The relationship between farm profit and nitrogen exports on representative dairy farms in the Moe River catchment, Victoria

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Abstract

Ambitious nutrient reduction targets have been set for the Gippsland Lakes, Victoria but at what cost to productive agriculture? An interdisciplinary approach is addressing this question for the Moe River catchment, a dairy-dominated catchment that is a major source of pollutants to the Gippsland Lakes. Off-farm nitrogen exports are being estimated by biophysical modellers, and economists are quantifying the impact of farming systems and agricultural practices on farm profitability. This information is assembled to form the interim profit-pollution frontier for nitrogen reported in this paper, and to calculate abatement costs. Phosphorus and sediment exports will be considered in future work. This information is intended for use in a landscape-optimisation model that highlights how land uses can best be spatially allocated in the catchment to meet end-of-valley pollution targets at least cost.

Keywords: nutrient management, profit-pollution frontiers, abatement costs.

Introduction

Nutrient and sediment loss from agricultural activities may be small by agronomic standards, but nitrogen and phosphorus imbalances have impaired the economic, social and environmental values of waterways throughout both Australia and New Zealand (Drewry *et al.* 2006, Doole and Pannell 2011a). The Gippsland Lakes, one of the most important environmental assets in the state of Victoria, is a prime example of an important Australian water body affected (Roberts *et al.* 2012).

Economic research is being undertaken to develop and apply a method that will determine how to cost-effectively satisfy a set of targets for multiple pollutants at the catchment scale. The pollutants are nitrogen (dissolved N), phosphorus (dissolved and particulate P) and sediment. The study area is the Moe River catchment, a dairy-dominated catchment that has been identified as a major contributor to pollutant exports in the Gippsland Lakes (Hancock *et al.* 2007).

This economic research is part of a larger interdisciplinary project involving biophysical modellers who are developing methods to enable assessment of changing farming systems on pollutant loads on high-value, threatened environmental assets. Pollutant loads are being assessed at the farm scale using DairyMod/SGS (Johnson *et al*. 2008) and HowLeaky (McClymont *et al.*, 2007). The impact of agricultural and landscape (gully and stream bank) pollutant sources on downstream assets is being evaluated with CatchMODS (Newham *et al.* 2004; Vigiak *et al.* 2011). Dependencies and linkages between the biophysical modelling and economic analysis are shown in Figure 1, with the economic component highlighted in blue.

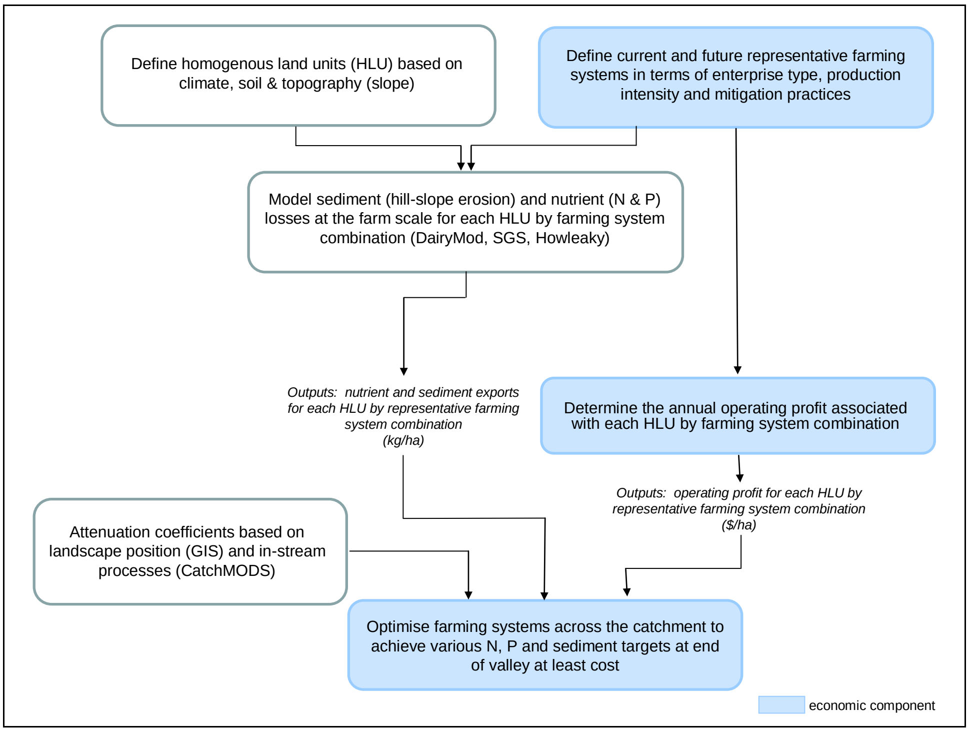

Figure 1. Biophysical and Economic Modelling Approach.

