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Assessing design options for a Nutrient Trading System using an integrated model

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Abstract

Water quality in many New Zealand waterways is currently declining leading to lakes and rivers being closed for contact recreation such as swimming and potentially threatening our clean, green image. Much of this decline is associated with an increase in the nutrient loss from agriculture in the surrounding catchment. Nutrient trading systems are being considered in a number of catchments across the county to restrict the nutrient loss entering the waterways and thus improve the water quality. Such a system is currently being implemented in Lake Taupo and Environment Bay of Plenty is exploring actively the use of such a system to manage nutrient loss in the Lake Rotorua catchment. Yet the design of such systems is challenging.

In a collaborative effort between Motu, NIWA and GNS-Science, we are developing a spatial, stochastic, dynamic simulation model, N-TRADER to simulate the effect of different aspects of nutrient trading policy for the Lake Rotorua catchment. This model combines the economics of land use and management decision making, the functioning of temporal nutrient allowance markets and a model of nutrient flows and lags and is based on the best available empirical information on the geophysical and economic conditions for this catchment. This paper will discuss the design of N-TRADER and some of the nutrient trading system design questions that

we plan to explore with the model including what is the impact of different nutrient caps and what is the impact of higher transaction costs.

Introduction

Declining water quality, including in iconic lakes and rivers, is becoming a concern in many parts of New Zealand. Lakes and rivers are being closed off for contact recreation, such as swimming, due to the health risk and iconic lakes become less attractive to tourists. Declining water quality in many of our catchments may also threaten New Zealand's clean, green image which has allowed New Zealand products to receive premia in international markets.

Much of the water quality decline has been attributed to increased nutrient flows into the waterways. To combat the increasing nutrient loads, nutrient trading systems are being considered by some regional councils. Environment Waikato is currently in the process of implementing a nutrient trading system for Lake Taupo. Environment Bay of Plenty (EBOP) is also currently considering the use of a nutrient trading system to control the level of nutrient loss into Lake Rotorua.

While there is a substantial theoretical literature on market based instruments, the practical design of such systems is challenging and empirical evidence is still quite limited. Lake Rotorua has a number of features which makes it ideal for a nutrient trading system such as a large number of heterogeneous participants and scientific understanding of the geophysical processes. But there are also challenges. Nutrients in this catchment can take up to 200 years to reach the lake depending on where they are lost. Thus a nutrient trading system where caps are set on nutrients lost off the land without taking into account the ground-water lags is unlikely to achieve the water quality improvements desired.

Over the past twelve months, Motu has designed a nutrient trading system for the Lake Rotorua catchment in a project funded primarily by EBOP and the Foundation for Research, Science and Technology, with supporting funding from the Ministry of Agriculture and Forestry and the Ministry for the Environment.¹ As part

¹ More information on the prototype nutrient trading system, including a summary of the prototype, can be found at <http://www.motu.org.nz/research/index.php?pid=111>.

of the design process, Motu convened meetings with a representative group of local stakeholders to discuss different aspects of the system.

