Nitrogen Trading in Lake Taupo

An Analysis and Evaluation of an Innovative Water Management Policy

Madeline Duhon, Hugh McDonald and Suzi Kerr

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Author contact details

Madeline Duhon
Stanford University
madelineduhon@gmail.com

Suzi Kerr
Motu Economic and Public Policy Research
suzi.kerr@motu.org.nz

Hugh McDonald
hugh.a.mcdonald@gmail.com

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Motu Economic and Public Policy Research

PO Box 24390
Wellington
New Zealand

Email	info@motu.org.nz
Telephone	+64 4 939 4250
Website	www.motu.org.nz

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Abstract

This paper provides an overview and early evaluation of the Lake Taupo nitrogen cap and trade programme, established as part of Waikato Regional Council's 2011 Regional Plan Variation Five. The policy establishes a catchment-wide cap on nitrogen losses by allocating farmers individual nitrogen discharge allowances and allowing those farmers flexibility to trade allowances amongst themselves and to sell allowances to a public fund while remaining within the overall catchment cap. The Taupo trading scheme is the world's first agricultural non-point-source water-quality cap and trade scheme. This paper explains the structure and evolution of the nitrogen trading market, and analyses its impact thus far. Research drawn from written material and descriptive quantitative data provides the basis for analysing the policy, while interviews with relevant stakeholders provide insight into the successful, surprising and contentious issues that arose throughout its development and implementation.

Contents

1. Introduction

Falling water quality as a result of nutrient losses from agricultural non-point sources (NPSs) is a pressing issue for many water bodies in New Zealand, as it is worldwide (Ministry for the Environment 2007; UN-Water 2011). An innovative market-based environmental policy has been established in Lake Taupo, New Zealand, to address this issue cost-effectively (Young and Kaine 2010). The scheme comprehensively caps discharges from diffuse NPSs of nutrients (in this case, largely farmers and foresters) and allows trading amongst these participants to cost-effectively achieve an environmental goal.

Market-based environmental policies are increasingly being applied to deal with water-quality problems (Selman et al. 2009).[1] A key motivation is the expectation that trading can achieve environmental goals at a lower cost, and with greater flexibility, than traditional command and control regulation (Shortle 2012). Environmental trading markets achieve this as they allow those who find it expensive to mitigate or abate their discharges to meet environmental requirements at lower cost by purchasing reductions from other participants who can reduce their discharges more cheaply. Those who can cost-effectively reduce their discharges are motivated to do so because if they can reduce their discharges below regulatory requirements then they can sell the excess allowances to others. As a result, trading markets will theoretically ensure the efficient distribution of mitigation: mitigation is carried out by those who can do it most cheaply, which minimises the cost of achieving an environmental goal.

The Taupo trading scheme is of particular interest as it is the world's first NPS–NPS cap and trade scheme (Shortle 2012). Despite the importance of NPS pollution worldwide, to date water-quality trading markets have predominantly been set up to facilitate nutrient discharge reductions by point sources (PSs), such as sewage plants and mines. Where agricultural NPSs are involved, they are generally not subject to a cap on emissions, and instead can choose to participate and decrease nutrient discharges in return for emission reduction credits that PSs purchase to offset their own discharges (Selman et al. 2009). The Taupo scheme is innovative in that controlling diffuse NPS nutrient discharges is its central aim.

Designing a catchment-wide trading system for a more than 180 diffuse NPSs of nitrogen presents a unique policy challenge. Losses from NPSs are more difficult to measure and monitor than those from PSs, such as large factories (Greenhalgh 2008). Also, given the smaller expected size and value of trades, minimising the transaction costs involved in trading is

[1] The development of these policies from early work by Coase (1960), Crocker (1966), Dales (1968) and Montgomery (1972) is outlined in Tietenberg (2006).

particularly important. The system must minimise these transaction costs whilst still accurately monitoring and measuring discharges and environmental impacts.

This paper analyses and evaluates the impact of the Taupo scheme by investigating the initial impacts and restrictions faced by participants as a result of the environmental cap, and examining how the ability to trade has affected landowner flexibility and outcomes. Our research draws on written materials, trading activity data and detailed interviews with stakeholders to provide the context surrounding the development of the policy and the basis on which to analyse the impact of the nutrient trading system. [2]

We find that while the introduction of a cap on nitrogen has effectively limited discharges into Lake Taupo, it has also imposed various economic and social costs on those who now face a limitation on the productive capacity and development potential of their land. The reduction of options and additional costs associated with farming under a cap has driven some landowners to exit the catchment, and may also have reduced the value of capped land compared to land not affected by a cap.

Although the trading market is still young and our conclusions are provisional, we find that the system has provided useful flexibility for landowners, and has decreased the potential costs of the cap. Between the first trade in January 2009 through to June 2012, 32 trades were carried out under the scheme. The majority of these sales were to the centrally funded trust tasked with decreasing the size of the cap, but 13 of the trades were farmer to farmer. Trading has enabled landowners to make land-use and management changes to increase, decrease or maintain production, and has facilitated the conversion of land to uses with greater profit per unit of nitrogen discharged. We find that while transaction costs in the system are low by international standards, they are still high enough to affect trading levels and to have a negatively effect on economic efficiency.

This paper contributes to the literature in three ways. First, it provides a detailed overview of an innovative policy addressing the widespread and growing problem of agricultural NPS pollution and its implementation, and identifies lessons for future policies. Second, our investigation of the immediate impacts of the policy casts light on potential flaws and areas for improvement. Third, our assessment of transaction costs within the scheme provides new evidence for the growing literature considering transaction costs in environmental trading markets.

[2] The research for this paper was completed in July 2012, so it does not include data or experience after that date.

The paper is structured as follows: Section 2 discusses the policy's development and provides an in-depth overview of its rules, which provides context for understanding and interpreting the scheme's impact; Section 3 provides the bulk of the analysis and evaluation of the policy overall and the trading system in particular, including descriptive data on trading and traders; and Section 4 concludes.

2. Overview of the policy design and evolution

In order to evaluate the impact of the Taupo scheme, it is important to understand its rules and the context for the key policy decisions that were made during its design. This section provides an overview of the local environmental problem and the development of the policy, a description of the Taupo catchment and an in-depth description of the policy.

2.1. Policy background and evolution

Lake Taupo is New Zealand's largest lake, and its 3,497-square-kilometre catchment plays host to a range of pastoral, forestry, urban and conservation land uses.[3] Those who benefit socially, economically and culturally from a healthy lake share a strong appreciation for the high quality of its waters (Vant 2008).

Although Lake Taupo currently exhibits exceptional water quality, scientific investigation has revealed a gradual but steady decline in key indicators of water quality over the past three decades (Vant 2008). Intensified pastoral and urban land use over the past 35–50 years has resulted in increased nutrient levels in the lake, decreasing water quality and clarity (Young 2007). Water quality is expected to decline further even if current discharge levels are capped because of considerable time lags in the Lake Taupo catchment between nutrient application to land and its eventual arrival in the lake via ground water. This time lag is thought to be greater than 100 years in some parts of the catchment (Hadfield 2008; Vant 2008).

Nitrogen losses from agricultural land use have been identified as the primary cause of increased nutrient loads into the lake (see Table 1). Total nitrogen discharges into the lake amount to an estimated 1,360 tonnes of nitrogen (tN) per year, of which 804tN/year originate from natural or unmanageable sources, compared to 556tN/year from manageable or human-induced sources. Pastoral activities account for 91 percent of all manageable sources of nitrogen loss. Specifically, non-dairy pasture land accounts for 79 percent of nitrogen discharges, while dairy pasture accounts for the remaining 12 percent.