This paper focuses on obtaining the farm-level information on nitrogen required for later use in landscape optimisation. This information comprises:

1. A cross section of base representative farms reflecting the intensity of land use in the catchment, focusing on dairy production.
2. Off-farm nitrogen exports (kg N/ha) from each representative farm for an homogenous climate and soil type.
3. Operating profits ($/ha) for each representative farm.

Operating profits and nitrogen exports for each representative farm are assembled to form an interim profit - pollution frontier, which shows the trade-off between operating profit and nitrogen exports. Abatement costs for nitrogen exports are also calculated. Management practices can be changed on each farm to mitigate the pollutant exports and reduce abatement costs, and these practices will be considered in future work. Phosphorus and sediment exports will also be considered in future work.

Methods

Study area

The study area is the Moe River catchment within the larger LaTrobe River Basin in West Gippsland (Figure 2), Victoria. The LaTrobe River Basin is, in turn, one of three river systems which form the total catchment of Lake Wellington, the western-most of the Gippsland Lakes.

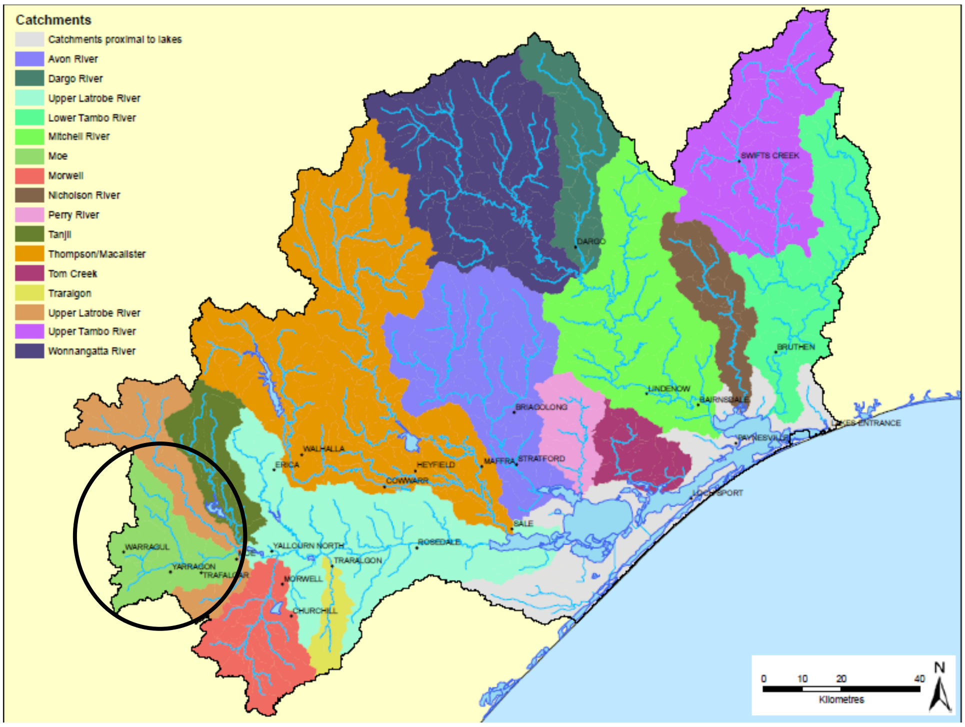

Figure 2. The Moe River catchment.

Nutrients entering water bodies mostly come from the dryland (non-irrigated) livestock industries that dominate land use in the area (Figure 3). The catchment area is 592 km^2. Average annual rainfall is over 1,000 mm in elevated areas and in excess of 700 mm elsewhere. Approximately 26% of the study area comprises dryland dairying, with a further 43% under mixed dairy/beef enterprises. Small forested areas remain, including timber plantations.

Dairy farms are typically based on perennial pastures, with stocking rates and the lactation profile of each herd aligned with expected pasture growth. This practice generally incorporates calving just before the onset of main pasture growth in an attempt to match the supply of feed with that required by the milking herd.

