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Research article

Integrating forest ecosystem services into the farming landscape: A stochastic economic assessment

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ABSTRACT

The objective of this study was to assess how payments for ecosystem services could assist plantation forestry's integration into pastoral dairy farming in order to improve environmental outcomes and increase business resilience to both price uncertainty and production limits imposed by environmental policies. Stochastic Dominance (SD) criteria and portfolio analysis, accounting for farmers' risk aversion levels, were used to rank different land-use alternatives and landscapes with different levels of plantation forestry integration. The study was focused on a modal 200-ha dairy farm in the Lake Rotorua Catchment of the Central North Island region of New Zealand, where national environmental policies are being implemented to improve water quality and reduce greenhouse gas emissions. Nitrogen and carbon payments would help farmers improve early cash flows for forestry, provide financial leverage to undertake afforestation projects and contribute to improved environmental outcomes for the catchment. The SD criteria demonstrated that although dairy farming generates the highest returns, plantation forestry with nitrogen and carbon payments would be a preferred alternative for landowners with relatively low risk aversion levels who consider return volatility and environmental limits within their land-use change criteria. Using the confidence premium concept, environmental payments to encourage plantation forestry into the landscape were shown to be lower when the majority of landowners are risk averse. The certainty equivalence approach helped to identify the optimal dairy-forestry portfolio arrangements for landowners of different levels of risk aversion, intensities of dairy farming (status quo and intensified) and nitrogen prices. At low nitrogen prices, risk neutral farmers would choose to afforest less than half of the farm and operate at the maximum nitrogen allowance, because dairy farming at both intensities provides the highest return among the different land uses available. However, at relatively low risk aversion levels, farmers would operate at levels below the maximum nitrogen allowance by including plantation forestry to a greater extent, compared to risk neutral farmers, due to its more certain returns. At a high nitrogen price of $400/kg, plantation forestry would completely subsume dairying, across risk aversion and intensity levels. These results confirm that plantation forestry as well as being an environmentally sound land-use alternative, also reduces uncertainty for landowners that are exposed to volatile international markets for dairy commodities.

1. Introduction

Exponential world population growth has sparked the need for more intensive and industrial production systems in agriculture (more product per hectare) and, hence, higher use of inputs (fertilizer, pesticides, stock units, etc.) per unit of area (Tilman et al., 2002). Such industrialized agricultural systems are affecting natural endowments such as air, land and water through, for example, higher rates of Greenhouse Gas (GHG) emissions, erosion and nutrient leaching. Certain international and local environmental policies aim to internalize these negative externalities produced by the intensification of agriculture (Pretty et al., 2001). International policies, such as the Montreal and Kyoto Protocols, address natural phenomena that are of global concern such as climate change. Due to their more localized impacts, land and water endowments are mostly covered by national and local policies that seek to mitigate

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problems such as erosion and nutrient leaching.

Environmental policies, setting limits on resource use and quality, together with the increased price volatility of globalized markets add to the pressures faced by farmers to remain competitive. Stricter environmental regulations that limit the potential for higher production through increased fertilizer and energy inputs also constrain farmers' options to increase competitiveness. Dependence on non-subsidized international commodity markets further adds to the pressures exerted on farmers due to high price volatility especially in small developing and some industrialized economies (e.g. New Zealand) (Huchet-Bourdon, 2011). High price volatility affects farmers' ability to plan long term and may elevate interest rates for business.

Policymakers, national and international, have identified environmentally vulnerable or marginal land as a means to comply with the different environmental policies and concurrently reduced the aforementioned economic burdens faced by farmers (Parks, 1995; Djanibekov and Khamzina, 2016). In this study, the term environmentally vulnerable land refers to currently or potentially productive land with high nutrient leaching rates. Owners of such environmentally vulnerable lands could capitalize on these environmental policies through payments for ecosystem services or conservation. For example, in Costa Rica, landowners are paid for the provision of four ecosystem services: carbon sequestration, biodiversity conservation, hydrological services, and provision of scenic beauty for recreation and ecotourism (Pagiola, 2002; Goldstein et al., 2006). Furthermore, the Conservation Reserve Program in the U.S. pays farmers an annual rent to remove environmentally sensitive land from agricultural production and establish ecosystems that will improve environmental health and quality (USDA FSA, 2015). In New Zealand, the government-funded (i.e. tax and rate payers' funds) Lake Taupo Protection Trust pays farmers to permanently retire their nitrogen discharge allowances by either transitioning to production systems with lower environmental impacts or undertaking afforestation (Shortle, 2013).

