pacing, sediment loss from fence-lines was 50% greater than losses from the rest of the paddock and double if fence-line pacing was observed (McDowell & Paton 2004). However, P loss will also be enhanced by the selective erosion of P-rich fine sediment over low-P coarse sediment. The enrichment ratio (i.e. the concentration of P in sediment within runoff compared to the same weight of whole soil) is equal to 2 - 0.16 * ln(sediment discharge) (Sharpley 1980). Normalised for a runoff event of 10 mm and an enrichment ratio of 1.76, P loss is approximately 4 times that of the rest of the paddock. Typically, fence-line pacing covers about 2% of the paddock. Therefore, an increase in P loss was modelled as base P loss × 0.98 + base P loss × 4 × 0.02, where base P loss is calculated as per normal for paddocks within Overseer®. It was assumed that the ratio of deer on the blocks (e.g. whether it was a pure deer block or mixed deer/cattle/sheep grazing) had no effect on these losses.
- Work by McDowell & Stevens (2006) and McDowell (2007) indicated that P losses from wallows ranged from 0.5 - 3.5 kg P/ha/yr averaged over catchment sizes of 6-36 ha on rolling, easy hill and steep country. No estimate is available for losses from wallows on flats either with or without streams fenced off. Apart from topography, no systematic indicator was found and as a consequence, if wallows are selected within a block, an additional load of 1 kg P/ha/yr was added onto the paddock load for non-flat topography.

In addition to changes due to fence-line pacing and wallowing, the following changes were made:

- The animal metabolisable energy requirement, or intake, model has been upgraded, using a model similar to that published by Nicol & Brookes (2007). The intake model is responsive to animal liveweight, rate of liveweight gain, and feed quality.
- Greenhouse gas emissions (methane and nitrous oxide) from ruminants are largely dependent on total amount of feed intake, which is determined by the animal's energy requirements and the quality of the feed eaten (Clark *et al*. 2003). The estimates of feed intake for deer have improved by incorporating the updated feed intake model as described above. Methane (CH_4) emissions are then calculated using a methane emission factor per unit of feed intake, while nitrous oxide (N_2O) emissions from deer excreta are calculated as follows: N_2O from deer excreta = [(Feed intake × N content feed) – N in product] × N_2O emission factor.
  The CH_4 and N_2O emission factors used in Overseer® are the same as those used in the New Zealand national inventory methodology (Ministry for the Environment 2007).
- Other changes to the model such as the addition of nitrification inhibitors, wetlands and riparian strips are

generic, but will also affect deer nutrient losses.