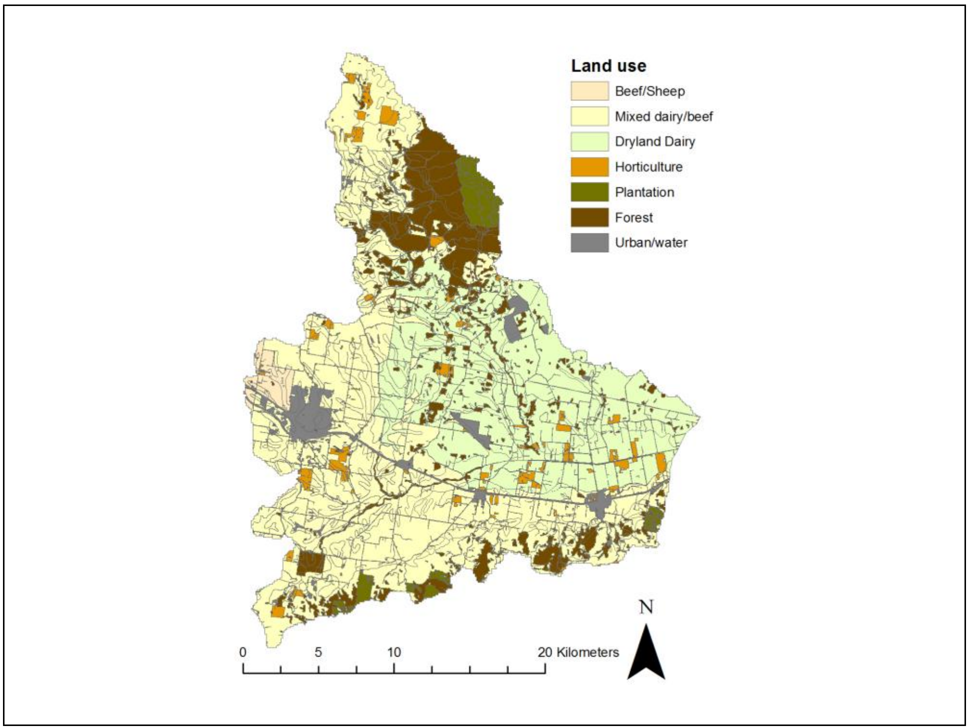

Figure 3. Land use categories in the Moe River catchment.

According to GippsDairy (a regional research, development and extension organisation led by Gippsland dairy farmers), there are about 177 licensed dairy farms located in the Moe River catchment (Melanie Smith *pers. comm*.).

Based on dryland dairy farms participating in the Gippsland Dairy Farm Monitor Project (Gilmour *et al.* 2011), the farm size (useable area) is just over 200 ha with the milking area estimated at about 140 ha. The average herd size is about 260 milking cows, giving an average stocking rate on the milking area of 1.9 cows/ha. Milk production averages about 12,100 l/ha (around 935 kg milk solids/ha) per annum. N application averages about 140 kg/ha per annum on the milking area, and P about 16 kg/ha per annum. Supplements are used to boost stocking rates and achieve higher milk production; the level of supplementary feed purchased is high, at around 1.9 t dry matter (DM) per cow on average (3.8 t/ha), constituting about 30% of total energy consumed.

Note that the physical measures quoted above on a per hectare basis relate to the milking area of the farm, and have been derived from figures reported on a per "useable area" basis in the Dairy Farm Monitor. The useable area includes any area of the farm that is used for grazing or fodder production, including outblocks and areas for young stock and dry cows, and the milking area comprises about 70% of this total.

Representative dairy farms

Four representative systems were constructed to cover the range of situations observed in the study area. The systems are differentiated according to their reliance (both in absolute and relative terms) on fertiliser and supplementary feed usage, and hence on their intensity of resource use (Figure 4).

