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Land use change from pastoral farming to carbon forestry: Identifying trade-offs between ecosystem services using economic-ecological spatial modelling

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Abstract: Ecosystem services are rapidly becoming a useful framework for policy and decision-making at the international, national and local level. Integration of multiple ecosystem services allows to evaluate trade-offs between alternative scenarios. Carbon sequestration is a fundamental service provided by forests. The New Zealand Government has introduced an Emissions Trading Scheme (ETS) to meet its international obligations in a cost-effective manner. This establishes a price on greenhouse gas emissions thus providing an incentive to reduce emissions or plant forests to absorb CO_2. The Waikato Regional Council has developed a Regional Carbon Strategy to benefit from the ETS by planting trees on marginal farmland used mainly for sheep and beef farming. A Geographic Information System (GIS) was used to identify the most suitable land and an integrated spatial decision support system was then used to compare cost/benefits and to assess various ecosystem services (for example biodiversity, water quality, water runoff) from a carbon forestry scenario against a reference scenario, both run to 2050. The carbon forestry scenario assumed an approximate net additional 75,000 hectares planted and reported reduced nitrogen and phosphorus loads to waterways, less runoff and enhanced biodiversity, while sequestration provided an economically viable opportunity for sheep and beef farmers on marginal land.

***Keywords**:* Spatial planning; ecosystem services; carbon forestry; emission trading system (ETS); integrated modelling.

1 INTRODUCTION

1.1 Regional Carbon Strategy

Ecosystem services are rapidly becoming a useful framework for policy and decision-making. Carbon sequestration is a fundamental service provided by forests. New Zealand has an emission trading scheme (NZ-ETS) that can provide income for landowners through the selling of carbon credits. The Waikato Regional Council[1] has developed principles and a framework for a regional carbon strategy to improve the economic returns from marginal land and also enhance ecosystem services such as carbon sequestration, biodiversity, water quality and soil health (www.waikatoregion.govt.nz/carbonstrategy). The concept is for the council to support forestry plantings and natural bush reversion on marginal farmland by

[1] The Waikato region is located in the North Island of New Zealand. The region has a land area of 25,000 km^2, a population of approximately 400,000 people and comprises 1 regional council (Waikato Regional Council), 1 city council (Hamilton) and 10 district councils (the smallest units of government within NZ).

acting as a facilitator to match up landowners and investors, for example by providing a service to aggregate, register and verify carbon credits from landowners within the region for bulk sales to purchasers.

The objectives of Council's carbon strategy are to: 1) utilise the cash flow from carbon credits to establish new forest plantings which generate environmental benefits; 2) create an incentive to channel investment in carbon forestry to wise land uses; 3) capitalise on potential added value to emitters which regional carbon credits may provide in terms of increasing biodiversity and protecting soil and water; 4) facilitate a coordinated approach to investment, which maximises environmental and financial benefits while minimising risk.

1.2 Use of the WISE model for integrated spatial planning

The New Zealand Local Government Act 2002 describes the purpose of local government *"to promote the social, economic, environmental, and cultural well-being of communities, in the present and for the future"*. This requires a holistic approach and new tools for integrated long term planning and decision-making. To assist integrated spatial planning WISE, a dynamic and spatially-explicit computer model for the Waikato region was developed by the multi-disciplinary *Creating Futures* research programme (Rutledge *et al,* 2008; Huser *et al,* 2009; Van Delden *et al,* 2010). WISE is a spatially explicit and dynamic decision support system integrating models of land use, terrestrial bioversity, hydrology, climate change, economics and demographics (Rutledge *et al,* 2009)[2]. WISE is currently being tested and evaluated for use in council's statutory and non-statutory planning and decision-making processes (Huser 2011). In its *Strategic Directions 2010-2013* the Waikato Regional Council has signaled its desire to provide greater strategic leadership and to collaborate more effectively with respect to strategic issues across the Waikato region and within the Upper North Island using an integrated spatial planning approach (www.waikatoregion.govt.nz/Council/About-us/WRC-strategy/).

