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Modeling the impact of carbon farming on land use in a New Zealand landscape

Jason M. Funk [a,*], Christopher B. Field [b,1], Suzi Kerr [c,2], Adam Daigneault [d,3]

[a] Environmental Defense Fund, 1875 Connecticut Ave. NW, Washington, DC 20009, USA
[b] Department of Global Ecology, Carnegie Institution of Washington, 260 Panama St. Stanford, CA 94305, USA
[c] Motu Economic and Public Policy Research, Level 1, 97 Cuba Street, PO Box 24390, Wellington 6142, New Zealand
[d] Manaaki Whenua/Landcare Research, 231 Morrin Road St Johns Auckland 1072, Private Bag 92170 Auckland Mail Centre, Auckland 1142, New Zealand

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ABSTRACT

The opportunity for private landowners to receive carbon credits from reforestation, or "carbon farming," will change the relative value of land uses for landowners, potentially having an impact on land-use decisions. We constructed a spatial model to evaluate the potential scale and location of carbon farming in a New Zealand landscape, the size of resulting carbon stocks, and the economic trade-offs for landowners considering carbon farming. We modeled the carbon accumulation, economic value, and potential uptake of a carbon farming management system that utilized native forest regeneration on set-aside land.

For the study area, the Gisborne District of New Zealand, we found that regrowth of native forest species on estimated Kyoto-eligible marginal pasture has the technical potential to store 104.2 Mt CO_2-e over 70 years over 379,000 eligible hectares. We found 102,951 ha where the potential economic revenues from carbon in our most conservative scenario could generate NZ$912 million in excess of expected grazing revenues over 70 years of forest regeneration. Our results suggest that reforestation could out-compete grazing on at least 27% of eligible land in the Gisborne District. Sensitivity analysis shows that uncertainty about the scale of carbon sequestration can have a sizeable effect on the estimated profitability of carbon farming, but estimated land conversion is strongly affected by the choice of discount rates among landowners and the utilization of compatible incentives for other environmental services. Potential profits from carbon farming are strongly affected by the uncertainty of the future value of carbon credits.

1. Introduction

Policy incentives for land management activities that sequester carbon create a shift in the rewards for different land uses available to landowners. Here, we develop an approach to estimate the impact of these rewards on land use for a New Zealand landscape by (1) developing a modeling methodology for quantifying the spatial and temporal dynamics of potential carbon sequestration, (2) examining the revenue potential

* *Corresponding author*. Tel.: +1 202 572 3388.
E-mail addresses: jfunk74@gmail.com, jfunk@edf.org (J.M. Funk), cfield@ciw.edu (C.B. Field), suzi.kerr@motu.org.nz (S. Kerr), daigneaulta@landcareresearch.co.nz (A. Daigneault).
[1] Tel.: +1 650 462 1047.
[2] Tel.: +64 4 939 4250.
[3] Tel.: +64 9 574 4100.

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under a variety of carbon price scenarios, (3) exploring the impact of concurrent incentives for reforestation, and (4) comparing the expected revenue from reforestation with expected returns from grazing.

New Zealand adopted a policy in 2007 called the Permanent Forest Sink Initiative (PFSI), which creates a mechanism for landowners to receive carbon credits for eligible forests on their lands (MAF, 2007b). Under New Zealand's domestic rules, any net conversion of land use to new forests after the baseline date of January 1, 1990 is considered eligible to receive carbon credits.

The availability of carbon credits to private landowners will increase the economic value of reforestation on eligible lands. Other incentives, such as non-timber forest products and subsidies for erosion control or biodiversity protection can provide additional revenues for permanent forests. Therefore, landowners who manage their land to comply with one or more of these programs can earn multiple revenues from a single block of land. For some lands, the additional revenue earned from carbon credits may make forest regrowth economically competitive with other land uses. To encompass all of these possibilities, we use the broad term "carbon farming" to refer to any land use in which landowners capture economic benefit linked to the amount of carbon sequestration.