[3] See Section 5.1.1 for a map of catchment land uses over time, and Section 5.1.3 for a breakdown of land uses within the catchment

Table 1: Breakdown of sources of nitrogen in the Taupo catchment, 2008[4, 5]

		Source	Load of N (tN/year)	Effective yield (kgN/ha/year)	% of total	% of category
Unmanageable load (natural)		Atmospheric deposition	272	4.4	20%	34%
		Undeveloped land	311	2	23%	39%
		Pine on unimproved land	122	2	9%	15%
		Tongariro Power Development	87	NA	6%	11%
		Pine on unimproved pasture	12	2.7	<1%	1%
		Sub-total	**804**		**~59%**	
Manageable load (human-induced)	Pastoral uses	Non-dairy pasture	442	8.6	33%	79%
		Dairy pasture	68	29	5%	12%
		Urban run-off	16	8	1%	3%
		Sewage	17	NA	1%	3%
		Pine on improved pasture	3-8	4.2–6.0[6]	<1%	1%
		Nitrogen-fixing scrub	7	12	<1%	1%
		Sub-total	**556**		**~41%**	
		Total	**1,357-1,362**		**100%**	

2.1.1. Policy development

Following growing community concern about water quality, Waikato Regional Council (WRC; formerly Environment Waikato) set a goal to restore water quality to 2001 levels by the year 2080. The council aimed to achieve the environmental goal whilst minimising the economic and social impacts on landowners whose land-use activities discharge nitrogen, and sharing these costs among local, regional and national communities (Environment Court 2011). With these goals in mind, WRC developed Waikato Regional Plan Variation 5 to limit and permanently reduce nitrogen losses from manageable sources across the catchment. The policy was developed

[4] This breakdown of nitrogen sources and total nitrogen load is a best estimate from 2008 when the programme was being designed. Data collected for benchmarking suggest that the numbers here are underestimates (see Section 2.4). The more accurate load data collected through benchmarking were used to update the cap (see Section 2.3).
[5] Source: Environmental Court, 2008a.
[6] Note that pine on improved pasture is assumed to trend down to a long-term average of 3kgN/ha/year. For a discussion on this, see Environmental Court (2008d: 37–40, 71).

over 11 years and included extensive stakeholder engagement, 136 submissions to WRC and several months of hearings in the Environment Court.[7] It became fully operative in July 2011.[8]

2.2. The policy

The policy consists of three key components. The first is a cap on nitrogen losses, which serves to limit nitrogen losses at historical levels and prevent further increases. The second component is the establishment of the Lake Taupo Protection Trust, a public fund with contributions from local, regional and national communities, charged with permanently reducing the cap by 20 percent through the purchase and conversion of land or purchase and permanent retirement of farmers' nitrogen allowances. Below we discuss the implementation of the cap, the role of the trust, the allocation of allowances, and the method of monitoring and measurement used in the scheme. The following section discusses the third component of the policy, the establishment of a nitrogen trading system that allows farmers to trade allowances with other farmers or with the trust, which is the focus of this paper.

2.3. The nitrogen cap and the trust

The environmental goal of Variation 5 is to restore 2001 water-quality levels by 2080.[9] It was decided that the key path to improving water quality lay in reducing nitrogen discharges. Due to the long transit time of nitrogen between its application through to its exit into the lake, it was concluded that returning lake water quality to 2001 levels in equilibrium would require a long-term cap on nitrogen set below current discharge levels (Environment Court 2011). The finalised Variation 5 sets the nitrogen cap at 20 percent below 2001-2005 discharge levels, with a provision to re-evaluate the cap in light of new data in 2018.[10]

It was decided that this 20 percent decrease would be achieved in two stages. First, farmers were set nitrogen discharge allocations (NDAs), which capped their annual discharges at

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[7] Tim Bennetts (of Local Government New Zealand at the time of interview and formerly of the Ministry for the Environment) explained in an interview on 8 July 2011 that the Environment Court became involved because, while all parties expressed general support for taking action to preserve the quality of Lake Taupo's waters, there was less agreement about what form such a policy should take. Understandably, landowners in the catchment expressed concern about what a limit on their allowable nitrogen discharge would mean for business, while others outside the catchment echoed with concern for what a nutrient management policy within the catchment would mean for forestry and farming industries as other catchments followed suit.

[8] See Section 5.1.4 for a timeline of the development of the policy.

[9] This environmental goal is defined in terms of nitrogen, phosphorus and algae levels, and water clarity (Environment Court 2011).

[10] The exact percentage chosen reflects a balance between the environmental impact of nitrogen and the social implications of reducing nitrogen (Young 2007). There is some scepticism about whether the 20 percent reduction target will be sufficient to compensate for the nitrogen load to come; indeed, the final policy notes that prevailing scientific opinion suggests that 30 percent or 40 percent may be more accurate (Environment Court 2011). Several sources indicated a preference for establishing the 20 percent target in the interest of moving forward, and leaving the option for future review as more scientific understanding becomes available (interview with Tim Bennetts, 8 July 2011).

near-current levels to limit further increases in leaching;[11] second, the Lake Taupo Protection Trust was tasked with using its funding to purchase and permanently retire NDAs from farmers to reduce the size of the cap by the required 20 percent. The trust was established with NZ$81.5 million in funding from central, regional and local governments in a 45 percent/33 percent/22 percent split (Environment Court 2011). Under the original proposal, NDAs (which sum to the baseline cap) were to be set at the average level of nitrogen discharges for 2001–05. Following appeals, each individual farm's NDA was set equal to the year in which they had their highest level of discharges during 2001–05. This had the effect of increasing the total cap by 160tN (Ledgard 2007). Following this appeal, the trust's 20 percent reduction goal equated to 183tN (Lake Taupo Protection Trust 2011).

2.3.1. Allocation

The decision to cap discharges at near-current levels and freely allocate NDAs to landowners based on this past level of production (known as grandparenting) was highly contentious.[12] Under historical allocation, all landowners can continue to operate at their current chosen land use and none is required by the regulation to make costly changes or to deintensify. By enabling landowners to continue operating at existing levels, grandparenting recognises and values earlier investments made to maintain a certain level of production but still places a marginal cost on intensification, and in conjunction with the overall cap, limits any increase in the total nutrients entering the lake. Grandparenting also met the regulator goal of 'minimis[ing] the cost of social change' (Environment Court 2011).

However, grandparenting significantly favours those with high discharges in the benchmark period (2001–05). Those lands previously used for low-nitrogen leaching activities, along with those farms previously facing capital constraints or other factors that historically restricted their ability to operate at a higher production levels, now face significant costs if they wish to convert their land to more nitrogen-intensive uses.[13] This restriction significantly affected the local iwi, Ngati Tuwharetoa.

In order to ease the restrictive nature of historical allocation on Tuwharetoa and other forest owners, the variation grants some costless flexibility for developing undeveloped land.

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[11] A baseline was individually set for each farm, and was equivalent to the highest annual level of leaching over the period 2001–05. See Section 5.3.1 for background on the single best year benchmarking decision.
[12] See Section 5.3.2 for background on the alternative allocation schemes proposed and considered.
[13] For this reason, many owners of forested and undeveloped land have expressed frustration that they should be disadvantaged by allocation intended to correct damage that had been largely caused by farming, whether intentionally or not. Tuwharetoa forest trusts in particular felt that extensively forested areas, for example on the eastern side of the lake, had been deliberately planted in order to protect the water from the adverse impacts of land use, and that such protection should not go unrewarded in a policy meant to achieve a similar goal.

This rule allows Maori and non-Maori owners of undeveloped and forestry land to increase their nitrogen leaching by 2kgN/ha/year above baseline leaching rates, an increase that will have only a small impact on water quality (Vant 2008).[14] The development allowance cannot be sold to other landowners as part of the trading system, and (though none have taken advantage of this rule to date) it should allow owners of undeveloped land to increase their nitrogen intensity without having to purchase allowances to do so.[15]

2.4. Measurement, monitoring and compliance

In order to set and enforce the nitrogen cap, historical nitrogen losses from each property had to be estimated in order to establish their individual baseline NDAs.[16] These were then summed up to make the aggregate cap. The method used to estimate baseline discharges is also used to measure ongoing compliance with the policy. We outline this method below, and discuss measurement and monitoring and compliance rules more generally.

2.4.1. Measurement and monitoring

Participants and regulators are not able to measure or monitor directly diffuse discharges from NPSs due to their highly stochastic and unobservable nature (Shortle and Horan 2001). To estimate true discharges based on observable inputs, the Taupo scheme uses a nutrient budgeting tool, OVERSEER® (Overseer).[17] Overseer estimates nitrogen and phosphorus loss from pastoral land using data that can be relatively easily obtained by farmers or consultants, whilst still demonstrating high performance in terms of a close correlation between measured and modelled nitrogen leaching. It also allows for comparisons between different farm types and management practices (Ledgard 2007). Although Overseer is being continuously updated, the Taupo scheme uses a set version of the tool. The same version used for benchmarking will be used to check compliance.

