Land Use Policy xxx (2014) xxx–xxx

Contents lists available at ScienceDirect

Land Use Policy

journal homepage: www.elsevier.com/locate/landusepol

Enhancing ecosystem services through afforestation: How policy can help

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ARTICLE INFO

Article history:
Received 11 January 2014
Received in revised form 6 March 2014
Accepted 20 March 2014

Keywords:
Ecosystem services
Afforestation
Avoided erosion
Marginal land

ABSTRACT

We employ an integrated spatial economic model to assess the net private and public benefits of converting marginal agricultural land into forest plantations (afforestation) in New Zealand. For numerous locations, we conduct policy analysis considering the magnitudes of net private and public benefits of land use changes to determine whether a policy response is justified and, if so, to identify the appropriate policy instruments to encourage adoption of afforestation. Net private benefit is commonly negative, so much so, that in most cases no policy response is justified. However, in certain cases, net private benefits are slightly negative and public benefits are significantly positive justifying the use of positive incentives as the most appropriate policy instrument to encourage afforestation in New Zealand. The most commonly used policy instruments for afforestation in New Zealand, extension and awareness training, are found to be appropriate in only a minority of situations.

Introduction

New Zealand's land cover has undergone dramatic change over the past century. Much of the original native vegetation has been removed to make way for pastoral agriculture, which has led to increased soil erosion, especially in hilly areas (Hicks et al., 2000; Jansson, 1988; Rhodes, 2001). The demand for agricultural activities in New Zealand is likely to increase as the country's population is expected to increase to approximately six million by 2061 from the current level of 4.4 million (Statistics New Zealand, 2011) along with a continued growth in export markets forecasted across the dairy, meat and wool industries (MPI, 2012a,b). This extra pressure for agricultural land means that the country's soils may deteriorate further. Appropriate policy intervention could reduce this deterioration. It has been highlighted in the New Zealand context that the use of science to inform such policy intervention should focus on the appropriate interpretation of data, which considers knowns and unknowns while being free from a particular political agenda (Gluckman, 2011). Although the approach, which follows, capitalises on data from a forestry perspective to inform land use policy, the process by which this data is brought together caters to the aforementioned issues for informing policy intervention.

Millennium Ecosystem Assessment, 2005 (MEA) highlighted forests, including planted forests, as providing the greatest number of ecosystem services across all ten key ecosystems examined (cultivated, dryland, forest, urban, inland water, coastal, marine, polar, mountain and island). Ecosystem services are categorised into four broad groups: cultural, regulating, provisioning, and supporting services (De Groot et al., 2002; Dominati et al., 2010; Millennium Ecosystem Assessment, 2005). For the New Zealand planted-forest ecosystem, cultural services include aesthetic experience, native species conservation, and recreation. Main regulatory services include flood mitigation, water quality improvement, avoided erosion and carbon sequestration (Dymond et al., 2012). Provision of wood and fibre, and raw materials are the main provisioning services, while supporting services are the biological, chemical and physical processes which underpin the provision of the other services.

Planted forests in New Zealand are usually a monoculture of the exotic species *Pinus radiata* D.Don (radiata pine). A number of ecosystem services from these planted forests can be valued economically and some examples are given below. Timber production, a provisioning service, represents a significant part of

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http://dx.doi.org/10.1016/j.landusepol.2014.03.012
0264-8377/

New Zealand's economy. Logs were the fourth largest export in 2012, contributing over NZ$1.3billion in export earnings (Statistics New Zealand, 2012). Another ecosystem service from New Zealand forestry is carbon sequestration. New Zealand is the only country to include forestry in its Emissions Trading Scheme (ETS), which began in January 2008. The ETS provides tradable New Zealand Units (NZUs) to forest growers for sequestered carbon (MAF, 2011a). Reduced soil erosion is another important ecosystem service from planted forests. The cost of erosion in New Zealand has been estimated at approximately NZD$200 million annually (Dymond et al., 2012; Krausse et al., 2001). Finally, New Zealand has also been considered as one of the top 25 biodiversity hotspots globally due to its exceptional levels of endemism and high levels of habitat loss (Myers et al., 2000). Planted forests provide habitats to at least 118 threatened native species, which include iconic (e.g., brown kiwi, bush falcon) and non-iconic (e.g., native vascular plants) species (Brockerhoff et al., 2008; Pawson et al., 2010; Seaton et al., 2009).

Our goal is to build on a previous study (Dymond et al., 2012) that compared various trade-offs among ecosystem services across New Zealand. Dymond et al. (2012) focused on ecosystem services such as water availability, soil erosion, and carbon sequestration, whereas we focus on timber production, carbon sequestration, avoided erosion, and biodiversity provision. We also conduct a policy analysis that takes into consideration both the net public and private benefits of afforestation using a framework developed by Pannell (2008, 2009). This framework has been applied in different studies to identify policy mechanisms and encourage land use change (Cary and Roberts, 2011; Parra-López et al., 2009). However, as far as we know, the framework has not been employed to identify relevant policy instruments for land use changes associated with perennial crops such as forestry.

