Economic value of improved soil natural capital assessment: a case study on nitrogen leaching

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Abstract
Soil survey is fundamental to assessing soil natural capital. However, over recent years there has been minimal investment in improving the quality of NZ soil survey, possibly due to poor articulation of the economic value. This paper demonstrates a positive benefit to both the farming and general community from the combination of a new soil survey, nitrogen leaching measurements, and a new mitigation technology to reduce N-leaching from dairy grazed pasture. In our study area the annual N-leaching is estimated to be approximately 25% greater than if estimated using data from the old soil survey. We argue that if nitrification inhibitors are applied to only 25% of our study area, the overall reduction in N-leaching can be improved by 10 t N/yr if the new soil map is used to target inhibitor application to the hotspot soils with the greatest N-leaching. We estimate the retained N is worth $42.49 per kg N for the farmers and the community. From this benefit alone, the cost–benefit ratio for the new soil survey is 1:6 in the first year. This study demonstrates the value of soil survey in soil natural capital assessment and its ability to provide a quick return on investment.

Key Words
Soil survey, soil natural capital, cost–benefit, nitrogen leaching.

Introduction
New Zealand (NZ) has had a patchy history of soil survey. The need for improved soil survey is well recognised within the land management industry (Manderson and Palmer 2006), but has yet to materialise as substantial investment. This may be due to the economic value of NZ soil survey not being clearly articulated to potential investors. Worldwide there are few studies that demonstrate the economic value of soil survey (Craemer and Barber 2007; Giasson *et al.* 2006). Craemer and Barber (2007) argue that if clear prospects exist for improved yields or farm returns, the private sector should have sufficient incentive to invest. They argue that the business case for public investment in soil information needs to be strongly linked to market failure and public good arguments. In Australia strong arguments for public investment exist in terms of basic research and development (e.g. natural capital assessment), externalities (e.g. groundwater pollution), and information failure (e.g. getting research findings to potential adopters). Investment may also be justified if data underpin an information value chain (i.e. basic research → applied research and innovation → end-user products and processes).

The concept of an information value chain is illustrated by the success of focus farms in NZ. Mackay *et al.* (1998) demonstrated a substantial potential economic return from using soil survey information to identify land management units on individual farms, for which the most suitable management practices could be matched. Cost–benefit analysis identified that if only 10% of NZ farmers adopted this approach and lifted profitability by 8%, then the return would be $20m per year over a 20-year period. A similar study analysed the cost–benefit ratio (CBR) of the monitor farm programme (MFP), where focus farms relevant to different geographical areas are used to demonstrate the value of new management techniques to the local farming community (Garland and Baker 1998). Local farmers reported a net benefit of $6,500 per year, resulting in a CBR of 1:20 in the first year.

In both these studies it is not possible to evaluate the net benefit arising directly from improved soil knowledge alone, as these projects integrate a range of management techniques. However, both of these studies support the argument that the value of improved soil survey extends beyond an assessment of soil natural capital, to underpinning an information value chain that identifies research findings relevant to a particular farm. The objective of this paper is to demonstrate the economic value that could arise from an improved assessment of soil natural capital in relation to nitrogen (N) leaching and the targeted application of a mitigation technology.

Materials and methods

Study area

The study area is located on the floodplains of the Mataura and Oreti rivers, Southland, New Zealand. The ecological health of these rivers is of high importance to the Southland community, with most of the population living in towns located adjacent to the rivers. The Oreti River is the water supply for Invercargill City, and the rivers have high recreation and ecological importance, both with renowned fisheries. Environment Southland (2008) report high ecological health in the upper reaches, but the middle and lower reaches are in poor health, exceeding the nitrate-nitrite nitrogen, total phosphorus, faecal coliform, and visual quality national standards set for lowland rivers (ANZEEC 2000).

Down-river trends in river health follow land use. In the upper catchment land use is mostly low intensity sheep and beef grazing or conservation land. In the middle to lower reaches intensive pastoral agriculture is the dominant land use, with an even distribution of sheep (32%), mixed sheep and beef (21%), and dairy (30%). In this study we focus on the 17 706 ha of land used for dairy farms, which are recognised as "hotspots" responsible for most non-point-source N pollution from agricultural land in NZ (Monaghan *et al.* 2008). Dairy farming is a growth industry in Southland, doubling in land area over the last decade to effectively 130 000 ha in 2008 (LIC 2008).

Soil survey

Until recently our study area was reliant on soil information from a soil survey at 1: 250 000 scale. Map units and soil types were carried through in later land resource inventory maps at 1:63 360 scale, which are still used today for national planning. In 1998–2001 there was a major community initiative to remap 800 000 ha of the Southland lowlands at a scale of 1: 50 000. In 2001 the total cost of the new soil survey was c. $2.5m, or c. $3.13 /ha (S Carrick, unpublished data).This cost includes field survey, laboratory analysis, and map production.

The ecosystem service of nitrogen retention

Nitrogen leaching is calculated for the study area based on the old and new soil surveys. Greenwood (1999) measured nitrate leaching from dairy grazed pasture on different Southland soil types over a one-year period (1998–1999) and under the same stocking intensity (2.4 cows/ha). This study showed marked differences in N-leaching between soil types under similar management (Table 1). These results correlate with later research where N-leaching from cow urine patches was approximately double on the stony compared with deep soils (Di and Cameron 2005, 2007).

