IMPACT OF ON-FARM BUILT INFRASTRUCTURE INVESTMENTS ON THE PROVISION OF ECOSYSTEM SERVICES: IRRIGATION FOR DAIRY SYSTEMS IN NEW ZEALAND

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ABSTRACT

Many of the on-farm built infrastructure investments to lift production often address inherent weaknesses in the farm's natural capital stocks. Investment in irrigation water immediately removes a constraint to pasture growth, by compensating for a lack of soil water holding capacity, often compounded by the lack of seasonal precipitation. This study explores the changes to the provision of ecosystem services beyond the provision of food from a dairy grazed system following the introduction of additional available water through awater take and investment in irrigation infrastructure. The changes in the flow of services, beyond food quantity and quality, including the support for human infrastructures and farm animals, fresh water availability, flood and drought mitigation, filtering of nutrients and contaminants, decomposition of wastes, net carbon storage, greenhouse gases regulation, and regulation of pests and diseases, were quantified using soil and pasture data collected from irrigated and rain fed pastures over several years, as well as from the use of Overseer® nutrient budget model. Neo-classical valuation techniques such as market prices, provision and replacement costs and defensive expenditure were then used to determine the economic value of resulting services.

An investment in irrigation infrastructure on a 250ha dairy farm on the sand country in the Manawatu enabled milking cow stocking rate to be lifted from 2.5 to 3 /ha, milk production increased from 875 to 1200 kgMS/ha/yr, while modelled N losses increased from 33 to 61 kgN/ha/yr. Introduction of water through irrigation increased the value of services from $5,288 to $7,678/ha/yr. The cost benefit analysis (BCA) of an investment in irrigation when limited to the value of the increased flow of provisioning (e.g. food production) services, revealed a positive net present value (NPV) over 10 years. When the costs of mitigating the additional N and P losses to the environment, associated with the introduction of irrigation and associated production increases, were factored in the BCA, the NPV of the investment was no longer positive, but a net negative. Inclusion of the change in the economic value of all the ecosystem services from the addition of irrigation water, along with the inclusion of the mitigation costs turned the NPV of the investment positive. This study provides an insight into the type of analysis required to inform future debates about the use of our finite resources within boundaries.

INTRODUCTION

Today's intensive agricultural systems are the product of combining and using built capital, alongside natural resources (e.g. land, water). Many on-farm built infrastructure investments to increase production address a direct lack of provision of the required ecosystem services from the soil's natural capital. Investment in irrigation immediately removes water as a constraint to pasture growth by compensating for a lack of soil water holding capacity, in addition to a lack of seasonal rainfall. The net effect is these built or added capital investments have the ability to mask or hide the contribution and hence the condition of the underlying natural capital stocks to the on-going provision of ecosystem services (ES).

An ecosystem service approach offers a method for separating out and assessing the contribution from both the inherent natural capital and built capital. It also offers a new lens for assisting in decision making, by enabling an assessment of the merits of new technologies to limit and mitigate degradation, maintain and enhance natural capital stocks as well as improve the provision of all ecosystem services, not just yield, which is still too often the case.

This study explores the changes to the provision of all ecosystem services from a dairy grazed system following an investment in irrigation infrastructure.

METHODOLOGY

The base dairy operation considered in this study is a constructed operation situated in the coastal sand country in the Manawatu in New Zealand. A farm consultant active in the District was interviewed and provided data on farm practices and performance before and after the installation of irrigation, in addition to average farm financials.

The 250 ha rain fed dairy operation included a permanent pasture grazed by 2.5 milking cows/ha, producing 875 kgMS/ha/yr, receiving fertiliser N and P (Table 1). Pasture silage is made from the farm in spring and fed to the cows as supplements in combination with imported supplements. A percentage of the herd is grazed-off in winter. The Districts average annual rainfall is 880mm.