[14] Aggregate increase limits are set at 11,000kgN and 3,100kgN for Maori and non-Maori lands, respectively.
[15] Geoff Thorp and George Asher of the Lake Taupo Forest Trust predict that this allowance will be most useful for owners of large land blocks who are considering intensive development of a portion of their land into residential or tourism uses. In these cases, the increase in nitrogen will average out to an allowable increase over the entire block, thus enabling development of land independent of purchasing nitrogen in the market (email correspondence with Geoff Thorp, forest operations manager for Lake Taupo Forest Trust, 17–18 August 2011; interview with George Asher, CEO of Lake Taupo Forest Trust, 8 August 2011).
[16] Nutrient discharge allowances are defined in terms of annual kilograms of nitrogen leaching per hectare (kgN/ha/year).
[17] For example, the Overseer pastoral farming model uses data on a farm and block level, and computes outputs based on farming region, animal shelters and feed pads, effluent management, animal species and their management and stocking rate, supplements, nitrogen inhibitors and wetland areas, topography, climate, soil and pasture type, and irrigation, along with soil analysis and fertiliser inputs (AgResearch 2009). More information on Overseer can be found online at http://www.overseer.org.nz

The use of modelling software to estimate nitrogen output presents several ongoing challenges. Its success relies on the accurate and complete disclosure of farm-specific information. For those farms with incomplete data, conservative default measures are assumed, which could underestimate the nitrogen leached by an individual farm (Hania 2008). Also, some farm management styles do not closely align with some of Overseer's assumptions – for example, those farms running a two-year rotation or changing animal stocking numbers throughout each year. Despite these potential issues, Overseer appears to be an adequate model of nutrient loss for the Taupo catchment.

2.4.2. 'Permitted' and 'controlled' activities

The first application of this measurement method was to set individual nitrogen discharge benchmarks, which was funded by the Lake Taupo Protection Trust. Not all farms face the same requirements under the policy – different properties have different responsibilities, restrictions and levels of flexibility depending on whether they have high or low levels of leaching (see Table 2).

High nitrogen-leaching farming activities are classified as 'controlled' activities and must apply for resource consent with the WRC, a process that requires properties to be formally benchmarked to establish an individualised nitrogen discharge benchmark. Since benchmarked allowances are based on a particular set of management practices, any proposed land-use or management changes must be reassessed to demonstrate ongoing compliance with a farm's NDA and ensure that the catchment-wide cap is not exceeded. In coordination with WRC staff, farmers must run any new land uses or management practices in a nutrient management plan (NMP) through Overseer to determine expected nitrogen losses. Farmers must provide the council with a new NMP if they change farm management in a way that will increase nutrient discharges. They must also self-monitor, keep records, provide information and allow access to sites so that the council can check compliance (Environment Court 2011). The costs of measurement and monitoring are covered by all 'controlled' participants, who are charged an annual consent-holder fee (NZ$400 in 2009) by the council (Environment Waikato 2009). Monitoring and measuring also take place at the time of trade; this is discussed in Section 2.5.

Activities associated with low rates or levels of nitrogen leaching are classified as 'permitted'. These include small lifestyle farms and forestry. Operators of these activities face some restrictions on land management and cannot develop their land in ways that will increase leaching without becoming controlled activities, and meeting the requirements this entails. They are not required to apply for consents or submit NMPs. More details on the rule specifics can be found in Section 5.2.

Table 2: Permitted and controlled activities (2012)[18]

Leaching level/rate	Low (less than 8kgN/ha/yr)	High (more than 8kgN/ha/yr)
Legal status	Permitted[19]	Controlled
Applies to	• Forests • Small farms (lifestyle blocks) • Undeveloped, low-intensity farms • Golf courses etc.	• Existing farms • Intensified 'permitted' land
Restrictions	Some restrictions, e.g. fertiliser applications	Benchmark (NDA) must be set
	Must apply to become a 'controlled' activity to intensify land use, and must offset any increases in discharges that result	• Require a consent to farm. This consent requires farmers to farm to an NMP (set with Overseer) that ensures discharges are within the farmer's NDA • Can't intensify land use without offsetting increased discharges and applying for a new consent
Data requirements	None	• Must provide data to run Overseer to establish a benchmark • Must also provide data for audit of Overseer runs, e.g. GST returns, annual accounts, stock records
Monitoring	• Low levels of monitoring • Priority will be given to permitted activity properties with stock, which are likely to be visited once a year	• Spot checks to ensure farm is being managed as per its management plan • Farms that are leaching close to their NDA, have sold NDAs or are intensively managed will be monitored more closely (1–2 visits per year)

2.4.3. Compliance

The close monitoring by regulators is in part to avoid compliance problems that may arise due to the small and uncertain penalties available to regulators to enforce compliance. The penalties regulators can use to enforce compliance in the trading scheme are set by the Resource Management Act 1991 (RMA), the central environmental management legislation in New Zealand. These penalties are generic, as they need to be applied to all of the environmental management issues covered by the RMA. As a result, they are small and are likely to require time-consuming, expensive and uncertain deliberation in court on a case-by-case basis (Rive 2012a).[20] This could be a potential problem if the council has to rely on penalties to enforce

[18] See Section 5.2 for in-depth discussion of the variation rules.
[19] The monitoring regime for permitted activities is still being finalised; the table indicates what was planned in 2012, but this may have been developed further (personal communication with Natasha Hayward, On Farm programme manager, WRC, 4 July 2012).
[20] Rive (2012b) outlines the available penalties for non-compliance.

compliance, although up to 2012 compliance had not been an issue in the scheme. There are several possible reasons for this, including the short time that the cap and trade scheme has been in operation, the generous initial allocation of allowances, and the council's close approval and monitoring system.[21]

2.5. Trading rules

The policy grants farmers flexibility to deviate from their benchmark NDA by allowing them to offset any nitrogen losses above and beyond their specified allowance by an equivalent corresponding decrease in nitrogen losses elsewhere in the catchment. This creates a nitrogen trading system, where farmers facing high nitrogen reduction costs in terms of output and profits may choose to buy nitrogen allowances from another farmer, and vice versa.

2.5.1. Market participants

Any consented ('controlled') farmers who have been benchmarked and are held accountable to an individual NDA are considered market participants. It is estimated that all farms greater than 20ha and roughly 50 of those farms smaller than 20ha will be required to apply for a resource consent as controlled activities, amounting to a total of approximately 180 participant properties.[22] Of these 180 participant farms, six are dairy farms and the rest are sheep/beef farms. Table 3 gives a breakdown of land use in the catchment. Not all of the land summarised in this table will be covered by the trading scheme, but the breakdown indicates that many of these participants are private farms, and that the local iwi, Tuwharetoa, is the largest landowner in the catchment, with significant holdings of forestry and developed and undeveloped pasture. Government-owned land also takes up a considerable portion of the catchment. Naturally, though all of these property owners are eligible to trade, not all will necessarily take advantage of the option.

Table 3: Breakdown of 2005 land uses in the Taupo catchment and summary of pastoral properties[23]

Land use	Tuwharetoa land (ha)	Government land (ha)	Privately owned land (ha)	Total	% of land in each use
Undeveloped	50,840	103,660	0	154,500	56%

[21] Personal communication with Natasha Hayward, 8 June 2012.
[22] See Section 5.1.3 for a summary of pastoral land uses in the catchment
[23] This table is based on court evidence from Young (2007). Benchmarking of farms has indicated that these data are only an approximation of the actual land-use areas.

Planted forests	35,500	4,300	24,700	64,500	24%
Sheep and beef	23,800	14,800	12,100	50,700	18%
Dairy	778	0	1,022	1,800	0.7%
Urban	0	0	3,500	3,500	1.3%
Total	110,918	122,760	41,322	275,000	
Proportion	40%	45%	15%		

We would expect traders to be those participants who perceive that they have something to gain from changing management practices and trading their surplus or deficit of allowances with others. Farmers who have a relatively inexpensive way to reduce nitrogen losses may choose to make management changes that will reduce their nitrogen discharges and then sell the surplus nitrogen for a profit. Buyers will be those farmers for whom more profits can be gained by intensifying production or converting to a more nitrogen-intensive land use (such as dairy) and purchasing additional allowances from another farmer. Another key participant will be the Lake Taupo Protection Trust, which is tasked with purchasing and permanently retiring nutrient allowances to achieve a 20 percent reduction in nitrogen leaching. The trading system is the key mechanism through which the trust purchases and permanently retires allowances from willing sellers.