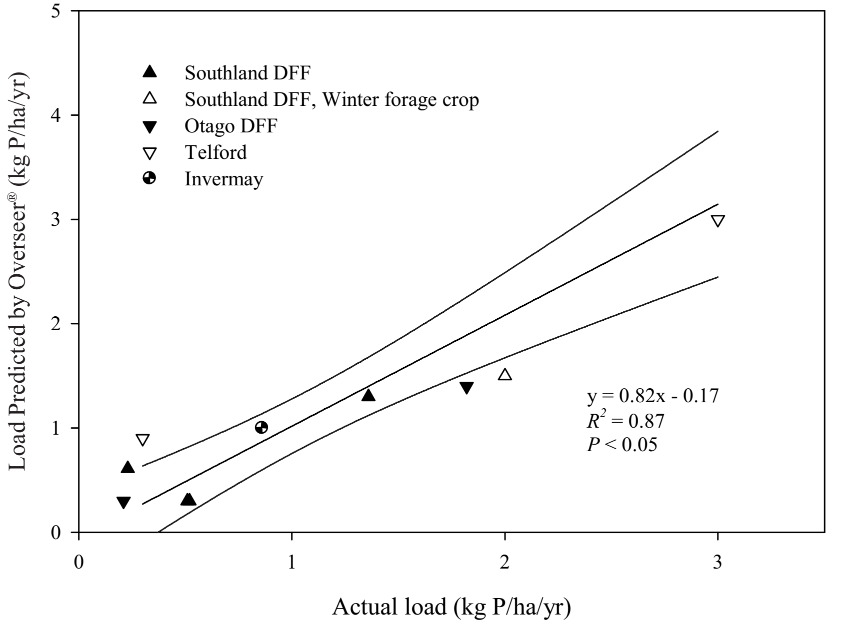
Spatial management

Overseer® predicted P losses ranging from 0.3 kg P/ha/yr at one sub-catchment in the Southland DFF to 3 kg P/ha/yr at one sub-catchment at Telford (Fig. 2). Actual data ranged from 0.2 to 3.0 kg P/ha/yr. As noted above, wallowing has a major impact on the losses of P within Overseer® (adding 1 kg P/ha/yr). In general, unless the farm is in a dry environment, wallowing will occur in rolling, or steeper, country. However, it was noted that while wallowing did occur in two of the sub-catchments at the Southland DFF they were not connected to the stream. Hence, they were input into Overseer® as not having wallows. The largest sub-catchment at the Southland DFF was buffered by a wetland/riparian strip that was predicted to mitigate P losses by 45%. This decreased the load from 1.3 to 0.6 kg P/ha/yr. Additional data at the Southland DFF indicated that a field sown in a forage crop and grazed in winter was likely to produce 2.0 kg P/ha/yr compared to the 1.5 kg P/ha/yr predicted by Overseer®. Unfortunately, during the 3 years of the study none of the sub-catchments were sown in winter forage crops and hence only plot data are available. Data for one Telford and the Invermay sub-catchment exhibited wallowing. However, at Invermay this has been mitigated to some extent by the fencing-off and riparian planting of the old wallow site. This caused Overseer® to decrease loads from 1.3 to 1.0 kg P/ha/yr compared to actual losses of 1.5 and 0.9 kg P/ha/yr, before and after fencing-off and riparian planting, respectively.

Overall, the model was able to predict 87% of the variation in actual P losses ($P<0.05$). Given the range in climate, topography, soils and management (e.g. fencing-off and riparian planting), Overseer® predicts annual P losses reasonably well. However, it is noted that there is considerable variation in P losses from sub-catchments influenced by wallowing (losses range from 0.8-3.0 kg P/ha/yr). This is largely due to access, determined by the number of grazing events per year (McDowell 2007). At present this is not accounted for by Overseer®. Hence, the mean annual loss from existing studies is used, but this could be an area for improvement. In addition, little data exist for fence-line pacing losses outside of Otago and Southland. Consequently, the influence of P losses by fence-line pacing is probably underestimated within Overseer® for areas outside of these regions with erosion prone soils (e.g. pumice). This can only be solved as additional data become available.

By breaking farm losses of P into sub-catchments, Overseer® should be able to give the farmer a better idea of the impact deer are having on surface water quality. Obviously, the degree of spatial scale is up to the user, and the management utility will reflect that choice. However, the upgraded deer module (at least for P losses) is able to predict P losses in sub-catchments varying from 9 to 190 ha thus far. Although some smaller plot scale (4 m^2) data were also included, the usefulness of such small scale data to management may be limited. Once the choice has been made to

Figure 2 Annual phosphorus loads lost (kg P/ha) from each sub-catchment versus those predicted (± 95% confidence intervals) by Overseer®.



manage on a sub-catchment scale, the farmer can then use Overseer® to play around with different mitigation strategies like minimising the flow of contaminants to stream flow by not grazing deer in sub-catchments with wallows during winter or creating alternative wallowing sites. Additional mitigation strategies could focus on minimising fence-line pacing by supplying plenty of feed, providing shelter for shade or by decreasing stress during calving.

Conclusions

The nutrient budgeting programme Overseer® has been altered to better account for nutrient losses to water and greenhouse gas emissions. The feed intake model has been altered and this indirectly influences nitrate leaching losses. The P loss model has been altered to account for two of the major loss mechanisms determined over the past 5 years of study, wallowing and fence-line pacing. Data presented for trials in sub-catchments (9-190 ha) with a range of climates, topographies, soils and managements showed that Overseer® predicted 87% of variation in observed P losses. However, this is based on limited data, requiring that additional data be incorporated when available. The use of Overseer® at a sub-catchment scale within a farm gives the farmer a "basic" spatial tool to show the relative effect that could inform management to mitigate surface water quality impacts by deer.

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