Much literature to date has recognised the inherently spatial nature of such ecosystem services (Bateman et al., 2011; Dymond et al., 2012; Wätzold and Drechsler, 2005) and Maes et al. (2012) have highlighted the reliance of policy on spatially explicit information describing ecosystem services. We extend this concept by developing a spatial economic model that has particular utility for policymakers because it:

- accounts for the value of the final ecosystem service benefits (Fisher and Turner, 2008);
- defines the ecosystem services to be valued according to relevant temporal and spatial scales (Fu et al., 2011);
- uses a safe minimum-standard approach to avoid introducing uncertainty from potentially overlapping valuation methods that are typically used for biodiversity valuation (e.g., choice modelling, contingent valuation) (Bateman et al., 2011);
- differentiates between public and private benefits (Pannell, 2008) to avoid potential double-counting of benefits across stakeholders of ecosystem-service benefits. The problem of double counting has been highlighted in similar studies in the past (Dominati et al., 2010; Jones et al., 2008) particularly in valuing benefits of avoided soil erosion.

Methodology

Spatial economic modelling of ecosystem services

This study focuses on areas of New Zealand that would be suitable for afforestation, henceforth known as future forests (Watt et al., 2011). These are areas considered to have relatively low economic value for agriculture and slight to extreme erosion severity. Biodiversity is likely to increase if these areas are forested compared to their current use for pastoral agriculture. The various forest scenarios modelled here are based on a structural (framing) regime (thinned to 600 tree stems ha^{-1} from initial planting of 900 tree stems ha^{-1}). The rotation length modelled is 28 years as this represents the most common rotation length practice in New Zealand.

Table 1
Data used to assess private net benefit'.

Costs (C)	Revenues (R)
Land Purchase ($/625 m^2)	Carbon credits ($/NZU)
Establishment ($/625 m^2)	Timber ($/tonne)
Silviculture ($/625 m^2)	
External road construction ($/km)	
Internal landing construction ($/625 m^2)	
Internal road construction ($/km)	
Harvesting ($/tonne)	
Transport ($/tonne/km)	
ETS compliance[a] ($/625 m^2)	

[a] This cost was assumed to be a constant value per hectare and was included after the spatial modelling, see also Appendix B.

Assessment of ecosystem services in combination with economic analyses can be grouped into two types: one focuses on 'sustainable analyses' of current land use and the other on 'programme evaluation'. 'Sustainability analysis' provides an investigation of changes up to the present day to assess the sustainable path of previous strategies while 'programme evaluation' provides a forward-looking assessment of potential sustainability policies (Bateman et al., 2011). We used a 'programme evaluation' of afforestation across marginal agricultural land suitable for forestry in New Zealand to identify, spatially, those policies that can efficiently enhance ecosystem services provision.

Private net benefits

The term 'private net benefits' refers to the benefits, minus the costs, of a land use change that accrue to the private landowner (Pannell, 2008). This term is calculated as the discounted sum of the costs and benefits (Net Present Value) to the private individual from afforestation, and includes the opportunity cost of land use change. For a consistent measure of opportunity cost across all future forests, land value data is used from a property valuation specialist (PropertyIQ, 2008). In New Zealand, land is typically valued by its "highest and best use" (New Zealand Institute of Chartered Accountants, 2004). The Land Expectation Value (LEV) is the net present value (NPV) of an investment in an even-aged stand from the time of planting, throughout infinite rotations of the same management regime (Faustmann, 1995). If the LEV is greater than the upfront cost of purchasing the land (i.e. the land value) then afforestation would be a rational investment from a private commercial perspective. Hence, if the land was already owned by the investor and the LEV was positive then forestry would be a viable option. This approach can also be applied to third-party investments, where the purchase of land represents an upfront investment in forestry cash flows. Table 1 lists the spatial revenues and costs calculated in the model. We also considered the transaction and learning costs of land use changes to forestry in policy analysis as per Pannell (2008); see Appendix D for detailed assumptions.

We use the ArcGIS 10 software (ESRI, 2010) to identify meshblocks[1] (the smallest geographic unit for which statistical data is collected) that contained future forest areas. Each meshblock has

[1] Meshblocks (1 ha in area) were used as the identifying area for land values instead of primary parcels. However not all primary parcels within each meshblock were identified, meaning that in some cases the dollar value per hectare may have been underestimated. Also some meshblocks where forests were located returned no data and therefore these forests have been excluded from the final economic calculation.