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Validation and enhancement of a spatial economic tool for assessing ecosystem services provided by planted forests☆,☆☆

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ABSTRACT

Planted forests provide multiple benefits to society such as timber, carbon sequestration and avoided sedimentation, which are collectively called ecosystem services. Assessing the economic viability of timber production and the value of other ecosystem services of planted forests has become increasingly important for policy and investment decisions. A spatial economic tool called the Forest Investment Framework (FIF) has been developed to enable the assessment of key ecosystem services provided by planted forests in New Zealand. The FIF has a timber viability component that has been used to assess where in New Zealand new forest establishment is viable. The framework can also estimate indicative values of carbon sequestration credits and avoided sedimentation of waterways. In this paper, FIF's timber viability component is validated using data from seven case-study forests in New Zealand. Results of the validation exercise suggest that FIF is a very good viability assessment tool because it provides very accurate estimates of costs and revenues that case-study forests actually generated. The paper also discusses the new ecosystem services that have been identified for incorporation into this framework: water quality, water yield, recreation and biodiversity conservation.

1. Introduction

Ecosystem services are the benefits derived by people from an ecosystem; some examples are food, fibre, carbon sequestration, recreation, and avoided erosion (Millennium Ecosystem Assessment, 2005). In New Zealand and other countries, planted forests provide a greater number of ecosystem services than many other productive land uses such as dairy cattle farming, sheep and beef cattle farming, and horticulture (Houghton, 1991; Carnus et al., 2006; Quine et al., 2011; Yao et al., 2013b; Ausseil et al., 2013b; Yao and Velarde, 2014). The total economic value approach employed by major frameworks on ecosystem services analysis (e.g. Millennium Ecosystem Assessment) allows for the accounting of forest ecosystem services that have private (land owner) and public (community) benefits. Private benefits such as the sale of wood, fibre and carbon credits have market prices and are usually accounted for in decision making (Yao et al., 2013a, 2013b). Private net benefits are the benefits that accrue to the private manager as a result of a proposed change in land management (e.g. changing from pasture to forestry) (Pannell, 2008). Public benefits include on-site (e.g. free mountain biking access) and off-site benefits (e.g. avoided sedimentation of water ways) that accrue to the community and to adjacent land uses (e.g. dairy farms). Some of these public benefits do not currently have market prices and they also vary in scale so it can be a challenge to represent these benefits in decision making (Kengen, 1997; Loomis et al., 2000; UN-Water, 2011). A number of public benefits from forests currently have no market prices but economic valuation techniques can be used to provide some approximation of their monetary values (e.g. the value of a forest recreational visit). Providing estimates of monetary values raises awareness of these benefits and conveys their importance relative to other marketed goods and services (Dhakal et al., 2012; Scarpa et al., 2000), which is crucial to improve efficient use of environmental resources.

A spatially explicit economic tool, the Forest Investment Framework (FIF), has been developed recently to account for the current market and non-market values in forestry investment decisions in New Zealand (Barry et al., 2014). At present, this framework accounts for three key ecosystem services provided by forests: timber production, carbon sequestration and avoided erosion. This framework enables the analyst to bring together spatial outputs from a range of forest growth and environmental models, and to combine them with biophysical and economic data. This approach assesses the viability of a forest investment and also provides estimates of the non-market values that can be derived from this investment anywhere in New Zealand.

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The New Zealand Government is currently developing a large programme that aims to reform the current management system for freshwater in the country (Ministry for the Environment, 2014). One of the options being evaluated is a change in land use from pasture agriculture to forestry so information is required on the possible effects of different land-use scenarios. More than half of the total land area of the country is presently in pasture and only about 7% is planted forests (Ministry for the Environment, 2010). Comprehensive data on productivity and profitability is publicly available for pasture (Beef + Lamb New Zealand, 2015; DairyNZ, 2015) but not for forestry. The FIF has been used to fill in this information gap by providing estimates of costs and revenues of timber production from afforestation and the associated values from carbon sequestration and avoided sedimentation of waterways.

The timber viability component of the FIF has been considered so useful that it has been preliminarily applied to assess the viability of a combination of nine proposed afforestation schemes and existing forests in selected regions in New Zealand. Those assessments were commissioned by local and national government agencies and indigenous Māori groups across the country (Yao and Harrison, 2015). However, it is critical that the accuracy of FIF estimates of timber viability are properly tested, so one of the aims of this research was to determine the validity of the timber economic viability component of the framework. In addition, the FIF can accommodate new spatial functions of other ecosystem services. Major environmental issues in New Zealand affecting society and the economy include water issues, recreation and biodiversity conservation (Dhakal et al., 2012; Yao et al., 2013a, 2014; Yao and Velarde, 2014). An additional aim of this research was to identify spatial functions for new ecosystem services that can be developed and incorporated into the FIF.

The FIF components and examples of their application are briefly presented in Section 2. In Section 3, the method used for validating FIF's timber viability component and the steps followed to identify new spatial functions are described. In Section 4, results of the validation exercise and the new spatial functions identified are discussed. Conclusions about the FIF validation exercise and possible future directions can be found in Section 5.