2.5.2. Format of the nitrogen trading system

The Taupo water-quality market differs from most other existing NPS water-quality trading schemes in that it is a cap and trade market, rather than an offset (or baseline and credit) scheme (Selman et al. 2009). In this manner, the Taupo scheme is similar to established emissions trading schemes such as the Acid Rain SO_2 market. Cap and trade systems, such as the Taupo scheme, have a comprehensive cap on the allowable discharges of nutrients in a catchment; this cap is then divided into individual, tradeable allowances. These allowances are then distributed to market participants, who must hold or remit an allowance for each unit of nutrients entering waterways from their property.[24]

The timing of monitoring and the required level of regulator pre-approval of trades are also defining characteristics of trading markets. The Taupo scheme is similar to other water-

[24] Baseline and credit markets differ as not all sources of nutrient discharge are regulated. Instead, only some regulated participants face a cap. Voluntary sources outside the regulated group can opt into the system and participate by decreasing their nutrient discharges in exchange for credits. Baseline and credit markets are subject to significant transaction costs and adverse selection (McDonald and Kerr 2011).

quality trading markets in its requirement of significant regulatory oversight and *ex ante* approval of trades. If a farmer wishes to trade allowances, he or she must first find a willing trader and negotiate the terms of trade. The farmers must then update their NMPs and provide the new NMP and supporting documents to the regulator to have the change approved. This NMP demonstrates how the farms will operate within their proposed new nitrogen allowances. Farmers are expected to fund the cost of creating the new NMP, and the cost of having the new NDA approved by council. Only landowners in the catchment can purchase allowances. No banking or borrowing of allowances is allowed,[25] but allowances can be leased on a short-term basis or sold for the duration of the resource consent. Resource consents have a lifetime of 25 years to improve farmer certainty.

3. Evaluation of policy impact

In this section we evaluate the performance of the trading scheme to date. Assessing the degree to which this policy maximises the sum of net social benefits from Lake Taupo, the economic optimality, is beyond the scope of this paper.[26] Instead, we assess the extent to which the policy achieves the environmental goal at minimum cost: its cost-effectiveness. We follow Tietenberg and Johnstone (2004), and Shortle (2012), and assess the performance (and likely ongoing performance) of the trading scheme on a number of criteria: we examine the economic efficiency of the scheme and present evidence on cost-effectiveness, market power, time-of-trade transaction costs, administration costs and innovation. We also comment on environmental effectiveness. Given the young age of the policy, our conclusions should be considered preliminary. Before evaluating the effect of the trading scheme, we explore the initial impacts of the policy's other two key components: the cap at current discharge levels, and Lake Taupo Protection Trust's reduction of this cap through NDA purchases.

Conclusions in this section are guided by quantitative data on trading in the catchment, interviews with key stakeholders, and a reading of the institutional structure of the trading market. The descriptive data we present come from two administrative datasets collected by the WRC, the regulator in Lake Taupo. The first dataset records descriptive data for every farm that

[25] Banking and borrowing were avoided when the policy was first written up as they were seen as an unnecessary complication (personal communication with Justine Young, senior policy analyst, WRC, July 2011). Farming groups requested that the cap be applied on a three-year average, as opposed to strictly every year, but the council declined this request as they believe that the initial allocation of allowances has been at such a level as to allow flexibility without these changes (personal communication with Natasha Hayward, 8 June 2012).

[26] This is not because the environmental target appears to be endogenous to the policy instrument chosen, which is a potential barrier to assessing optimality highlighted by Tietenberg and Johnstone (2004). In the case of the Taupo catchment, it appears that the environmental target of restoring 2001 water-quality levels was established before nutrient trading gained traction as the desired policy instrument (Yerex 2009). We restrict ourselves to economic efficiency because of the difficulty of quantitatively assessing the benefits of cleaning up the lake.

has sold nutrient allowances up to June 2012: farm characteristics (farm type, location, size and original NDA) and trade data (buyer, seller, amount of nitrogen traded, whether the trade was a sale or a lease, trade date and new forestry plantings). Unfortunately, the dataset does not include farm characteristics of the buyer (or leaser) of allowances, and does not include price information. The second administrative dataset includes farm characteristics for all farms in the catchment whose nitrogen leaching had been benchmarked by August 2011 (89 percent of farms had been benchmarked at this time, with generally just small landholdings remaining to be benchmarked). While these data are limited,[27] they do provide some evidence of economic efficiency in the market.

3.1. Impact of the policy

The policy was made fully operational on 7 July 2011. However, council staff began its implementation in 2007, and the Lake Taupo Protection Trust was given the ability to make NDA purchase decisions in 2007 (Young and Kaine 2010). The trust made its first trade in January 2009, which was also when the first private trade was completed. Implementation progress is well underway. By June 2012, roughly 90 percent of farmland in the catchment had been benchmarked and allocated nitrogen allowances, with all of these farms having completed NMPs and either been granted or applied for consents, the final stage in the process (Hayward 2012). Bigger farms with greater leaching were benchmarked and processed before smaller farms; this means that the farms remaining to be benchmarked and consented as at June 2012 are either small or farms with limited data for benchmarking.[28]

3.1.1. Impact of the cap

The implementation of the cap on current discharges has had a number of impacts on landowners. The most obvious of these are the additional record-keeping and legal costs associated with introducing the requirement for landowners to hold a resource consent. Several farmers indicated frustration at having these additional costs and hassles imposed on top of normal operations, while others expressed a philosophical opposition to the requirement of a resource consent to farm.

It is likely that the cap has reduced the value of some land. To the extent that the value of a block of land is related to its productive capacity, any land subject to a binding upper limit

[27] Ideally, these two datasets would be linked, but unfortunately we do not have the ability to do so without more information. An ideal dataset would also collect information on the buyer of nitrogen allowances and the price of the nitrogen trade. Information on how the surplus allowances were created for sale (e.g. land retirement, mitigation, land-use change) would also be useful for future work.
[28] Personal communication with Natasha Hayward, 8 June 2012.

on the amount of nitrogen it can discharge is worth less than land operating in an uncapped environment. The cap has certainly increased the cost of converting from sheep and beef farming to dairy,[29] with significant potential impact on the capital value of land that previously had this option value, and on owners of this land.[30] The magnitude of this impact on land values in the catchment is disputed; the company responsible for land valuations contends that the impact on catchment land values has been ambiguous compared to similar land outside the catchment, while others believe that land values have suffered a 5–10 percent reduction.[31] The impact on land values (before any sale of NDAs) has not been equal across the catchment; those lands assigned a below-average allowance compared to lands with similar characteristics experience a greater decline in the value of their land.[32]

On the positive side, the imposition of the cap has given certainty to landowners in the catchment. The lengthy development process saw many farmers stalled in uncertainty, unsure of whether to invest in farm improvements or of their future viability in the catchment and unable to sell land; the implementation of the cap has ended this.

3.1.2. Impact of the trust

A transition to the long-term cap (a 20 percent reduction in current agricultural discharges) is being achieved through the Lake Taupo Protection Trust. In this section we discuss how the trust is achieving its nitrogen goals, outline the trust's innovative use of the carbon market to supplement nitrogen payments to farmers, and discuss the trust's dual efficiency and equity goals.

The trust is reducing nitrogen in the catchment in two ways. The most straightforward method sees it purchasing and permanently retiring NDAs from farmers who have surplus allowances; the impacts of this are discussed in Section 3.2. The trust is also achieving cuts by purchasing whole farms, converting them to uses that leach low levels of nitrogen such as forestry, and then on-selling them. To ensure that the nitrogen reductions are permanent, the trust is not just relying on consent changes, which can expire after 30 years, but is also placing

[29] Concern about the potential for significant levels of dairy conversions in the catchment (and their environmental impact) was an early motivation for the cap (Tony Petch, group manager, Environment Waikato, quoted in Yerex (2009)).

[30] To illustrate, assume that a sheep and beef farmer was assigned an average NDA of 18kg/ha/year. A dairy farm would need an allowance of approximately 36kg/ha/year. At a nutrient allowance price of NZ$300 (approximately the market price in 2012), the cost of purchasing allowances that would allow a dairy conversion would be 300 × 18 = NZ$5,400/ha. This has clearly decreased the option value of this land.

[31] Phone conversation with Mark Grinlinton of Landmass Technology, Ltd, 15 August 2011, and interview with Graeme Fleming, CEO of Lake Taupo Protection Trust, 15 July 2011.

[32] A property's NDA is considered when calculating the land value (phone conversation with Mark Grinlinton, 15 August 2011).