Table 1: Farm properties

	Dry Pastoral block	**Management change block**	
Properties		**Dry**	**Irrigated**
Area (ha)	80	90	90
Soil type	Carnavon	Himatangi	Himatangi
Soil order	Gley	Brown	Brown
Soil group	sand	Sand	Sand
Drainage	poor	moderately well	moderately well
Stocking rate (cows/ha)	2.5	2.5	3
Irrigation (mm/yr)	0	0	360
Milk production (kgMS/ha/yr)	875	875	1200
N fertiliser (kgN/ha/yr)	140	115	196
P fertiliser (kgP/ha/yr)	36	36	48
Olsen P	30	30	30
ASC	43	35	35

For the purpose of this study, the addition of irrigation on a 90ha block of the farm was modelled using the OVERSEER® Nutrient Budget. This investment led to a number of changes in the management of that block. Milking cow stocking rate increased from 2.5 to 3 cows/ha, milk production increased from 875 to 1200 kgMS/ha/yr, as did the amount of fertiliser applied and supplements fed (Table 1).

The introduction of irrigation to the permanent pasture grazed by dairy cows, together with higher stocking rates, generate changes to soil natural capital stocks and thereby the provision of ecosystem services. The changes in the flow of services, including food quantity and quality, support for human infrastructures and farm animals, fresh water availability, flood and drought mitigation, filtering of nutrients and contaminants, decomposition of wastes, net carbon storage, greenhouse gases regulation, and regulation of pests and diseases, were quantified over 10 years after the addition of irrigation using data from the literature (Houlbrooke et al. 2011; Kelliher et al. 2013) on soil and pasture change under irrigation.

Neo-classical valuation techniques such as market prices, provision and replacement costs and defensive expenditure were then used to determine the economic value of services. For details of the methodology to calculate ecosystem services indicators and their economic value, we refer the reader to Dominati et al., (2014b).

A cost benefit analysis (CBA) over 10 years of an investment in irrigation was undertaken to consider a range of different scenarios including the increase in milk production, the costs of mitigating the additional N leaching losses to the environment, and the economic value of ecosystem services.

RESULTS AND DISCUSSION

Results presented are for the pastoral block when rain fed and after the introduction of irrigation. An investment in irrigation enabled milking cow stocking rate to be increased from 2.5 to 3 /ha, milk production from 875 to 1200 kgMS/ha/yr, while modelled N losses increased from 33 to 61 kgN/ha/yr and modelled P losses from 0.1 to 0.2 kgP/ha/yr.

The overall value of the ecosystem services provided by the paddocks following the introduction of irrigation was increased by 44% from $5,288 to $7,678/ha/yr (Figure 1). The addition of irrigation increased the provision of both provisioning and regulating services but at the same time the losses to the environment (+85% N loss and +100% P loss) also increased.

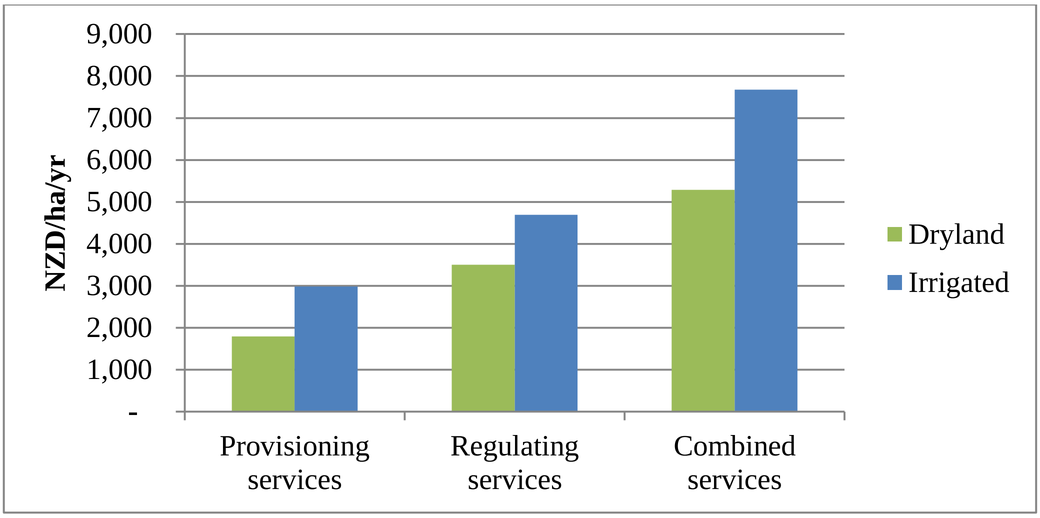

Figure 1: Economic value (NZD/ha/yr) of the ecosystem services provided by the irrigated block, before and after the installation of irrigation.