1.3 Aim and scope

The aim of the paper is to demonstrate the use of integrated spatial modeling as a tool for policy analysis and implementation. In particular, WISE is used to evaluate environment-economy trade-offs between different scenarios for the development and implementation of effective policies to achieve Waikato Regional Council's Carbon Strategy. WISE is assessed for its capability to evaluate economic analysis and non-market values to optimize ecosystem services.

2 METHOD

2.1 Identification of Suitable Land for Carbon Forestry

Using GIS analysis the Waikato Regional Council has identified approximately 400,000 ha of predominantly low quality (i.e. low output per ha) sheep and beef farming land that could potentially be converted to carbon forestry. For the purposes of this study it was assumed that 80,000 ha would convert to carbon forestry. This was comprised of 75,000 ha of existing sheep and beef farming land, and 5,000 ha of existing dairy land. Table 1 provides a breakdown of when the conversions were assumed to take place.

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[2] Details on WISE system design, individual model components, integration and linkages between them are available from www.creatingfutures.org.nz.

Table 1 Land Conversion to Carbon Forestry

Period	From Sheep and Beef Farming to Carbon Forestry ha	From Dairy Farming to Carbon Forestry ha
2011 to 2016	-10,000	-625
2016 to 2021	-20,000	-625
2021 to 2026	-15,000	-625
2026 to 2031	-15,000	-625
2031 to 2050	-15,000	-2,500
Total 2011 to 2050	-75,000	-5,000

2.2 Carbon Forestry Sector Model

The economics module within WISE was extended to incorporate a carbon forestry sector[3]. This required several steps. Firstly, development of a carbon forestry model. Based on earlier work (NIWA, 2010) this was developed for a typical 100 ha forestry holding in the Waikato Region. The model, constructed in liaison with Council's policy analysts, represented a composite of three forestry silviculture regimes: (1) pruned exotic Pinus *radiata*; (2) untended Pinus *radiata* 'lock-up'; and (3) indigenous trees. The model was developed for a two period rotation; with an assumed rotation period of 26 years. The model provided annualised operating and capital costs and revenues (harvests, carbon credits) in the form of Discounted Cash Flows Analysis. The model allowed some flexibility in setting the appropriate forestry regime (rotation period, pruning/thinning and harvest dates, timber prices) and ETS policy (scheme and carbon credits price). For this study a sequestration price of NZ$20 per tonne of carbon was assumed[4].

Secondly, incorporating the carbon forestry model to the Economics module contained within WISE. This required adding a new (the 49th) economic sector to represent the new carbon forestry sector and, in turn, matching capital and operating expenditure and revenue streams to appropriate economic industries, final demand or primary inputs categories available in the economics module.

Thirdly, incorporation of land use conversions. Obviously, the loss of sheep and beef farming and dairy farming land lead to an associated reduction in the economic output of these industries. It was assumed that the economic output generated per ha from the land being converted was only a fraction (between 10-15 percent of the regional average) for the converted land, reflecting the low quality of the land being converted.

Fourthly, flow-on impacts. This included not only the positive impacts associated with the land use conversion (capital, operational, changes in business operation, management practices) that occurred over the implementation period for both domestic consumption and exports, but also any negative impacts associated with 'who pays' and, in turn, what this means for the regional economy. Importantly, the WISE Economics module automatically takes care of flow-on linkages (e.g. losses in the dairy, meat and textile processing industries and gains in wood and paper product industries) associated with the land use conversions. Furthermore, backward supply linkage economic impacts (i.e. through supply chains) associated with the capital/operational expenditures and revenues are also accounted for.

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[3] The carbon sector is defined as a composite of 45% pruned forestry (mirroring the existing New Zealand pine forestry sector), 25% locked-up pine forestry and 35% indigenous forestry with manuka honey production.

[4] This can be easily changed in the model. Current carbon prices (February 2012) are NZ$7-8.

3 INTEGRATED POLICY ANALYSIS

3.1 Scenarios

A carbon forestry scenario was designed, simulated, analysed and evaluated against a reference (or baseline) scenario that reflects expert opinion of current trends ("business as usual"). While most of the inputs and parameters from the economic model in the carbon forestry scenario are identical to those in the reference scenario, significant increases in demand for the carbon forestry sector were modeled at key time steps of the simulation. Subsequent changes to the demand for other rural sectors that could be influenced by changes in the carbon forestry sector were also modeled. These demand inputs were supplied directly from the Carbon Forestry model (see section 2.2).