999-year covenants on the land that allow intensification only if nitrogen allowances offsetting the increase are purchased by the landowner. The effects of this land purchase and retirement method on the catchment differ from those of simple allowance purchases.[33]

On the positive side, these transactions have facilitated land-use change and enabled willing sellers to exit the catchment. On the negative side, the conversion of whole tracts of productive and attractive farmland into forestry has had unwelcome impacts on sellers as well as on remaining farmers. One couple who considered themselves unable to wait for the development of alternative management practices expressed feeling pressure to exit the catchment and leave behind not only their business but also their home. Another farmer remaining in the catchment emphasised that seeing farmers go 'has hit me quite hard', and that the imposition of the policy overall, with no recognition of the hardship it entails, had dampened his enthusiasm and mental well-being:

> From my farm I can look out the window and see four farms that have been traded; these farms are soon going to be covered in pines. As a farmer I rely on my neighbours – they help you out if you run out of something, or help you out with big jobs. And the social side – these are the people you socialise with, and they have left the area. So yes, it does affect you.[34]

Social costs of this sort have been highlighted by a number of stakeholders. There is also concern from those farmers left that the sale and afforestation of neighbouring farming land will decrease the value of their own land when it comes time to sell.[35]

The trust has also turned to New Zealand's Emissions Trading Scheme (NZ ETS) to make tree-planting a more attractive mitigation strategy for farmers. In deals facilitated by the trust, landowners who plant portions of their land in forestry can, in addition to selling nitrogen to the trust, sell carbon credits to nearby power companies who require carbon credits to meet requirements under the NZ ETS. In doing so, these sellers are able to reap dual financial benefits from planting trees by earning nitrogen income in the short run and a stream of carbon income in the longer run.[36] In many of these cases, the forest conversions occur on marginal or less productive lands, so that remaining productive lands can be farmed more efficiently.[37] These partial conversions hint at efficiency gains; trading has moved nitrogen from less productive uses and preserved it for more productive uses.

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[33] Interview and email correspondence with Graeme Fleming, 15 July 2011 and 5 July 2012.
[34] Personal communication with Alex Richardson, Taupo farmer, 5 July 2012.
[35] Ibid.
[36] See Mighty River Power (2010) for a description of one such deal involving interactions between nitrogen and carbon markets.
[37] Interview with Graeme Fleming, 15 July 2011.

To 2012, while the trust has been focused primarily on purchasing enough nitrogen to achieve the environmental goal within its funding, equity considerations have also affected its trading decisions and the prices it is willing to pay for nitrogen. The decisions made for equity reasons may have increased the cost of achieving the environmental target in straight dollar terms, but have helped ease the cost of the policy for farmers in the catchment. An example is that the trust made an early decision to offer all Tuwharetoa landowners the same set price so that they did not have to compete with one another for nitrogen reduction funding. This price was set at the upper end of the trust's acceptable price bracket, in part to recognise that Tuwharetoa had planted land in forestry to protect the lake before the trading scheme was introduced. A second example is that some of the first nitrogen purchases made by the trust were wholesale purchases of farms that were then forested and sold on. These purchases allowed the trust to retire large amounts of nitrogen, but proved an expensive way of achieving reductions. These trades were motivated, at least in part, by a desire to enable farmers who wanted to leave the catchment to do so, and hence ease the social transition. The ultimate cost of reducing nitrogen was higher than in other trades because the farmers were paid pre-policy prices for their farms. Both of these examples highlight the dual goals of the trust when buying nitrogen: it is balancing a desire to achieve the nitrogen decreases at low cost, but is also taking equity considerations into account.

3.2. Impact of trading and evidence of cost-effectiveness

One potential indicator of the economic efficiency and cost-effectiveness of the trading market is the number of trades that are occurring. High levels of trading can indicate gains from trade and cost savings, while a lack of trading activity can indicate market inefficiency or market failure (Shortle 2012). However, we might want to be cautious when measuring the success of a trading scheme by its trading levels because low trading can be a result of many things other than a poorly designed scheme. Two key sources of low trading internationally are non-binding caps and homogeneity of traders. Market power can also restrict trading. Before presenting data on trading levels, we discuss why we would not expect these sources of low trading to affect trade in Taupo. As a result, unless there are high transactions costs, we would expect to see trading in the Taupo scheme. The potential for transaction costs in decreasing the number of trades and cost-effectiveness of the policy is discussed in Section 3.3.

3.2.1. Potential limits on trading

Selman et al. (2009) note that many existing water-quality trading markets have seen little or no trading as a result of weak regulatory requirements that mean there is little demand for allowances. This is unlikely to be a source of low trading in Taupo, as the trust is actively seeking the sellers it needs to purchase 20 percent of allocated allowances to permanently reduce the cap. This could potentially change once the trust leaves the market; there has been some suggestion that the single best year benchmarking standard and future climate conditions may prevent farmers from reaching their individually allocated caps, and thus reduce demand for units.[38] However, as long as dairy prices remain high, demand for allowances that would enable dairy expansion is likely to continue beyond the exit of the trust.[39]

Likewise, homogeneity of traders does not appear to be a trade-limiting factor in Taupo. Shortle (2012) argues that when dealing with agricultural externalities, as a result of the importance of natural factors in agricultural production and the variability of these natural factors across space and time (e.g. topography, weather), there will always be a significant degree of heterogeneity in mitigation costs.[40] The existence of dairy, sheep/beef, and deer farming in the district, and the wide distribution of farm sizes and intensities, also suggest that significant heterogeneity exists to support trading.

Finally, while a market approach has many advantages over other pollution-control mechanisms available to regulators, it is the only approach that is potentially subject to manipulation by market power (Tietenberg 2006). However, market power does not appear to be a significant risk in the Taupo scheme: there are many small and medium-sized allowance-holders in the nutrient trading market, and no dominant holders. A calculation of a Herfindahl index measure of market competition carried out on the initial distribution of NDAs finds that the market is highly competitive.[41] Additionally, ownership of allowances has been restricted to landowners in the catchment, which will limit the ability of any outside investors to accumulate market power.

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38 Early monitoring indicates that at most farmers' current operating intensity, this cap is not binding, with leaching levels often 10 percent below this benchmark (personal communication with Natasha Hayward, 8 June 2012).

39 The ability for undeveloped land owned by Maori and non-Maori to be intensified without purchasing the full allotment of allowances has the potential to dampen demand in the market, although as noted above, we do not believe that this will have a significant effect on total allowance demand. See Section 2.3.

40 While this statement is generally true, the ability to capture this heterogeneity in a trading scheme depends on the ability of the discharge estimating tool to capture site specificity. As described in Section 2.4, Overseer captures much of this heterogeneity.

41 We calculate a Herfindahl index value of 2.8 percent. The Herfindahl index is a blunt measure of the degree of market concentration. It is calculated by expressing the market shares of agents as fractions and calculating the sum of squares. Our Herfindahl index is calculated using data on the initial NDAs of benchmarked farms. We would expect this index to decrease (i.e. our measure of market power would fall) if we estimated it on the NDAs of all farms, rather than on just the large farms that had been benchmarked by August 2011 and are in our dataset.

3.2.2. Evidence from trading

Given that a non-binding cap, homogenous participants and market power are unlikely to restrict trading in the Taupo scheme, we now consider the trading data for evidence of the market's economic efficiency. In an efficient market we would expect to see a high number of trades, large volumes of nutrient allowances traded, a large proportion of the total cap traded and a large proportion of potential participants trading. We would also hope to see the existence of small trades or short-term trades, as this would indicate that any fixed costs of trading can be outweighed in even relatively small transactions. Below, we investigate the size and length of trades (long-term trades or short-term leases), as well as the previously mentioned measures.

We would also hope to see the existence of both private trades (trades between two private farmers) and public trades (trades between one private farmer and the trust). Both types of trade are indicative of efficient reductions of nutrients, but private trades may be a better indicator of efficiency as they are voluntary in a way that public trades are not. While we might still expect the public trust to carry out trades in a poorly functioning market because it must meet its nutrient-reduction goals, entirely voluntary trades between two private farmers would not occur unless gains from trade were present. Evidence of private trades would therefore be a more trustworthy indicator of market success. Private trades are also interesting because they are the future of the market: the public trust will leave the market when it has met its nutrient-reduction goal, leaving only private trades. We investigate trades by type below, and consider any differences between public and private trades in an attempt to ascertain how the market may change following the departure of the trust.

Ideally, we would also like to study price data to assess whether the market is efficiently meeting the law of one price, but we have only qualitative data on prices; this and potential evidence for inefficient market segmentation is discussed following the quantitative evidence. The potential for transaction costs to decrease economic efficiency is discussed in Section 3.3.

