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

Sam Carrick[A], Eva-Terezia Vesely[A], Allan Hewitt[A]

[A]Landcare Research, PO Box 40, Lincoln 7640, New Zealand

Abstract
Soil survey is fundamental to soil natural capital assessment. 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 clear positive benefit to both the farmer and the 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 24.6% greater than if 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^{-1} if the new soil map is used to target the inhibitor application to the hotspot soils with the greatest N-leaching. Such targeting could save the farmers and the community \$363 000 yr^{-1}, with a cost benefit ratio for the soil survey of 1:7 in the first year of targeted N-leaching mitigation. This study demonstrates the value of soil survey in soil natural capital assessment and its ability to provide a return quick return on investment.

Keywords: 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, and worldwide there are only 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 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). Public investment could also be justified for building a knowledge infrastructure, where there is little value to soil information itself unless it is combined with other skills and knowledge, and is of relevance to final users (Craemer and Barber 2007; Manderson and Palmer 2006). Investment in soil survey can be justified if the data and maps underpin an information value chain (i.e. basic research → applied research and innovation → end-user products and processes). Unfortunately in both Australia and NZ a soil knowledge infrastructure is not strongly developed. It is argued that there is substantial information failure, with poor uptake and use of soil information, which impedes optimum generation of value from soil information (Craemer and Barber 2007; Manderson and Palmer 2006).

The concept of building a knowledge infrastructure to underpin an information value chain and overcome information failure is illustrated by the success of focus farms in NZ. MacKay et al. (1999) demonstrated a substantial potential economic return from using soil survey information in farm planning. Their approach used land resource information as the basis to identify land management units on individual farms, for which the most suitable best management practices could be matched. On the two farms of their study they showed that six of seven alternative management strategies were more profitable than the status quo. Using cost/benefit ratio analysis (CBR) it was identified that if only 10% of NZ farmers adopted this approach and lifted profitability by 8%, then the return would be \$20 million yr^{-1} over a 20 year period. A similar study analysed the CBR of the monitor farm programme (MFP), where focus farms relevant to different geographic area's are used to demonstrate the value of new management techniques to the local farming community (Garland and Baker

1998). Local farmers who attended MFP events reported a net benefit of \$6500 yr^{-1}, resulting in CBR of 1:20 in the first year.

In both these studies it is not possible to evaluate the net benefit arising directly from just improved soil knowledge, 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 acting as an information transfer platform used to identify research findings relevant to a particular farm. The objective of this paper is to demonstrate the economic value that could arise directly from an improved assessment of soil natural capital, in relation to estimating nitrogen (N) leaching and the effectiveness 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, with both renowned trout and whitebait fisheries. Environment Southland (2008) report high ecological health in the upper reaches, but the mid 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.

Down-river trends in river health follow landuse. In the upper catchment landuse is mostly low intensity sheep and beef grazing or conservation land. In the mid to lower reaches intensive pastoral agriculture is the dominant landuse, 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 pollution from agricultural land in NZ (Monaghan *et al.* 2008). Consequently there is also a large body of research literature on nutrient losses and mitigation techniques for dairy farms. Dairy farming is a growth industry in Southland, doubling in land area over the last decade to 130,000 effective ha in 2008 (LIC 2008).

Measuring soil natural capital

Until recently our study area was reliant on soil information from a 1: 250 000 scale soil survey. Map units and soil types were carried through in later 1:63 360 land resource inventory maps which are still used today for national planning (Landcare Research 2009). 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. After map units were delineated at least one soil pit was used to characterise the attributes for each soil type to one metre depth, with a total of 66 pits used to characterise soils on the Matuara and Oreti floodplains.