Among the set of productive land-use alternatives, plantation forestry has been identified as the cheapest and most environmentally sound option for marginal land (Richards and Stockes, 2004; Djanibekov and Khamzina, 2016). The term forestry refers to plantation forestry throughout the text. Forestry provides both provisioning (e.g. timber production) and regulating services (e.g. highest carbon sequestration rates and lowest leaching levels compared to pastoral farming, cropping and horticulture) (Lewandrowski et al., 2004; Murray et al., 2005). Furthermore, forestry discharges the least amount of nutrients into water bodies among different land-use alternatives (Menneer et al., 2004); and as shown by Yao et al. (2013), offers other regulating and cultural services such as biodiversity, recreation and tourism.

Plantation forestry, like any other investment, has proven to be uncertain due to the long time horizons (price uncertainty and lack of revenues before harvest at 28–30 years for *Pinus radiata* in New Zealand), lack of knowledge of forestry practices and relatively high initial investment (afforestation costs) (Parks, 1995; Goldstein et al., 2006). High opportunity costs in certain parts of the world, due to the favorable market circumstances and tax incentives (e.g. non-taxable capital gain) for alternative land uses, have also challenged land-use decisions based on a purely economic (i.e. profit) and market-based criteria (Engel et al., 2015).

However, developing business strategies that capitalize on global or local environmental policies offering alternative revenue streams provides the opportunity for forestry to be integrated into the farming landscape in a manner that complements other land uses (e.g. dairy, sheep/beef cattle and horticulture). According to Goldstein et al. (2006), such "revenue streams could come from several sources, e.g., payments for ecosystem service provision, government conservation payments, partnerships with nongovernmental organizations, and sustainable production and natural resource extraction." With these payments, planted forests become more profitable, farms with forestry improve their environmental performance and, to an extent, their financial resilience. The farm portfolio could also include environmentally sound farm management practices such as reduction of stocking rates and nitrogen fertilizer applications, and effluent management among others. However, the point of the study is to show the economic potential offered by the forestry land-use alternative.

The lack of environmental policies rewarding the full set of ecosystem services (use and non-use) and their divergent non-market valuation approaches have to date precluded an objective comparison of the contributions of different land-use alternatives to society. However, it is of the utmost importance to assess forestry's economic and environmental contributions to farming when at least some ecosystem services can be monetized (e.g. carbon and water quality) through policy incentives. By internalizing a fraction of the potential benefits forests offer to society, afforestation would become more attractive as a land use to farmers, particularly those with marginal or environmentally vulnerable lands.

This background context prompted the objective of this study to quantify the contribution of ecosystem service payments to support the adoption of forestry as a complementary land use. It was hypothesized this would help farmers cope with price uncertainty and production limits imposed by environmental policies; and thereby improve the viability of their business. Stochastic dominance criteria and portfolio analysis, accounting for farmers' risk aversion levels, were used to rank different land-use alternatives and landscape structures at different levels of forestry integration.

New Zealand provides an ideal location for this study due to the comprehensive nature of policies addressing climate change and water quality issues. Over the last decade, intensification of New Zealand's dairy farming has raised public concerns due to the declining quality of some of its most iconic water bodies (Parliamentary Commissioner for the Environment, 2012, 2013). The dairy industry's dependence on international markets contributes to high price volatility and directly affects farmers' financial position (Nolan, 2013; Kiernan, 2013).

The New Zealand Emissions Trading Scheme (ETS) and the National Policy Statement for Freshwater Management (NPS-FM) present farmers with opportunities to access alternative revenue streams, instead of paying monetary penalties, and reduce farm business risk by incorporating forestry into their portfolio of land use. The ETS is a domestic implementation of the United Nations Framework Convention on Climate Change (UNFCCC) to meet New Zealand's international obligations around climate change. It assigns a price to a recorded New Zealand (NZU) Unit of GHG sequestered, representing a tonne of CO_2e, to provide an incentive to reduce emissions while encouraging tree planting (Ministry for the Environment, 2007). The NPS-FM is a working framework for councils to set objectives, policies and rules about freshwater quality and quantity in their regional plans. While council information on water quantity and quality should assess the current state of water and support the negotiation of objectives, the community will assess the ways and timeframes to meet the objectives (Ministry for the Environment, 2014).

The paper is structured as follows: (1) justification for the use of stochastic dominance ranking criteria among other alternative approaches; (2) characteristics of the most important region in New Zealand for the dairy and forestry industries; (3) description of the methodology and data sources used; (4) interpretation of results and sensitivity analysis; and (5) conclusions and recommendations for further studies.