The CBA of an investment in irrigation reveals a positive net present value (NPV) over 10 years, when the analysis was limited to the increase in the flow of provisioning (e.g. food production) services (Figure 2). When the costs of mitigating the additional losses to the environment (N, P and N_2O losses) associated with the introduction of irrigation were factored in the BCA, the NPV of the irrigation investment became negative.

Adding the economic value of all the ecosystem services (i.e. regulating in addition to provisioning) to the BCA returned the NPV positive, even with the inclusion of the mitigation costs (Figure 2).

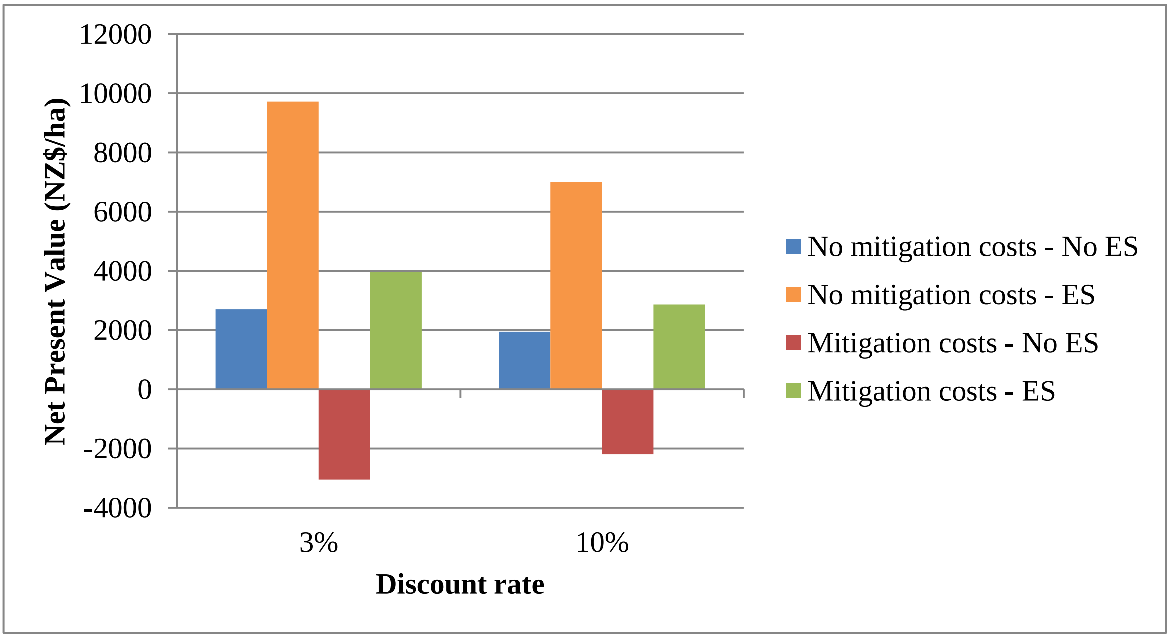

Figure 2: Net present value (NZ$/ha) over 10 years of the 4 scenarios considered, for 2 discount rates.

An ecosystem services approach has potential to make visible the environmental performance of an agro-ecosystem, and can inform how best to integrate built infrastructure, such as irrigation in this study, or ecological infrastructure (Dominati et al. 2014a) into the farming system to achieve multiple goals such as improving the delivery of provisioning and regulating services while maintaining or decreasing the environmental footprint of the system. The exercise realised in this study can be repeated for a range of management practices to better adapt the irrigation to the farming system and the boundaries associated to its natural resources (e.g. topography, soil type, climate). An ecosystem services approach, because it is based on the performance of the system as a whole, provides information for decision making beyond standard management practise evaluation.

CONCLUSION

This study showed an example of how an understanding of the links between ecosystem services provision and outcomes at different scales can inform the performance of an agro-ecosystem as well as decision about how to best integrate built infrastructure into the farming system for multiple outcomes.

An ecosystem services approach can also help switch the focus from compensating for a lack of natural capital with added built capital to increasing natural capital stocks, and investing in ecological infrastructures (Bristow et al. 2010; Jury et al. 2011), matching land use with land capability and enhancing the ecosystem services provision from the land by managing condition (McBratney et al. 2014). Further it opens the door on exploring the viability of an investment that changes natural capital stocks (e.g. increasing water holding capacity), by enabling an analysis of the influence that then has on the flow of services over time.

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