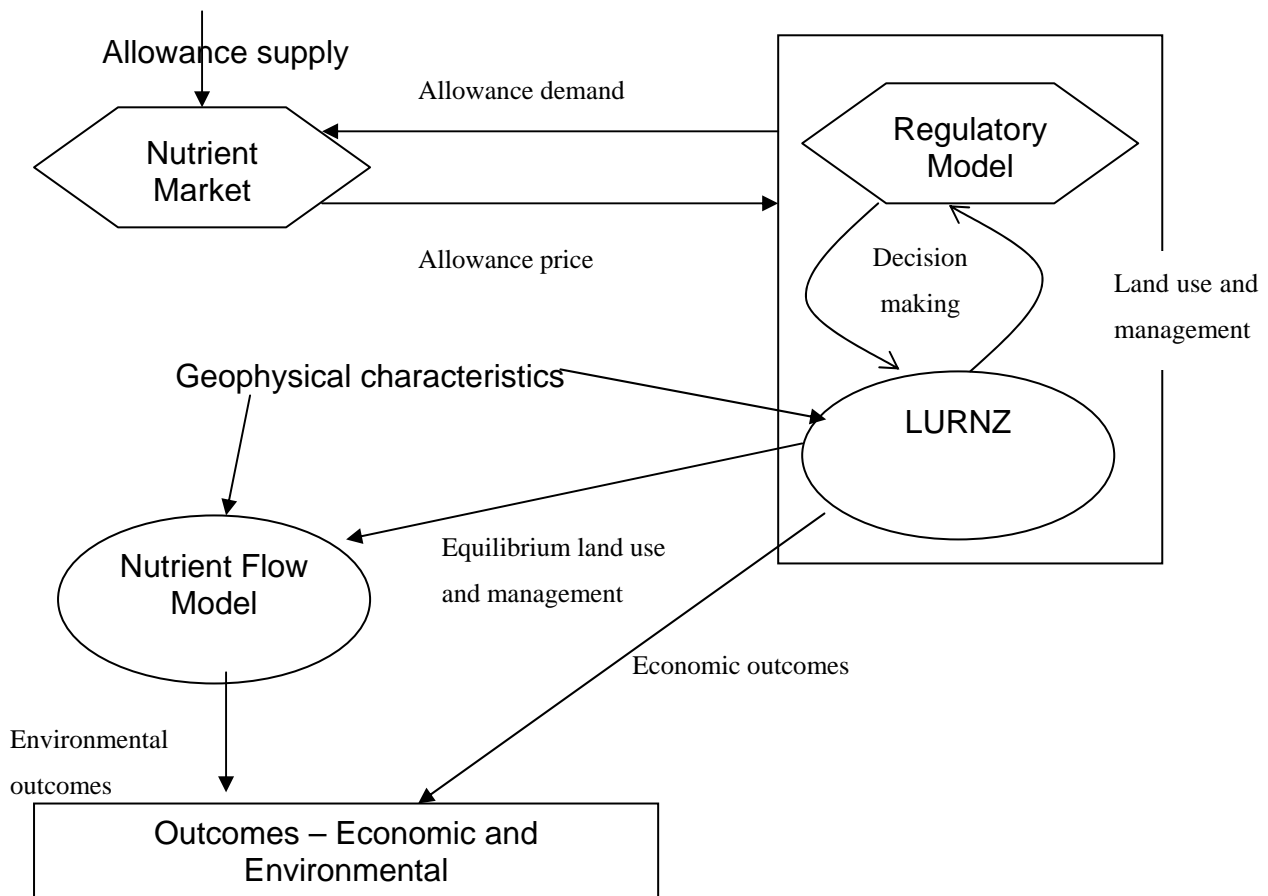
The next stage of this work focuses on building a model which will allow us to simulate the likely impact of a nutrient trading system. In a collaborative effort between Motu, NIWA and GNS-Science, we are developing a spatial, stochastic, dynamic simulation model, N-TRADER, which combines the economics of land use and management decision making, the functioning of temporal nutrient allowance markets and a model of nutrient flows and lags. The model is based on the best available empirical information on the geophysical and economic conditions for this catchment. NTRADER will allow us to simulate a variety of design questions. For example, what would be the impact of voluntary opt-in by small properties? What is the impact of higher transaction costs?

This paper will discuss the design of N-TRADER and some of the nutrient trading system design questions that we plan to explore with the model.

N-TRADER Design

The N-TRADER model is a spatial, stochastic, dynamic simulation model which combines the economics of land-use and management decisions making, the functioning of temporal nutrient allowance markets and a model of nutrient flows and lags. The model is calibrated for the Lake Rotorua catchment and has three main components – a nutrient flow model, a nutrient market and a land use and management module (Figure 1). The combination of these three components leads to information on the lake water quality and economic effects of the system given a particular policy design.