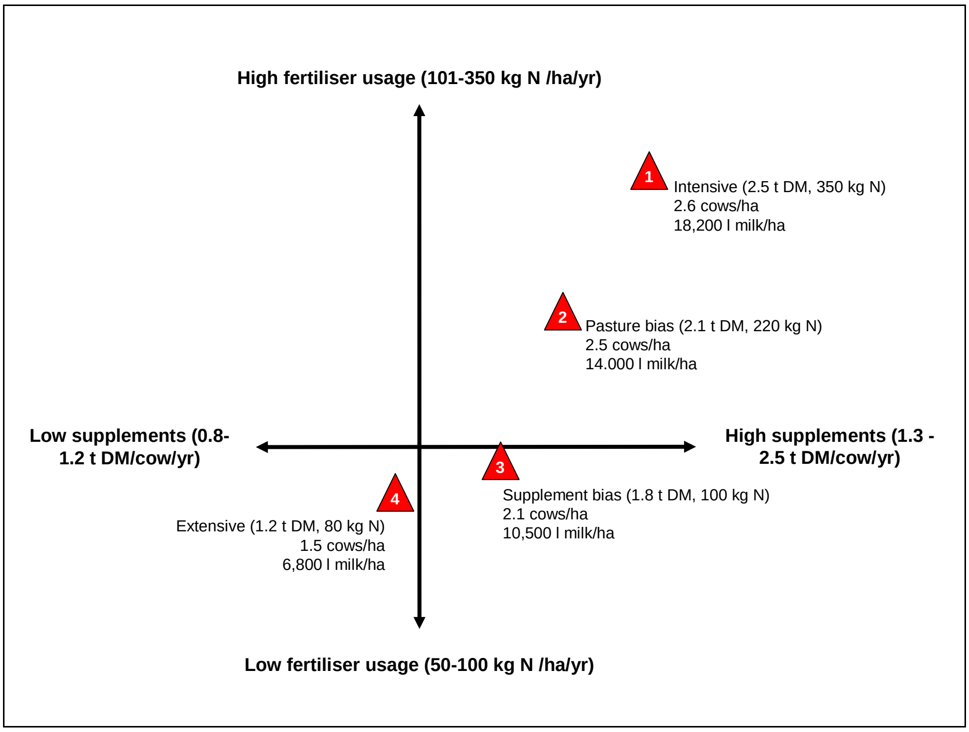

Figure 4. Representative farming systems for the Moe catchment, Gippsland Victoria.

Fertiliser usage on these farms is classified as either low (100 kg N/ha or less) or high (greater than 100 kg N/ha), while supplementary feed usage is classified using a 1.2t DM/cow threshold. These parameters were derived in consultation with DPI extension staff and with reference to DPI's Farm Monitor data (Gilmour *et al.* 2011) and GippsDairy's feedbase stocktake (Mulvany 2008).

Representative farms 1 and 2 ("intensive" and "pasture bias", respectively) have high fertiliser and supplementary feed but differ in the amount of these inputs used. System 3 ("feed bias") has low fertiliser usage but high supplementary feed. System 4 ("extensive") has low fertiliser usage and low supplementary feed. It is rare to find farms in the study area that have high fertiliser usage and low supplementary feed, so no representative farms are defined for this category.

Specific details for each of the four representative farms, in terms of N fertiliser usage, feed usage, stocking rate and milk production are shown in Table 1.

Table 1. Representative farm attributes (on milking area).

	System	N	P	Supplements fed		Stocking rate	Pasture consumed	Milk production	
		kg /ha/yr	kg /ha/yr	t DM /cow/yr	t DM /ha/yr	cows /ha	t DM /ha/yr	l /cow/yr	l /ha/yr
1	Intensive	350	20	2.5	6.5	2.6	8.8	7,000	18,200
2	Pasture bias	220	20	2.2	5.3	2.4	6.9	6,000	14,500
3	Supplement bias	100	20	1.8	3.8	2.1	5.7	5,000	10,500
4	Extensive	80	20	1.2	1.8	1.5	4.3	4,500	6,800

Data on dryland dairy farms participating in the Gippsland Farm Monitor used to help characterise the representative farms are shown in Figure 5.

In this figure, each farm is plotted in terms of three numeric parameters. The x- and y- axis are, respectively, supplementary feed and N fertiliser purchases on a per hectare basis. The bubble size indicates the magnitude of the third parameter: supplements purchased per cow in Figure 5(a), stocking rate in Figure 5(b), milk production per cow in Figure 5(c), and milk production per hectare in Figure 5(d). The Figure shows the extent to which milk production increases as input usage increases, and the variation in the input mix at different levels of production.