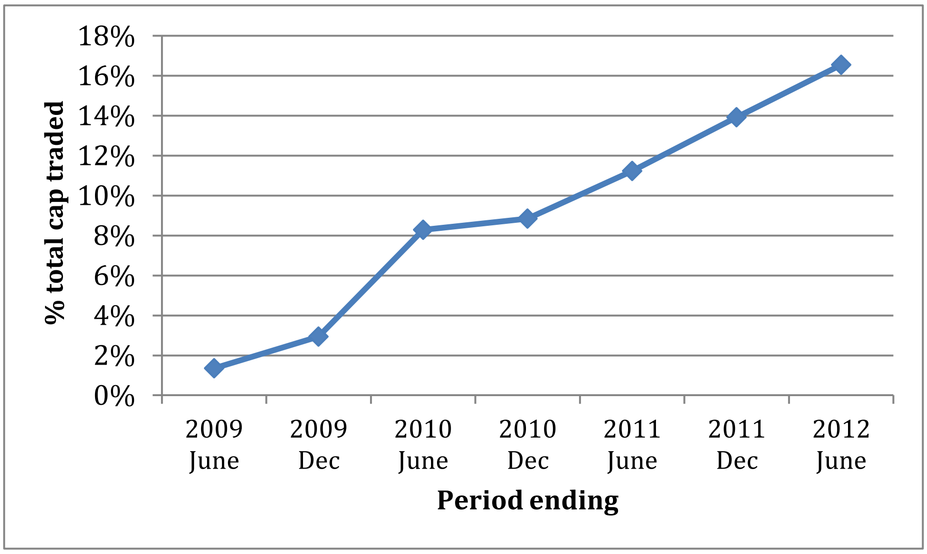
3.2.3. Levels of trading

Up to 2012, the Lake Taupo trading scheme has seen 32 trades, cumulatively constituting in volume more than 16 percent of the cap.[42] Additionally, those participating in trading represent a significant proportion of the catchment. To 2012, 30 out of approximately 180 farm owners in the catchment have traded; that is, 17 percent of the potential traders have traded at least once between 2009 and 2012. These traders own a disproportionate 46 percent of the total

[42] There are approximately 180 participants in the trading scheme (see Section 2.5.1).

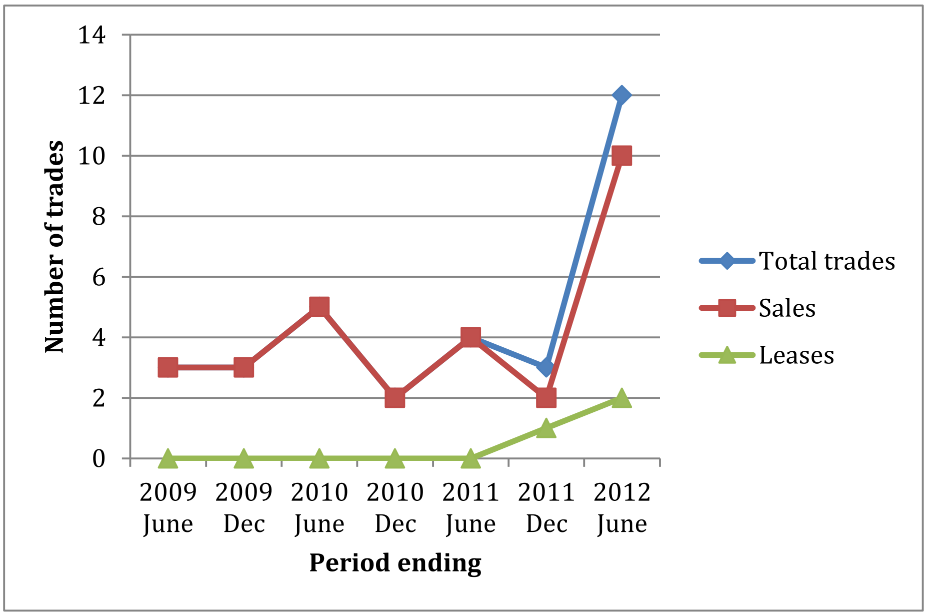
catchment farming land. Likewise, the volume of allowances traded is also relatively large: Figure 1 shows the cumulative proportion of allowances that are now in the hands of someone other than the owner to whom they were originally allocated, be this the trust or a private farmer. This has increased since the first trade in 2009, such that by June 2012, 17 percent of the total cap had been traded. This compares favourably to many other existing water-quality trading markets, where trading levels were low (King 2005).

Figure 1: Cumulative proportion of total cap traded over time



Due to the small number of trades in the Taupo scheme, it is difficult to discern any long-run trade patterns, either in terms of number or size of trades. Figure 2 shows the number and type of trades completed in the Taupo scheme between June 2009 and June 2012. While the number of trades is highest in the most recent time period, with 12 total trades, it is unclear whether this is an outlier or evidence of an increase in trading volumes from the previous average around three sales every six months. No leases of allowances were agreed to until December 2011, but there have been an additional two leases in 2012. One limit to trading in early years was the relatively small number of farms that were benchmarked and therefore able to trade. We might expect to see a greater number of trades now that all farms have been benchmarked.

Figure 2: Trades in the Lake Taupo nutrient trading scheme over time



There is also no discernible time pattern in the total volume of allowances traded in each period (see Table 4). The largest volume traded occurred in the first half of June 2010, when more than 48tN was traded in five trades, equivalent to 5 percent of the cap. By contrast, despite the high number of trades in the June 2012 trading period, the volume traded was only 22tN; an average trade size of only 1,965kgN, which is significantly lower than the average trade volume over the whole period of 4,653kgN. We might expect the size of allowance sales to be closer to this smaller June 2012 size once the trust leaves the market and farms move to a new optimal land use under the nitrogen trading scheme. The number of trades will also probably fall as the catchment moves to a new equilibrium of land use and management. Either way, the existence of these relatively small trades (and short-term leases) is further evidence of a well-functioning market.

Table 4: Number and size of allowance trades over time

Date	Total trades	Sales	Leases	Volume (kgN traded)	Average trade size (kgN)	Proportion of total trades that were private
June 2009	3	3	0	12,226	4,075	67%
Dec 2009	3	3	0	14,200	4,733	33%
June 2010	5	5	0	48,200	9,640	20%
Dec 2010	2	2	0	5,000	2,500	50%
June 2011	4	4	0	21,378	5,345	25%
Dec 2011	3	2	1	24,311	8,104	67%
June 2012	12	10	2	23,581	1,965	42%
Total	**32**	**29**	**3**	**148,896**	**4,653**	**41%**

3.2.4. Types of trade

Trades in the market differ by whether they are between a private farm and the trust ('public' trades), or between two private farmers ('private' trades). Purchases by the trust serve to remove nitrogen permanently from where it is least costly to do so, while transactions between private farmers represent cases where the market enables nitrogen allowances to be reallocated to its most highly valued uses. While both private and public trades are indicators of market efficiency, private trades are of particular interest as they represent truly voluntary trades, and, given the eventual departure of the trust, are a better indicator of long-term market activity. Table 4 shows that private trades made up 41 percent of trades between June 2009 and June 2012, but with no clear time trend. Table 5 and Table 6 compare public and private trades and traders.