The simulation was then run from 2006 to 2050 and the results as at 2050 were analysed and compared with the results of the reference scenario as at 2050[5]. Significant changes were considered those that were more than 2% different from the reference scenario. The Map Comparison Kit (http://www.riks.nl/mck/) was used to compare maps from the two scenarios as at 2050 and show the location and amount of change. Key indicators that were explored were; land use, land use demand versus allocation, water quality and quantity, biodiversity, value added (Gross Regional Product) and employment.

3.2 Results

3.2.1 Land Use Change

Compared with the reference scenario the carbon forestry scenario showed significant increases in forestry (~74,000 ha) and significant decreases in dairy farming (~10,000 ha) and especially in sheep, beef and deer farming (~75,000 ha). The additional forestry is widely scattered as many thousands of small clusters throughout the hill country and remote parts of the Waikato Region (Figure 1). However, there is a noticeable increase in size and frequency of clustering near the west coast, adjacent to indigenous vegetation and in remote parts of the Coromandel Peninsula. The vast majority of the loss of sheep, beef and deer farming is to forestry, especially in steeper terrain and more remote locations.

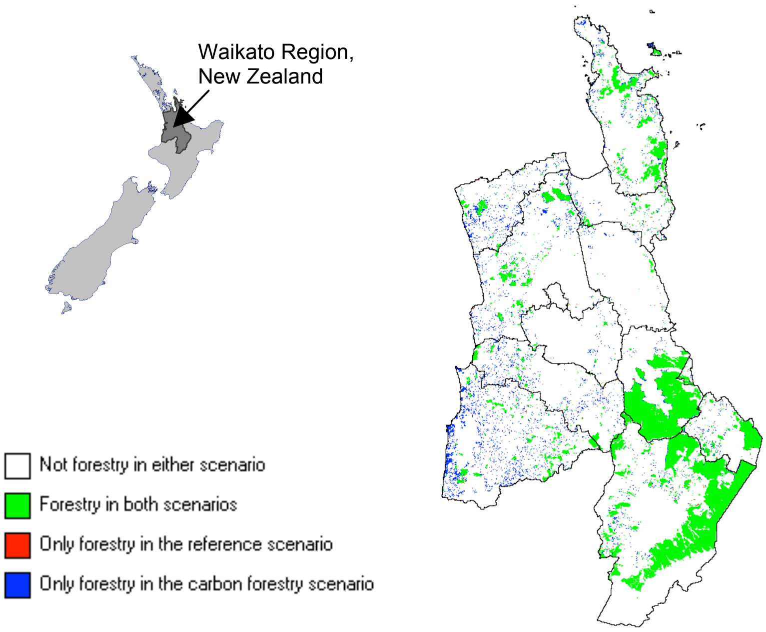

Figure 1. Map comparison of the forestry land use in the Waikato Region as at 2050 between the reference scenario and the carbon forestry scenario.

[5] Results are based on a single simulation run.

3.2.2 Land Use Demand versus Allocation

The changes in land use lead to some significant differences between the area of unconstrained demand and the actual area of land allocated, most significantly for agriculture; sheep, beef and deer farming; and forestry.

3.2.3 Water Quantity and Quality

There is minimal difference in hydrological indicators when comparing the two scenarios, with a slight increase in the amount of land with low annual runoff (0-400 mm/year) and summer flow yield (0-4 l/s/km^2). Both phosphorous (P) and nitrogen (N) loads (tonnes/year) as at 2050 showed similar behavior when compared at key locations in the region's hydrological network. The results for N loads are shown in Figure 2. The most significant change is a 6-7% reduction in phosphorous and nitrogen loads at the Mokau River mouth on the west coast. Across the region it is the headwater tributaries in hill country that most frequently exhibit significant reductions in phosphorous and nitrogen loads.