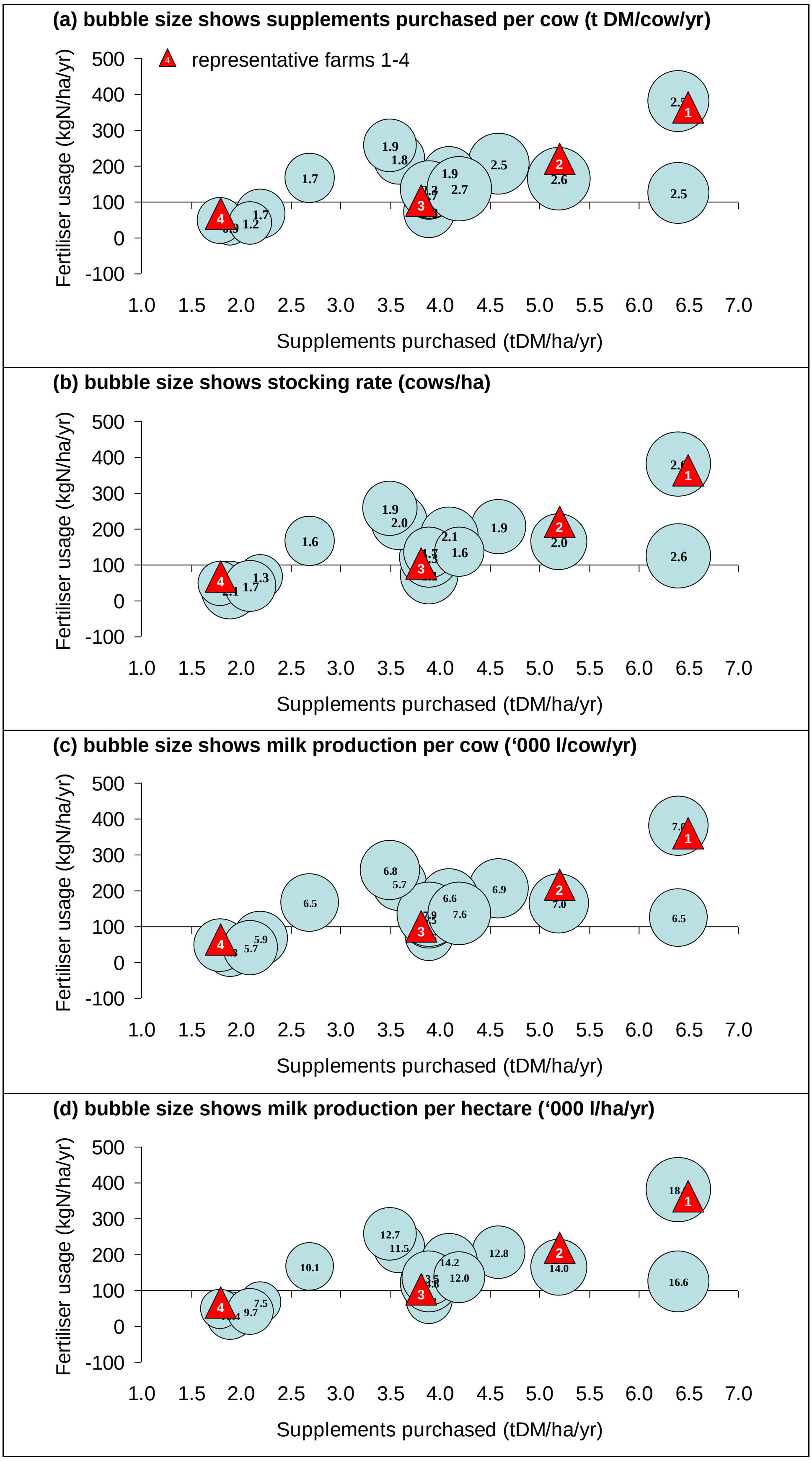

Figure 5. Attributes of the population: (a) supplements purchased per cow, (b) stocking rate, (c) milk production per cow, and (d) milk production per hectare. Bubbles show Gippsland Farm Monitor dairy farm data; triangles show representative farm numbers.

N losses on the milking area

N leaching from the milking area of each representative farm was computed by statistical analysis of outputs from DairyMod. Numerous combinations of milk production, fertiliser usage, supplementary feed and stocking rates were used to simulate the N losses used in the statistical analysis.

Nitrogen losses vary by soil type, and for this exploratory analysis, a sandy-loam soil was used. Note that N leaching losses on this soil type will over-estimate losses on less permeable soils.

DairyMod was run for the period 1981-2001. The first 10 years were used to initialise the model (remove bias introduced by the set of initial conditions) and N losses were avaraged for 1991-2001.

SILO-Ellinbank weather data (http://www.longpaddock.qld.gov.au/silo/) were used throughout the simulation period.

Alternative management practices can be used to mitigate the pollutant exports from each base representative farm, such as matching nitrogen supply to pasture demand, and timing fertiliser application to minimise nitrogen loss. These management options are not accommodated in this paper.

Operating profits for the representative farms

The efficiency of resource use on each representative farm was evaluated in terms of operating profit at full equity, i.e. revenue minus fixed and variable costs (Malcolm *et al.* 2005, p79). Farm revenue includes returns for milk, sale of livestock and inventory changes. Variable costs include feed and fertiliser costs, herd and shed costs.

Operating profit was derived by statistical analysis of Farm Monitor data for the three years to 2010/11. The latter is the most recent year for which data are available; it was also a more profitable year for the industry after two years of depressed prices on the back of the global financial crisis.

Results

N losses for the representative farms

Similar to Graham (2008), statistical analysis of the DairyMod simulations confirms that N losses are driven by annual fertiliser application rates and to a lesser extent by supplementary feed usage on a per hectare basis. The reason for this is that increasing fertiliser N and supplementary feed usage boost stocking rates to achieve higher milk production per hectare, and it is this intensification of land use that drives N leaching (Monaghan *et al*. 2007).