Figure 1 Outline of the N-TRADER simulation model



Nutrient Market

The total nutrient levels able to enter the lake, and hence the supply of nutrient allowances, needs to be determined by a political process. The demand for nutrients is determined by landowner decisions. The module will equilibrate demand and supply for allowances.

Land Use and Management

The land use and management module will be the Land Use in Rural New Zealand (LURNZ) model developed by Motu.² LURNZ takes predictions of exogenous economic and geophysical conditions and predicts land use and intensity over time. In this module, the land use and management decisions that are made for particular pieces of land will depend on geophysical characteristics of the land, output

² See Hendy et al (2007) for more information on the LURNZ model. For N-Trader LURNZ is being further developed in a number of ways.

prices, production costs, the interest rate, the cost of nutrient mitigation, the number of nutrient allowances required for each land use and management option, as calculated in the regulatory nutrient management module, and the price of nutrient allowances as determined in the Nutrient Market module. The land use and management decisions that landowners make will depend on the cost of losing nutrients into the lake, and the specific form of the regulatory model.

Regulatory nutrient monitoring module

The regulatory nutrient monitoring module will calculate the nitrogen leaching from each parcel in the catchment based on the geophysical information and land use and management decisions identified in the Land Use and Management module. This module represents the model that landowners in the nutrient trading system will have to use to calculate their nutrient loss. It will be a simpler model than the one used in the nutrient flow module below and will be based entirely on verifiable data. Landowners will interrogate this model as they make management decisions throughout the year. By aggregating the nutrient loss from all properties based on landowners actual decisions at each nutrient price, the catchment's demand for allowances can be calculated.

Nutrient Flows

The full nutrient flow module will simulate nitrogen loss from the entire catchment and thus the impact on the lake. Once a set of equilibrium nutrient prices is found, the equilibrium land use and management decisions are fed into the nutrient flow model. This model is likely to be more detailed than the regulatory nutrient monitoring module as, in order to reduce compliance costs, landowners in the catchment may not have to report all of the data necessary to run the complex model. The nutrient flow model will also include attenuation effects as well as full impulse-response functions to account for groundwater lags rather than fixed lags for each property. Running this module using the equilibrium land use and management decisions for each of the parcels, allows us to identify the total nutrient loads reaching the lake in each year and from the Land Use and Management module we can identify the profit achieved and the cost of mitigation for each path of water quality in the catchment.

Using N-TRADER for Simulations

The N-TRADER model is being developed to analyse several different trading policies and regulation frameworks, and to see whether and how they alter economic and environmental outcomes. Policy scenario outcomes will be compared with a reference case to evaluate the economic and environment consequences of specific policy decisions. While this model will be able to simulate a variety of policies, these fall into three categories – changes to the nutrient cap, which sets the allowance supply; changes in the regulatory model which defines how land use and management decisions are translated into landowners' demand for allowances; and changes in market operation. We plan to use N-TRADER to explore a number of different policy options including altering the nutrient cap; altering the number of groundwater zones, their locations, and the flow of nutrients from groundwater zones; voluntary use of complex data for monitoring nutrient loss; and altering the transaction costs that participants face.

Changing the nutrient cap

The economic and environmental impacts of a nutrient trading system depend on the level of the nutrient cap. Reducing nutrient loss quickly will have the best environmental impact but will have large negative economic impacts. Reducing nutrient loss slowly will be better economically but will have larger negative environmental impacts. Thus the trade-off between the environment and economic outcomes needs to be assessed.

The setting of the nutrient cap needs to be carried out through a political process but the N-TRADER model is able to inform this debate. By running scenarios with different nutrient caps, we can approximate the economic and environmental impacts of the system. Thus it will provide policy makers with a more robust estimation of the costs of setting the nutrient cap at different levels.