Although this definition could also include timber plantations, in the analysis presented here, we examine a land management system that utilizes native forest restoration to earn carbon credits through the PFSI. We analyze native forest regeneration for several reasons: (1) because the potential for carbon policy to trigger expansion of the extent of native forests is important ecologically and culturally, (2) because native forests deliver a greater variety of ecological co-benefits than timber plantations, and (3) because the conditions necessary for earning credits would require substantial changes to the current management regimes of timber forests, which is not the focus of this work. Nevertheless, we recognize that under some conditions, a modified system of timber forestry to include carbon credits may be optimal in many places.

Our purpose is to identify areas and conditions where a carbon management system could compete economically with grazing. By mapping these areas spatially, we estimate the areas of potential conversion and the total resulting carbon sequestration in the region, as well as identify areas of higher or lower revenue potential from carbon farming. For this study, we examined the Gisborne District of New Zealand – a district with large areas of marginal grazing land, where native tree species quickly invade pastures with low grazing pressure, and where indigenous Māori landowners often struggle to profitably manage large areas of communally owned land. To evaluate whether carbon farming could be a beneficial enterprise, we compare the net present value of carbon farming and grazing over a long time horizon (70 years) in order to capture the long-term implications of a commitment to "permanent" reforestation. We also evaluate a variety of discount rates to reflect the different time preferences that landowners may apply to their land-use decisions.

1.1. *Research objectives*

This analysis had several objectives:

1. Model the amount of Kyoto credits that could be generated by the conversion of eligible land in the Gisborne District to native forest;
2. Model the economic revenue potential of these credits under several price scenarios;
3. Model how complementary incentives add to the value of native reforestation as a "carbon farming" land management system;
4. Compare carbon farming as a land use with the opportunity cost of grazing.

2. Study area: land-use and policy interactions

The Gisborne District in the North Island of New Zealand has a number of factors that could make it favorable for carbon farming. It is a large area (about 835,500 ha) dominated by rugged hills, and it has relatively small population of 44,460, of whom 19,758 (44.4%) self-identify as Māori, the indigenous people of New Zealand (Statistics New Zealand, 2013). Residents are relatively isolated and remote from access to markets. Geologically, much of the area has a high risk of landslides on steep slopes, especially slopes that have been cleared of trees (Phillips and Gomez, 2007; Glade, 2003). After a major cyclone caused extensive landslides in 1989, the NZ government sponsored a program called the East Coast Forestry Project (ECFP) to subsidize landowners planting trees on erodible areas.

In the Gisborne District, native forests can regenerate on abandoned pastures in a forest successional process that predominantly begins with the invasion of manuka tree species (*Leptospermum scoparium*), or sometimes kanuka (*Kunzea ericoides*). These pioneer species establish easily in pastures where grazing pressure is low (i.e. less than 2 stock units per hectare per year), which is frequently the case with hill country pastures in the Gisborne District, where carrying capacity is low (Landcare Research, 2000). Without periodic clearing, manuka typically sprouts from wind-dispersed seeds in pastures, grows through a shrub phase, and eventually matures as a closed canopy "scrub" phase of small Trees 6–10 m in height (Wardle, 1991; Stephens et al., 2005). Its rapid establishment and growth mean that some areas that were still pasture in 1990 were closed-canopy scrub by the beginning of the first Kyoto commitment period in 2008, even when managed for low-intensity grazing.

Native forests in various stages of maturity offer economically valuable goods and services. For instance, residents use native forests and scrub as a source of fuelwood, medicine, and food (Stephens et al., 2005). The manuka tree (*L. scoparium*) is used for medicinal tea and oil, and it supplies honey with unique antibacterial properties (Stephens et al., 2005; Allen et al., 1991; Molan and Russell, 1988). Manuka oil and honey from the Gisborne District are produced commercially and marketed internationally (Kerr, M., personal communication, 2006).