The relative importance of N fertiliser usage on N leaching is shown in Figure 6(a). If the yearly application of N is increased from 40 to 360 in 20kg increments and supplementary feed and stocking rates increase in line with local practices (Figure 6(b)), then total N leaching increases from about 30 to 220 kg N/ha for the soil type and climate simulated.

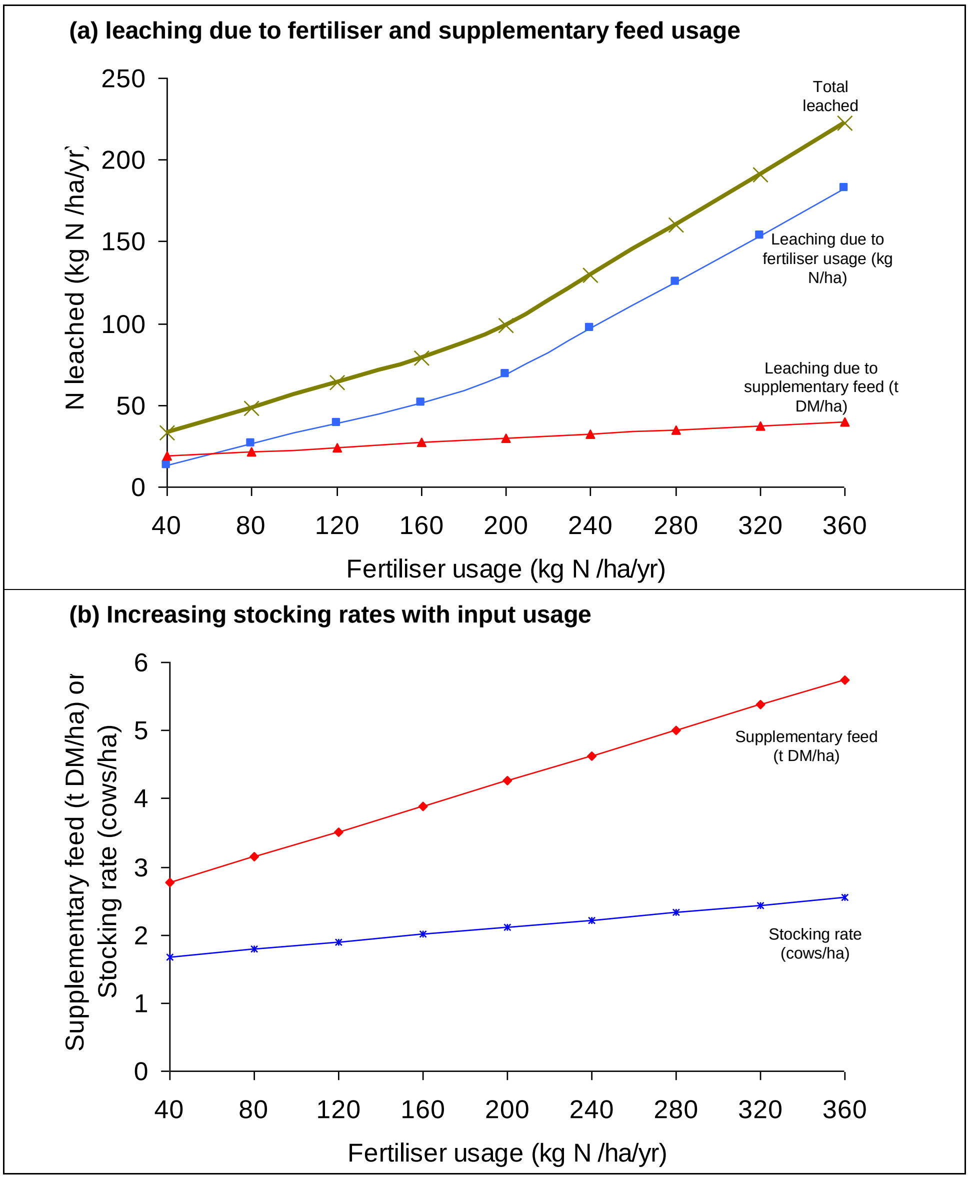

Figure 6. Simulated N losses in leaching: (a) losses due to fertiliser and supplement usage, (b) increase in carrying capacity with increasing fertiliser and supplement usage.

N losses for the representative farms are shown in Table 2. Losses were calculated using the relationships depicted in Figure 6 and on the assumption that N leaching on the non-milking area is similar to losses on the milking area for the extensive farm. It can be seen that N losses increase in line with the intensity of the system modelled, with N losses from the intensive farm 344% higher than for the extensive farm.