Changing the number of groundwater zones

In the Lake Rotorua catchment, nutrients can take up to 200 years to reach the lake depending on where they are lost. To take into account the groundwater lags, in our proposed system the nutrient caps are on the nutrients reaching the lake in each

time period.³ We call this a temporal market because trades occur over time as well as space but not through banking. Each landowner must hold allowances for the 'vintage' in which the nutrients off his property actually enter the lake. Each property will be assigned to a vintage based on maps of ground-water lag zones. If his nutrients take 100 years to reach the lake, then he must surrender 2109 vintage allowances for nutrients lost in 2009. To avoid having 200 markets which are likely to be thin, we may wish to group zones together. So a landowner with a one to five year lag could use any allowances with a vintage between 2010 and 2014 to cover nutrient loss in 2009.

How many zones do we wish to have? One zone is likely to be too inaccurate to achieve our water quality goals efficiently. The location of groundwater zones and the travel time of nutrients within them are still uncertain. Clearly we should not have more zones than science can credibly support. Having a large number of zones (and hence allowance markets that operate simultaneously) also increases the complexity of the system and could lead markets to be illiquid.

N-TRADER will provide insight into the consequences of different numbers of trading zones and also the implications of uncertainty in where the boundaries of the zones are. By carrying out simulations with the number of zones and/or the boundaries of the zones, the environmental and economic consequences of each of the scenarios can be identified.

Voluntary use of detailed data

In our proposed system, tiny parcels (<10 ha) are not required to participate directly in the nutrient trading system; their nutrient loss is covered by the regional or district council.⁴ Small parcels (between 10 and 25 ha) that have less than 10 ha of high nutrient loss land uses are included in the system but are only required to report limited data to monitor their nutrient loss. The remaining parcels must report a full set of data to enable their nutrient loss to be calculated. Small parcels are able to opt-in and report a full set of data. This allows those who feel that they are disadvantaged by reporting only a limited set of data and thus having only a limited

³ For more information on the temporal markets in our proposed nutrient trading system for Lake Rotorua see Kerr et al (2007)

⁴ For more information on what sources are and aren't included in our proposed nutrient trading system for Lake Rotorua see Lock and Kerr (2008)

set of mitigation options, to report more data but minimises the compliance costs to small landowners.

N-TRADER will be able to assess the economic and environmental impact of allowing these small landowners to voluntarily opt-in reporting more detailed data. The model will assess each parcel to see if they would be better off reporting a full set of data. Those that would be better off, such as those with low costs of mitigation options that are assessed only in the full monitoring model but have low compliance costs, would opt-in to the system. By comparing the economic and environmental outcomes of simulations without and with voluntary opting in to the system, the impact of this policy can be assessed.

The N-TRADER model can also assess the economic and environmental impacts of changing the participation rules – e.g. to include only very large parcels or exclude some land uses.⁵

Altering the transaction costs

The transaction costs of participating in the system will significantly affect the trading, and consequently land use and management decisions, landowners make. If there are high transaction costs in the system, landowners may be less likely to undertake changes to land use changes as the benefit of buying or selling allowances is lower. The exact economic and environmental impacts of higher transaction costs are unclear.

By using the N-TRADER model we can examine the impact of higher transaction costs. A baseline case would be first calculated. For the policy scenario, each of the changes in land use and management decisions will be assessed to see if the increase in profit is greater than the increase in transaction costs. Only the changes that generate more profit than the increase in transaction costs will be carried out in the policy scenario. Changes that generate less profit should no longer be undertaken as the landowner will be worse off if he made the change.

⁵ Our prototype system includes non-land-based nutrient sources as well but these are not incorporated in Ntrader.

Progress to date

The N-TRADER model is still in the early stages of development. We expect to have the prototype version of the model developed by June 2009. This will demonstrate the structure of the model and the methodology for different scenarios. Real simulation results with increasing realism will be produced from July 2009.

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