Table 5: Number and size of trades (June 2009–June 2012), private and public

	Sales of allowances			Leases of allowances		
	Total sales	Average NDA sold (kgN/yr)	Average percentage of NDA sold	Total	Average lease (kgN/yr)	Average length of lease (years)
Private trades	10	1,808	42%	3	1,167	3.7
Public trades	19	6,722	41%	0	0	0
All trades	29	5,154	42%	3	29	3.7

Table 6: Trader characteristics (June 2009–June 2012), public and private

	Farm characteristics			Intensity (kgN/ha/yr)		New forestry	Farm type[43]			Location
	Original NDA	Average effective area	Additional retired area[44]	Before trade	After trade	% of Effective area[45]	Dairy	Sheep/beef	Deer	Northern catchment
Private trades	3,483	104	12%	27	15	0%	55%	45%	0%	71%
Public trades	23,367	1,234	40%	15	8	23%	8%	74%	18%	26%
All trades	16,531	857	38%	19	10	24%	24%	64%	12%	45%

3.2.5. Public trades

In addition to purchasing five whole farms and their accompanying nitrogen allowances, up to June 2012, the trust has completed 14 transactions in which it purchased and retired

[43] If a farm is reported as either a dairy milking farm or a dairy grazing farm, it is recorded here as dairy. These proportions are rough estimates: if a farm is reported as both dairy and sheep/beef farm we recorded that the farm was half dairy and half sheep/beef.
[44] The amount of additional land that is owned by the farmer but is retired before the trade, as a proportion of their effective area.
[45] How much extra land is retired after the trade, as a percentage of original effective area.

nitrogen allowances from farmers. While some farmers have simply sold their excess allocation or reduced their stocking numbers, the majority have made partial farm conversions by planting trees on less productive, marginal lands, reducing their effective nitrogen output and selling their surplus allowances. About 5,800ha of land have been converted into forestry, approximately 11 percent of the 52,500ha of effective pastoral land that was in the catchment before the implementation of the policy. The average public trade of nitrogen has been for just over 40 percent of a farm's initial NDA. Excluding those farms sold outright to the trust, the average public trade has been for 42 percent of the seller's original NDA. Apart from one small trade, the 19 total transactions the trust has made have each removed between 3tN and 22tN, with most clustered on the lower end of that scale.[46] The average public trade has been for 6.7tN. The trust has not been involved in any leases of allowances as it is aiming for long-term reductions. Although the trust has made positive progress to date, having removed 128tN of its target of 185tN, it is cognisant of the fact that the final reductions will prove more difficult than the first.[47]

3.2.6. Private trades

Ten private trades were made between the first trade in January 2009 and June 2012. Seven of the trades consisted of one expanding dairy farmer purchasing allowances from other farmers, though two other farmers also purchased allowances. The average private trade is much smaller than public trades: only 1.8tN. The average trade is for a similar proportion of original NDA to public trades, at 41 percent. Private trades have also involved short-term leases of allowances. Three of these were carried out over the time period, with an average length of 3.7 years and average lease size of 1.1tN. These leases involved traders who have also sold allowances either to the trust or to the expanding dairy farmer.

Our dataset also allows us to compare the characteristics of those who sell in private and public trades (farms that sell to the trust); this is shown in Tables 5 and 6. As suggested by the size of trades in Table 5, farms that sell to the trust are much larger than those who sell privately. These farms are on average more than 12 times the size of a private trader's farm, and their initial NDA is on average seven times as large. This is potentially due to the trust targeting large trades, and as a result not dealing with smaller farms with lower initial NDAs. However, public traders have less intensive farms than private traders, both before and after trading. They are far more likely to be sheep/beef farmers before trading, and are far more likely to retire productive

[46] Interview with Graeme Fleming, 15 July 2011. See Section 5.1.5 for a summary of nitrogen removed between 2009 and June 2012.
[47] Interview with Mike Barton, Taupo farmer and member of Lake Taupo Protection Trust, 14 July 2011, and interview with Graeme Fleming, 15 July 2011.

land for forestry in order to free up nutrient allowances for trading. By contrast, a majority of private traders were initially dairy farmers and are more intensive, on average, both before and after trading allowances. Apart from private traders who also traded with the trust, no private traders have planted forests on their land.

The existence of these 13 private sales and short-term leases is strongly suggestive evidence of economic efficiency gains and market flexibility: farmers can intensify their operations even within the boundaries of the nitrogen cap. That it is profitable for the dairy farmer to intensify his operation even at the expense of purchasing nitrogen allowances demonstrates that nitrogen is valued more at the margin in that dairy use than it is in its previous allocated use. In this way, the intensification of dairy farming using the trading mechanism provides evidence of improved efficiency of catchment production from an economic standpoint. The private trades are also heartening for the ongoing success of the trading scheme, suggesting that gains from trade can be achieved in the market even in absence of the trust.

3.2.7. Prices

We have no data on prices in the trading market, and as a result cannot test whether the market is achieving an efficient law of one price. Qualitatively, the limited evidence available suggests that the current market is fragmented and that, as a result, purchasers of allowances have the ability to negotiate different prices with different sellers; there is no 'market' price. The trust has established a standard price of approximately NZ$400 per kgN permanently reduced. The trust pays this over time, which with discounting is estimated to equate to an upfront price of roughly NZ$300/kg.[48] This price was reached by considering the total amount of nitrogen the trust would need to remove, an estimation of the cost of removing that nitrogen, and the trust's available funding. Although trading is a confidential process, the largest private buyer of allowances explained that his price is set as a combination of market forces, including the value he attributes to additional nitrogen and the price offered by the trust. In this way, price is not yet determined fully by market forces, but is also heavily influenced by arbitrary factors such as the trust's funding.

[48] The trust has to pay for allowance purchases in instalments over time as it receives its funding in annual increments. Interview with Graeme Fleming, 15 July 2011, and interview with Mike Barton, 14 July 2011. For the purposes of valuation of consented land with a particular NDA, valuation company Landmass Technology assumes a sale price of NZ$300kgN/ha/year and a purchase price of NZ$330kgN/ha/year to account for risk.

3.3. Market efficiency

3.3.1. Time-of-trade transaction costs

Time-of-trade transaction costs can adversely affect the economic efficiency of a trading market (McDonald and Kerr 2011). Time-of-trade transaction costs include the costs of optimising operations, search and bargaining costs of finding trading partners, and the costs of trade approval and trade registration. Taupo regulators have attempted to minimise these in a number of ways, but the transaction costs involved in trade approval may prove to be a substantial limit on trading in the Taupo scheme.

3.3.2. Minimising transaction costs

The transaction costs faced by participants at the time of trade can be minimised by ensuring that participants have easy access to information, as much political and regulatory certainty as possible, and by maximising liquidity. The literature also suggests that transaction costs will fall with time as participants learn by doing (Woodward 2003). We would expect to see transaction costs fall over time as participants and regulators become more familiar with the system.

Information

In an unfamiliar market such as a nitrogen trading system, improving the information available to potential participants may prove to be a key element that will encourage trading. In order to inform market participants about the mechanics and usefulness of trading, the council has published an online guide for farmers that outlines how the trading process should take place and what conditions would help a farmer gain from trade (Environment Waikato 2009). Frequent newsletters from members of farming alliance Taupo Lake Care (TLC) and high participation in benchmarking during the policy development process have enabled many farmers to gain a good understanding of how the process works and how trades can take place.[49]

In an effort to minimise search and bargaining costs for participants, an online marketplace was also established to advertise allowances for sale or solicit nitrogen for purchase.[50] In theory, this format should facilitate trading by making the process transparent and allowing all interested parties access to information regarding who is offering NDAs for sale or for purchase, proposed prices, and proposed length of trades. Interestingly, the online message

[49] Interview with Mike Barton, 14 July 2011.
[50] See Waikato Regional Council, http://www.waikatoregion.govt.nz/Templates/Public/Classified/Search.aspx

board has not been used for facilitating trades, perhaps since farming communities favour face-to-face interactions and transactions.[51]

Uncertainty, be it at a political, regulatory or scientific level, will result in defensive and trade-inefficient behaviour from participants. Scientific uncertainty has been minimised by the council in the design of the regulation. Compliance is predetermined using the establishment of NMPs; as long as a participant follows their plan they will be in compliance. This approach maximises certainty for farmers as they are not held responsible for shocks outside of their control, such as freak weather events. Scientific uncertainty is additionally limited by setting a specific version of the discharge estimating tool, Overseer, to be used to measure future compliance. As a result, changes in scientific knowledge that impact Overseer will not affect participants' ongoing compliance.

Political and regulatory uncertainty is considered to be relatively low. Farmers fundamentally support protecting water quality in the lake, and as they begin to get used to the idea of the trading scheme, acceptance has increased.[52] As a result, there has been no political support for revisiting this issue.[53] A process for reviewing the scheme in terms of environmental success and workability for users has been agreed following discussion and legal appeals between WRC and stakeholders. This is explicitly laid out in the final version of the policy; the transparency of these reviews will help to minimise participant uncertainty.

One source of considerable uncertainty that does remain for participants is around the ability to access allowances in the future. Trading in the market has been limited so far, and this lack of liquidity could decrease participants' willingness to sell excess allowances in case they are unable to purchase them back in the future. The existence of lease agreements is potentially evidence of this: instead of selling allowances now and buying them back in the future, participants are lending their allowances with an explicit promise that they will be returned at the end of the lease period. This lack of liquidity could significantly limit trading, although lease agreements seem to be an obvious solution.[54]

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51 Interview with Mike Barton, 14 July 2011.