Table 2. Simulated N losses in leaching for the four base representative farms*.

	Representative farm			
Attribute	**1 "intensive"**	**2 "pasture bias"**	**3 "supplement bias"**	**4 "extensive"**
N fertiliser use (kg/ha/yr)	350	220	100	80
Supplementary feed (t DM/ha)	6.5	5.3	3.8	1.8
Total N leached (kg N/ha)	169 (+344%)	98 (+158%)	51 (+34%)	38

* percentage increase shown in brackets is relative to the "extensive" system

Operating profits for the representative farms

The operating profits for the four base farm systems during the three years 2008/09 to 2010/11, plus the 3-year averages, are shown in Table 3. Also shown in table 3 are stocking rates, milk production per cow and supplementary feed purchases per cow, which were all statistically significant explanatory variables in determining the operating profit for each representative farm.

The 3-year average shows that operating profit increases with increased input usage and milk production, though returns in individual years are volatile reflecting price and climate variability. Over the three years, the operating profit for the "extensive" farm was 72% less than that for the "intensive" type.

Table 3. Operating profit for the four base representative farms*.

	Representative Farm			
Attribute	**1 "intensive"**	**2 "pasture bias"**	**3 "supplement bias"**	**4 "extensive"**
Milk Production/cow (kg MS/cow)	538	462	385	346
Stocking rate (cows/ha)	2.6	2.4	2.1	1.5
N fertiliser use (kg/ha/yr)	350	220	100	80
Purchased feed (t DM/cow/yr)	2.5	2.2	1.8	1.2
Operating profit ($/ha) 2008/09	1,107	942	751	512
Operating profit ($/ha) 2009/10	1,016	650	269	-22
Operating profit ($/ha) 2010/11	2,661	1,962	1,256	826
Operating profit ($/ha) 3 year average	1,594	1,184 (-26%)	759 (-52%)	439(-72%)

* percentage decrease shown in brackets is relative to the "intensive" system

Profit-Pollution Frontier

Table 4 shows the change in nitrogen losses and operating profits between each of the representative farms, and the abatement cost associated with system change.

The table shows that a reduction in the intensity of land use represented by a move from farm 1 to farm 2 involves a 42% decrease in N leaching for a 26% decline in operating profits. Similarly, a move from farm 2 to 3 involved a further 48% fall in N leaching for a further 36% decline in profits. Farms 3 and 4 are both relatively low polluting systems, and a move from 3 to 4 involves a more modest 25% reduction in N loads for a still considerable 42% decline in profit.

As the intensity of production decreases, abatement costs increase from a low of $5.80/kgN/ha to a high of about $25.40/kgN/ha. The lower abatement costs for the more intensive systems reflect the more substantial amount of N mitigated for a more moderate decline in profits.

Table 4. Abatement costs associated with system change*.

	Representative farm			
Attribute	**1 "intensive"**	**2 "pasture bias"**	**3 "supplement bias"**	**4 "extensive"**
Operating profit ($/ha) 3 year average	1,594	1,184	759	439
- absolute change		-410	-425	-320
- percentage change		-26%	-36%	-42%
Total N leached (kg N/ha)	169	98	51	38
- absolute change		-71	-47	-13
- percentage change		-42	-48	-25
Abatement cost ($/kg N/ha)		5.80	8.93	25.40

* absolute and percentage change figures are compared to the next most intensive system.

Farm nitrogen exports and profits are assembled to form the profit - pollution frontier shown in Figure 7. The four representative farms are indicated by the red triangles. The triangles locate the "base" N leaching and operating profit for each representative farm, as they exclude consideration of any farm management practices that may mitigate pollution loads.