2. Forest investment framework

The Forest Investment Framework (FIF) combines a wide range of data to assess key ecosystem services values provided by planted forests in New Zealand (and potentially elsewhere). A flow diagram showing FIF's components, required inputs, processes and analytical outputs is presented in Fig. 1. The FIF enables market (timber and carbon) and non-market (avoided sedimentation) values of ecosystem services from proposed afforestation sites as well as existing planted forests to be estimated (Barry et al., 2014; Yao et al., 2013b; Yao and Velarde, 2014). The framework can be used to estimate the net-private and the net-public benefits of afforestation following the work by Pannell (2008) to incentivise landowners to provide ecosystem services (Barry et al., 2014). It can also provide meaningful results for strategic-level planning objectives across different types of forestry regimes such as pruned, unpruned, bioenergy and permanent forests (Harrison et al., 2012). The three components of the FIF applied in this current exercise are: (1) financial viability of timber production; (2) quantification and valuation of carbon sequestration credits; and (3) quantification and valuation of the off-site value of avoided erosion. These three components of the FIF are described in Barry et al. (2014) and Yao et al. (2016). Highlights from the validation of the financial viability component are presented in this paper. The models for the carbon and avoided erosion components which are respectively called *C*-change (Beets et al., 2012) and New Zealand Empirical Erosion Model (Dymond et al., 2010) have been previously validated (Beets et al., 1999; Dymond et al., 2010).

The financial viability and carbon sequestration components of FIF are mainly based on productivity surfaces for *Pinus radiata* (radiata pine) (Palmer et al., 2010a, 2010b, 2009). These productivity surfaces were developed by combining statistical techniques with mapping technology to predict 300 Index and Site Index for any location in New Zealand. The 300 Index is an index of volume mean annual increment, and Site Index measures height at a reference age (see Palmer et al. (2009) for details). The productivity indices and temperature were obtained from New Zealand productivity surfaces. To enable the 300 Index and Site Index surfaces to be used in modelling, data were pre-processed using the "eucAllocation" function in Arcmap™ to

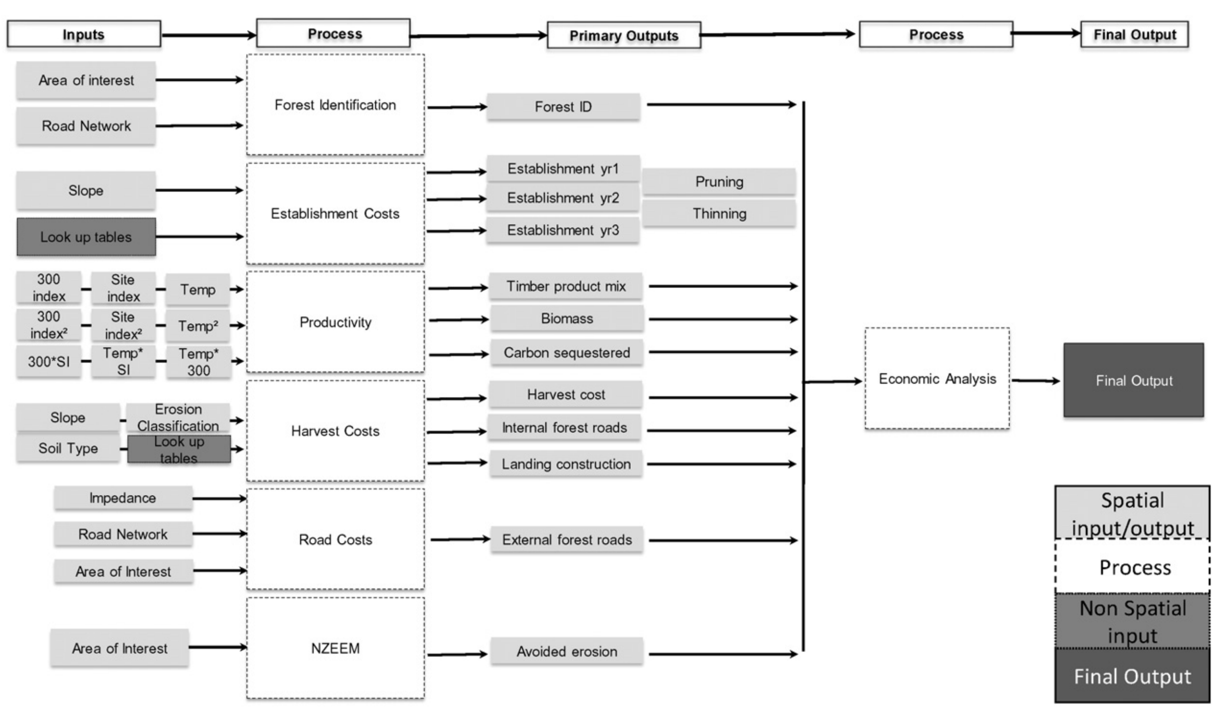

Fig. 1. Flow diagram showing the FIF's components, inputs, processes and outputs.