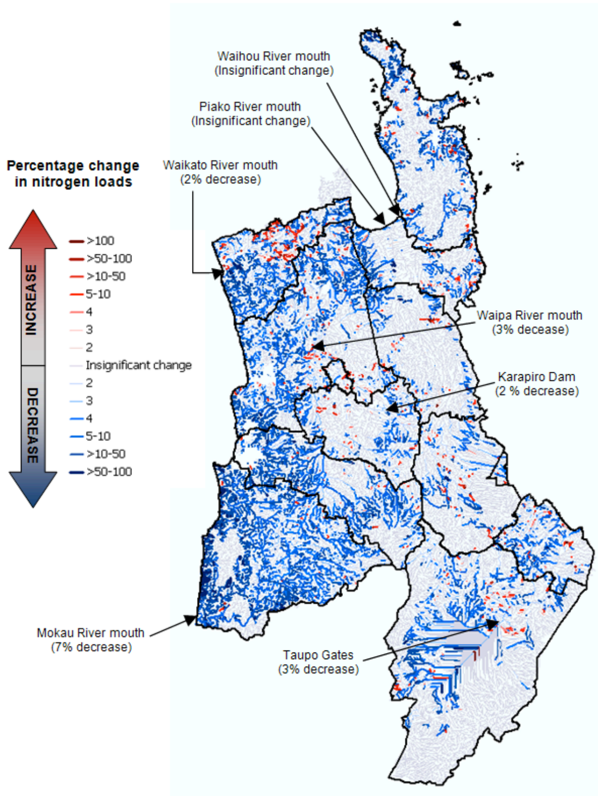

Figure 2 Change in nitrogen loads (tonnes year) in the Waikato Region resulting from the carbon forestry scenario. Changes at key locations in the Region's hydrological network noted.

3.2.4 Biodiversity

The carbon forestry scenario results in a 2 % reduction in the total amount of land that would be "chronically threatened" (the highest risk environment class) as at 2050. Most of this land changes to the lesser threatened environments class of being at risk on West Coast dune landforms.

3.2.5 Economy and Employment

As at 2050 there are significant increases in value added for the Horticulture and Fruit Growing sector (9%) and Forestry and Logging sector (4%) in the carbon forestry scenario and only minimal change in value added for other key rural sectors. In the carbon forestry scenario, by 2050, the value added for the Carbon Forestry sector is NZ$\$_{2007}$49 mln, compared to 0 mln $(2007) for the reference scenario. However, there is insignificant change for the Waikato Region when comparing the total Gross Regional Product as at 2050 between the two scenarios.

As at 2050 there are significant changes in employment for some sectors, such as meat and dairy processing. However, overall there is minimal change for the Waikato Region as at 2050 between the carbon forestry scenario and the reference scenario.

3.3 Discussion of Results

This discussion focuses on the significant differences between the reference and carbon forestry scenarios and will also highlight uncertainties where future investigations should be directed.

3.3.1 Land Use Change

For the major land uses (by area) most changes are as expected given the changes in demand sourced from the carbon forestry model. Forestry, which predominantly replaces sheep, beef and deer farming on marginal land, has greater potential for profit from this marginal land. The indigenous forest land use gains nearly 5,000 ha more in the carbon forestry scenario. The scattered growth of forestry in marginal land areas may connect may be linking some fragments of indigenous forest (which also commonly occur in marginal land areas) and helps to reduce fragmentation and increase cluster size of woody vegetation thereby reducing the ability of other pastoral land uses to encroach on them (the so-called “buffer effect”). The location and clustering of forestry in the west coast, adjacent to indigenous vegetation and in remote parts of the Coromandel Peninsula, reflects the difficulty in making profits from pastoral land uses with poor land productivity and potentially high transport costs.

3.3.2 Land Use Demand versus Allocation

Changes to the economic model in the carbon forestry scenario reduced demand for sheep, beef and deer farming. Sheep, beef and deer farming is now able to be fully allocated to demand by 2050 as, not only is the demand lower, but it is the marginal, unproductive land that was lowering this land uses’ productivity per ha. This marginal land has been abandoned by sheep, beef and deer farming in the carbon forestry scenario thereby actually increasing the average productivity per ha for what remains of this land use, and reinforces allocation. The increase in demand and allocation of forestry is also a direct result of the changes to the economic model in the carbon forestry scenario.