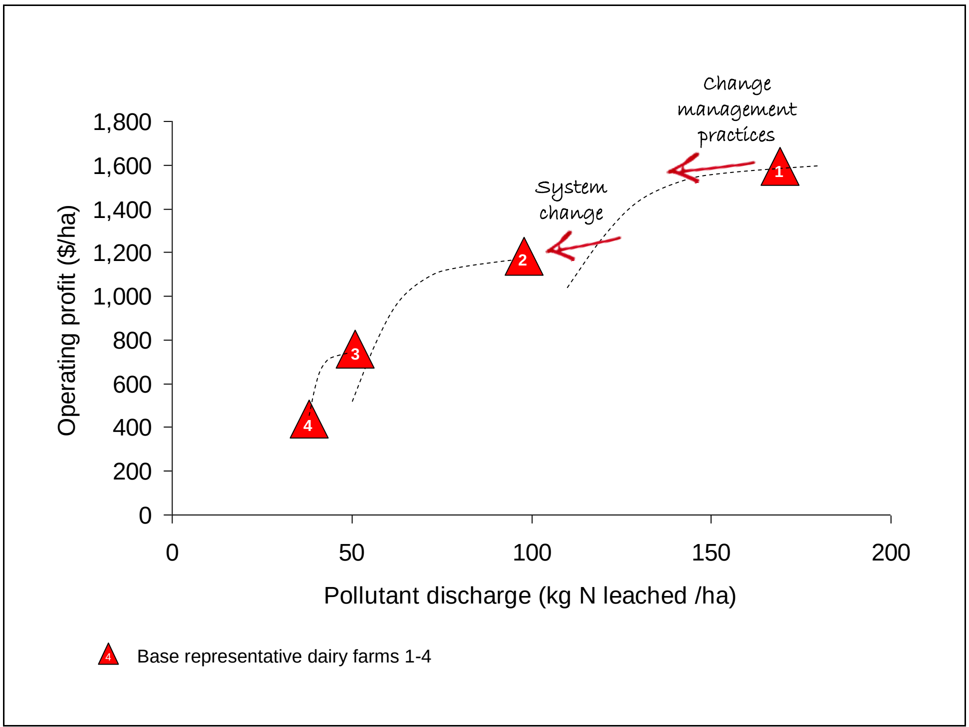

Figure 7. Profit-pollution frontier (indicative).

The dashed lines in Figure 7 indicate the hypothetical level of mitigation possible for each representative farm, and the associated decrease in profit, obtained by changing management practices. It is speculated that farm operators may move along this path by adopting increasingly expensive mitigations. Previous research by Monaghan *et al.* (2009), Roberts *et al.* (2011), and Doole and Pannell (2011a, b) suggest that the trade-off between pollutant reductions and mitigation costs is highly non-linear and that only low to moderate pollutant reductions can be achieved before farmers incur significant costs involving reductions in stocking rates. This research suggests that it is unlikely that more than 30-40% of pollutants can be abated without requiring a significant reduction in stocking rates, and hence a move to a less-intensive, and less-profitable, farming system (say from farm 1 to 2, 2 to 3, or 3 to 4).

Discussion and Summary

Declining terms of trade and increased urbanisation have led to greater intensification of land use on Victorian dairy farms over the last 30 years. This is reflected in increased stocking rates and milk yields, driven in turn by increased pasture production and use of supplementary feed (CIE 2011, Lubulwa and Shafron 2007).

The results of this study confirm that intensification of dairy farming systems will have an increasingly negative impact on the environment. Environmental assets such as the Gippsland Lakes already have significant nutrient issues and the dairy industry, an important contributor to the Victorian economy, is already targeted as a major contributor. The dairy industry and government policy makers need to be actively engaging in discussions about addressing environmental concerns associated with intensification.

Using detailed farm level survey data and biophysical modelling, operating profits and N losses were calculated for four representative dryland dairy farms in the Moe River catchment. The four representative dairy systems span the range of systems observed in the study area and are differentiated according to their reliance on fertiliser and supplementary feed usage, and hence on their intensity of resource use.

The calculated operating profits and N losses were used to construct an interim pollution-profit frontier for a particular soil type and climate and marginal abatement costs were also calculated. It was shown that more intensive systems are more profitable but also much more polluting in terms of N leaching. A reduction in the intensity of land use resulted in substantial profit and pollutant reductions of 25% or more. It was also shown that the cost of abatement in $/kg terms is cheaper for more intensively operated farms, reflecting the more substantial amount of N mitigated for a more moderate decline in profits.

As this paper has focused on dairy systems in the catchment, the profit-pollution frontier does not show enterprise change driven by the need to reduce pollutant loads to such an extent that it becomes more profitable to switch into alternative farming enterprises (e.g. beef production), or, ultimately to retire land from agriculture (to non-commercial native forests, for example).

The analysis explicitly considered dairy farm heterogeneity, albeit not to the extent outlined by Doole and Pannell (2011b) - and arguably insufficiently because the more intensive farms with fertiliser usage above 100 kg N/ha/year have much larger pollution loads and are widely spaced on the profit-pollution frontier.

Finally, the high marginal abatement costs for the more extensive systems that use 100 kg N/ha or less highlight the importance of including low cost management practices to mitigate N losses. The inclusion of these practices in the analysis would reduce the average abatement cost for each farm type, and may obviate the need for costly stocking rate reductions and possibly even land-use change under ambitious pollution reduction targets of 30% to 40% or more.

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