Monaghan *et al*. (2008) evaluated the economic return to dairy farmers from N-leaching mitigation techniques across four NZ catchments. Nitrification inhibitors were the most promising mitigation technique, with a net benefit in 2005 of $16 per kg N retained for the case study farm in the Waikakahi catchment, which has similar soils to our study area. Monaghan *et al*. (2008) assumes the inhibitors achieve a 30% reduction in N-leaching, which is much lower than experimental results (c. 50–70%) but is a conservative reduction generally accepted by industry to recognise that more research is required before specific reductions can be quantified for different environments and management.

An estimate of the economic value for the general community of retaining N can be transferred from the N-trading scheme established for Lake Taupo, NZ. Within the catchment a nitrogen leaching cap has been implemented, allowing farmers a maximum Nitrogen Discharge Allowance (NDA). The only official trader at present is the publicly funded Lake Taupo Protection Trust; set up to achieve a 20% reduction in nitrogen loading by 2021. The trust will pay farmers to permanently reduce nitrogen leaching through land-use change. In 2004 the budgeted average cost for compensation was $425 per kg N (Environment Waikato 2007), which over an infinite lifetime and 5% discount rate equates to $21.80/kg N/yr.

The improved estimation of N-leaching in our study area allows targeting mitigation to high-N-leaching soils. The value added by targeted mitigation is compared with the cost of the new soil survey, with both standardised as 2009 NZ$ by adjusting for inflation. In our calculations the 2009 soil survey cost is $3.99 per hectare, and the value of the retained N is $42.49 per kg ($17.30 per kg for farmers, $25.19 per kg for the community). We assume that inhibitors achieve a 30% reduction in N-leaching.

Results

Natural capital assessment

Management of non-point-source pollution is dependent on a reliable inventory of the soil natural capital. In our study area the old soil map identified a single soil type, characterised as a well-drained Recent Soil formed into deep fine alluvium (Table 1). The new soil map shows that less than 17% of the area is the original soil type. Most of the area was mapped as either stony or poorly drained soils.

Table 1. Comparison of soil attributes and annual nitrate leaching from our study area, when using data from either the old or new soil survey.

Map	Soil type	NZSC order[A]	Depth of fines	Drainage	Area (ha)	Area (%)	N-leaching (kg N/ha/yr)	Estimated study area total N-leaching (t N/yr)
Old	Recent	Recent	Deep (>0.45 m)	Well	17706	100	50	885
New	Recent	Recent	Deep	Well	2946	17	50	147
	Stony	Recent + Brown	Stony (<0.45 m)	Well	5020	28	70	351
	Brown	Brown + Pallic	Deep	Well	3702	21	50	185
	Gley	Gley	Deep	Poor	4940	28	70	346
	Pallic	Pallic	Deep	Poor	534	3	70	37
	Gley	Gley	Stony	Poor	512	3	70	36
	Peat	Organic	Deep	Very Poor	53	0.3	Not studied	

[A]New Zealand Soil Classification (Hewitt 1998)

Ecosystem service of nitrogen retention

Based on the results of Greenwood (1999) the new survey estimates N-leaching in the study area of 1103 t N/yr, which is 24.6% greater than if predicted from the old soil map. The estimate of N-leaching is likely to be conservative, as the average 2008 stocking intensity was 2.8 cows/ha (LIC 2008), higher than the 2.4 cows/ha in Greenwood (1999). Table 1 does not also take into account N-leaching from paddocks that receive applications of dairy shed effluent, where Greenwood (1999) measured N-leaching to be 28–57% greater than grazed paddocks.

Economic value of the new soil map

The middle to lower Mataura and Oreti rivers have poor ecological health, and it is arguable that farmers and the community are legally obliged to improve water quality in order to met national standards. Nitrification inhibitors provide one option to reduce N-leaching and give a positive economic return to farmers (Monaghan *et al.* 2008). The new soil map shows that the hotspots of N-leaching are the poorly drained and stony soils (Table 1), and therefore these should be targeted for inhibitor use.

If the farmers and community decide an achievable target is to apply inhibitors to 25% of the study area, and the new soil map was used to target the hotspot soils, then the expected reduction in N-leaching would be 93 t N/yr. Without the new soil map the expected N-leaching reduction would be less, as hotspot targeting would not be possible, and we would expect at least 38% of the inhibitor to be applied to soils with lower N-leaching (Table 1). As such the expected reduction in N-leaching would fall to 83 t N/yr. Under this scenario, use of the new soil map is able to improve the reduction in N-leaching by 10.25 t N/yr. The cost of surveying the study area is $70,605, meaning a 10.25 t saving of N would require $6.42 per kg N in added benefit to recover the survey costs in the first year. We have estimated the added benefit of the retained N is $42.49/kg N/yr, which is well above that needed to recover the survey costs in the first year. We recognise the value of retained N may vary between catchments, but it is unlikely to be substantially lower in our study area given the concerns over water quality.

Using our estimate of the value of the retained N, the CBR of the new soil map would be 1:6 in the first year of targeting inhibitor application to hotspot soils. However, application of inhibitors to 25% of the study area only achieves an 8.4% reduction in the total N-leach. If research shows that improved water quality requires the N-leach reduction to be at least 15%, as is the case in the Lake Taupo catchment, then it would be necessary to apply inhibitors to about 50% of the area. If all of the application was targeted at the hotspot soils identified in the new soil map, the CBR for the first year would increase to 1:13.

Conclusions

This paper demonstrates a net positive benefit to both farmers and the general community from the combination of a new soil survey and a new mitigation technology to reduce N-leaching. It would appear that there is a sound business case for joint investment by the private and public sectors to improve the quality of NZ soil survey. The study also underlines the need for the development of value chains that will enable economic benefits of new knowledge on soil natural capital to be realised. While this paper demonstrates the economic benefit of the new soil map, it accounts for only one ecosystem service. Accounting for other soil services might add further benefits.

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