Valuing the ecosystem service of nitrogen retention

In New Zealand an N-trading scheme is being established for Lake Taupo. Within the catchment a nitrogen leaching cap has been implemented, allowing farmers a maximum Nitrogen Discharge Allowance (NDA) based on the highest leaching year between July 2001 and June 2005. The rules allow farmers to buy, sell, or lease nitrogen from other land owners in the catchment to alter their NDA. The only official trader at present is the Lake Taupo Protection Trust; set up to achieve a 20% reduction in nitrogen loading by 2021. The publicly funded trust will pay farmers to permanently reduce nitrogen leaching through land use change, compensating farmers for the reduction from their NDA. At present compensation is in the range of \$300 – 400 kg^{-1} N. This represents the value the community is willing to pay to maintain the lake water quality, which over the 15 year lifetime of the trust equates to \$20 - 26 kg^{-1} N yr^{-1}. The economic value to a farmer of retaining nitrogen has also been estimated by Monaghan et al. (2008), who evaluated the economic return to dairy farmers from a number of N-mitigation techniques across four different New Zealand catchments. Nitrification inhibitors were the most promising mitigation technique, with an average net benefit of \$16 kg^{-1} N retained for the Waikakahi catchment which has very 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.60-70%), but is a conservative reduction generally accepted by industry. In the calculations of our study we also assume that inhibitors achieve a 30% reduction in N-leaching, and the economic value of the retained N is worth \$36 kg^{-1} (\$16 kg^{-1} for farmers, \$20 kg^{-1} for the community).

Cost of soil survey
The total cost of the new soil survey was ~\$2.5 M, or ~\$3.13 ha^{-1}. This is similar to the \$3.70 ha^{-1} estimated by Manderson and Palmer (2006).

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 the old soil map provided a very poor soil natural capital assessment. Table 1 shows that less than 17% of the area was mapped as 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	Depth of fines	Drainage	Area (ha)	Area (%)	N-leaching (kg N ha^{-1} yr^{-1})	Estimated study area total N-leaching (t N yr^{-1})
Old	Recent	Recent	Deep (>0.45 m)	Well	17706	100	50	885.3
New	Recent	Recent	Deep	Well	2946	17	50	147.3
	Stony	Recent + Brown	Stony (<0.45 m)	Well	5020	28	70	351.4
	Brown	Pallic + Brown	Deep	Well	3702	21	50	185.1
	Gley	Gley	Deep	Poor	4940	28	70	345.8
	Pallic	Pallic	Deep	Poor	534	3	70	37.4
	Gley	Gley	Stony	Poor	512	3	70	35.8
	Peat	Organic	Deep	Very Poor	53	0.3	*Not studied*	

Ecosystem service of nitrogen retention
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 per ha^{-1}). 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 to deep soils. Based on the results of Greenwood (1999) the new survey estimates the study area N-leaching of 1103 t N yr^{-1}, which is 24.6% greater than if predicted from the old soil map. The estimate of N-leaching is also likely to be conservative, as the average 2008 stocking intensity was 2.8 cows per ha^{-1} (LIC 2008). 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
It clear that the Mataura and Oreti Rivers have poor ecological health, and it is arguable that farmers and the community are legally obliged to improve water quality to met national standards. Nitrification inhibitors are an obvious choice, as they are capable of achieving a reduction in N-leaching and a positive economic return to farmers (Monaghan *et al.* 2008). The new soil map shows that the hotspots of N-leaching in our study area are the poorly drained and stony soils (Table 1), and therefore should be targeted for inhibitor use.

If the farmers and community decide that an achievable target is to apply inhibitors to 25% of the study area, and the new soil map was used to target only the hotspot soils, then the expected reduction in N-leaching would be 93 t N yr^{-1}. 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^{-1}. Under this scenario use of the new soil map is able to improve the reduction in N-leaching by 10 t N yr^{-1}. If the retained N is worth \$16 kg^{-1} N yr^{-1} to the farmer and \$20 kg^{-1} N yr^{-1} to the community, the value of the knowledge from the new soil map is \$363 000 yr^{-1}. The CBR of the new soil map would be 1:7 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 Taupo, 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 would then increase to 1:13. It is also important to note that whilst this paper demonstrates a clear economic benefit of the new soil map, this is accounts for only one ecosystem service. Taking other soil services into account will add further benefits.

Conclusions

This paper demonstrates a clear net positive benefit to both the farmer and the 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 soil natural capital knowledge to be realised.

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