3.3.3 Water Quantity and Quality

There is a slight tendency for annual runoff and summer flow yields to be lower in the carbon forestry scenario, especially in the north of the Waikato Region. As the climate model is identical for both the reference and carbon forestry scenario these changes may be attributed to changes in land use. The location of changes to phosphorous and nitrogen loads in rivers as part of the carbon forestry scenario comes as no surprise. Forestry will contribute much less phosphorous and nitrogen to water bodies than most other rural land uses, especially dairy farming. Given the scale of the reduction in dairy farming and sheep, beef and deer farming and the growth of forestry in some catchments (Lower Waikato, Waipa, Upper Waikato, Taupo and especially Mokau) the water quality model delivers an expected reduction in phosphorous and nitrogen loads at the exit point location of those catchments.

Whether or not the scale of reduction is correct is uncertain. Further investigation and consultation is required to fully understand how land use change influences water quality over time.

3.3.4 Biodiversity

The reason for the observed changes (see 3.2.4) is inconclusive and requires further investigation.

3.3.5 Economy and Employment

The increase in value added for the carbon forestry sector is directly derived from the values provided to the economic model from the carbon forestry model. The observed increase in value added for the forestry and logging sector comes as no surprise given the growth of forestry land use in the carbon forestry scenario. Less expected and requiring further work is the increase in value added for the horticulture and fruit growing sector that results from the carbon forestry scenario. Perhaps one of the most telling results of the carbon forestry scenario is that total value added (summed for all sectors in the Waikato Region) by 2050 does not change significantly between the two scenarios. It appears that the economic gains and losses resulting from such land use changes cancel each other out at the regional scale. Also, the carbon forestry scenario is a relatively small economic event at the regional scale. Employment figures are directly derived from the carbon forestry model and the increase in employment for the horticulture and fruit growing sector and forestry and logging sector is expected given the land use expansion and economic growth of these sectors. The total employment, by 2050 does not change significantly between the two scenarios.

4 CONCLUSIONS AND RECOMMENDATIONS

The basic concept of the regional carbon strategy is to capture the economic opportunity that the NZ-ETS presents to encourage better land use on marginal land by providing a more sustainable land use that would also provide downstream or offsite environmental benefits, including soil conservation, improved water quality, increased biodiversity, aesthetics and landscape benefits. Economically, initial analysis indicates that carbon forestry opportunities (carbon credits) can make forestry plantings substantially more profitable than pastoral use of marginal hill country. The environmental benefits would be mainly seen in cleaner waterways and more stable soil in steep hill country, and potentially improved hydrology (less peak flow) and enhanced biodiversity values (e.g. connecting ecosystems). These are high priority community goals included in Council's Regional Policy Statement. While the returns form carbon credits will be the main incentive to encourage a change in land use, some public funding (e.g. rates relief) may also be required to ensure the change is most effective both economically and environmentally.

Scenario analysis shows that there are strong synergies between the economic benefits of land use changes and improved water quality and other environmental benefits. Integrated spatial planning using computer simulation models such as WISE allows policymakers to evaluate the consequences of policy options and their associated environment-economic trade-offs

The addition to WISE of a carbon forestry sector model (section 2.2) has enabled a more detailed economic analysis of likely benefits for both land owners as well as for the regional economy. Linking any land use changes to other modules in WISE (e.g. hydrology, water quality, biodiversity) allows for assessing and optimising environmental co-benefits of implementing Council's Carbon Strategy.

Further work along the efforts described in this paper is currently undertaken to effectively implement the Waikato Regional Carbon Strategy. This is part of a comprehensive research and policy work programme (2012-2022) the Waikato Regional Council is undertaking to apply WISE for integrated scenario and policy analysis for a number of priority issues to test, evaluate and further improve WISE as a tool for integrated spatial planning. This programme includes investigating the issues encountered in the behaviour and use of WISE as described in the discussion as well as providing recommendations to enhance its use for the effective implementation of the Regional Carbon Strategy. Regarding the latter suggested improvements were identified relating to flow-on implications through the Waikato Region economy; and the incorporation into WISE of non-market and ecosystem services valuations.

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