52 Personal communication with Natasha Hayward, 8 June 2012.

53 Personal communication with Justine Young, June 2011.

54 McDonald and Kerr (2011) also suggest retaining some allowances so that regular auctions can be held. They also suggest that liquidity can be improved by decreasing restriction on trading due to environmental concerns. Given that the Taupo scheme allows trading amongst all participants, regardless of potential spatial effects or lake arrival times, it would appear that improvements to liquidity have already been achieved in this manner.

3.3.3. Transaction costs of trade approval

The most significant source of time-of-trade transaction costs in the Taupo scheme are faced in the trade approval process. The scheme requires considerable regulatory oversight and pre-approval of trades. This *ex ante* monitoring can be useful in preventing non-compliance, as it offers plenty of scope for regulators to oversee participants' planned discharge activity and intervene if necessary. This issue of compliance is potentially an important one in New Zealand, where the legal system limits the ability of regulators to enforce compliance through the threat of easily enforceable or large penalties, as discussed in Section 2.4 (Rive 2012b). Unfortunately, *ex ante* monitoring can also greatly increase transaction costs (Schary and Fisher-Vanden 2004). In this section we outline the trade approval process, and discuss the different transaction costs involved in private and public trades. We then consider the trading to 2012 for evidence of transaction costs.

Ex ante monitoring in the Taupo scheme requires both parties to apply for a resource consent change and supply an updated NMP. This introduces additional and substantial time costs, as well as administration and legal costs: a farmer wanting to trade would first have to consider the economic benefits of trading, find a trader and pull together the information required to update an NMP. If the farmer wanted to get an agricultural consultant to review the NMP, he or she would then have to commit to approximately four hours of face-to-face time with the consultant, at a cost of NZ$400–500.[55] Finally, the farmer would have to get their trade signed off by the regulator, which was originally expected to cost farmers approximately NZ$400 (Hania 2008), although more recent estimates have put the cost lower, at around NZ$100–200 per change.[56] The final transaction cost faced by traders in the system is additional monitoring: WRC monitors those who have traded more frequently and with greater requirements than those who have not traded.

A farmer's transaction costs differ by whether they are dealing with the trust or trading with another farmer: costs are artificially low when transacting with the trust. Not only does the trust act as a certain buyer offering a standard price for nitrogen, it also agrees to cover legal costs and to fund business consultants and accountants to ensure that nitrogen transactions make business sense. In this way, transactions with the trust are relatively cheap for farmers in terms of potential for risk and in terms of undertaking the trade itself.

[55] Personal communication with Alex Richardson, Farmer, 5 July 2012.
[56] Personal communication with Jon Palmer, Waikato Regional Council 6 July 2012.

Despite this, trading with the trust can be time-consuming and expensive. Depending on the degree to which the seller of nitrogen wishes to negotiate the terms of a standard agreement, organising a trade with the trust can take weeks or months from beginning to completion. These time costs will clearly be a detriment to trade. In total, the cost to the farmer of trading with the trust, above time costs, is estimated at approximately NZ$2,000–3,000. The trust bears the majority of the costs and estimates that the cost to the trust of making a trade falls somewhere around NZ$2,000–8,000.[57] Trust CEO Graeme Fleming argues that, relative to the value of the trade, these costs are not large: 'These trades are often for millions of dollars, so you want to make sure that the trade makes sense and that the other party is aware of the terms and responsibilities.'[58]

While trade assistance facilitates the removal of nitrogen from the catchment and eases the burden on sellers of nitrogen, it is also a costly process for the trust, and discourages transactions where sellers can offer only small amounts of nitrogen.[59] Despite the time involved with trading with the trust, one farmer who considered such a trade described the process as straightforward and mentioned that the trust were quick and easy to deal with, given the job they are tasked with carrying out.[60]

It is unclear whether transaction costs would be greater in private trades between farmers: such trades have no support from the trust, and greater risk and uncertainty, but potentially lower administrative requirements. When trading with another farmer, both parties are responsible for judging the relative costs and benefits of that trade without the assistance of a trust-provided consultant. There is also an additional risk that the other party may not be approved and that the trade cannot continue as planned. However, trades with the trust require additional administrative requirements that could increase the cost. One dairy farmer who has been an active trader of allowances acknowledged the transaction costs but also indicated that the trades are nevertheless worthwhile, potentially providing evidence that the level of risk involved in one-to-one trades is not prohibitively high.[61] Additionally, the fact that there were 13 private trades between January 2009 and June 2012 may indicate that the private transaction costs are not overly restrictive.

[57] These estimates come from a personal communication with Graeme Fleming, 5 July 2012.
[58] Ibid.
[59] As the trust reaches a point where it may need to entertain these smaller transactions to reach its target, these forms of assistance to sellers may make those transactions very costly for the trust.
[60] Personal communication with Alex Richardson, 5 July 2012.
[61] Interview with Colin Armer, large dairy farmer in the Taupo catchment, July 2011

Evidence from trading

The trading that has occurred so far provides some evidence of transaction costs. Trades will occur only if the net benefits to both the buyer and seller outweigh the transaction costs of carrying out a trade. Given that this is most likely to occur with large trades (where the fixed transaction costs and time costs make up a smaller proportion of trade value), we would expect to see limited small or short-term trades (leases) of NDAs; to 2012, this is what we have observed – trades have been large and of high value. While three leases have been agreed, they have been for an average total trade volume of 4.8tN each; given volumes of this sort, the transaction costs of trading will make up only a small proportion of the trade value. The importance of transaction costs has also been recognised by the trust: to 2012, they have avoided trading less than 3tN.[62]

Differences between trading and non-trading farms may also show some evidence of transaction costs. We observe that owners of larger farms with larger initial NDAs, who are more likely to be able to benefit from selling allowances if fixed transaction costs are present, are the farmers who are trading: on average, traders' farms are 60 percent larger than those of non-traders (see Table 7).[63] This is reflected in the size of traders' NDAs; on average, traders received a larger initial allocation of NDAs than non-traders. We also observe that traders and non-traders have similar average farm nitrogen intensities per effective hectare, but that dairy or dairy grazing properties are more likely to trade. This would imply that the marginal benefit of intensifying beyond baseline nutrient leaching is higher in dairy farming than in other land uses.

Table 7: Average farm characteristics, traders versus non-traders

	Observations	Average farm size (ha)	Average effective area (ha)	Original NDA (kgN/yr)	Average intensity (kgN/ha/yr)	% total traders who are sheep/ beef farmers	% total traders who are dairy farmers
Non-traders	71	737	522	9,516	18	81%	9%
Traders	29	1,171	856	16,337	19	64%	24%

Finally, while these transaction costs are significant, they are low by international standards. The decision to make the Taupo scheme a cap and trade scheme rather than an offset scheme has significantly decreased time-of-trade transactions costs of participants. The compulsory benchmarking of all farmers at the scheme's implementation has ensured that this

[62] Interview with Mike Barton, 14 July 2011.
[63] This difference in farm size may be even larger than that reported here: the non-trader data we have access to includes all large farms in the catchment but does not include all smaller farms (as these were not benchmarked at the time the data were compiled).

significant cost[64] is not faced at the time of trade, but instead is a sunk cost and, as a result, independent of a farmer's decisions to participate in the trading market. In an offset market, this cost, and the significant costs of adapting to the regulation and meeting its ongoing requirements, would be faced by a participant only if he or she decided to trade; under offset markets participants face much higher transaction costs at the time of their first trade than in the Taupo scheme (McDonald and Kerr 2011).

3.4. Administration costs

Horan and Shortle (2011) identify high regulator information requirements and the correspondingly high set-up and administration costs as a 'fundamental barrier' to achieving efficient environmental goals with diffuse-source water-quality markets such as the Taupo scheme. They argue that these information requirements lead to administration costs that outweigh the potential efficiency gains of trading schemes. Unfortunately, the limited data available on set-up and administration costs for the Taupo scheme restrict our ability to assess the relevance of this barrier for Taupo. However, the available data do allow us to comment on the cost of benchmarking, the initial costs of consent applications, and the expected ongoing staffing levels required to handle trading and compliance. Finally, it is likely that the set-up costs in Taupo were higher than they would be if the same scheme was replicated today, simply because it is the first market water-quality scheme to have been established worldwide, and the first strong regulation of catchment-wide nutrient leaching in New Zealand. As a result, the council (and other stakeholders) were involved in a long design and negotiation process, including a protracted environment court case, which will hopefully be avoided in any future schemes as a result of the Taupo experience

Market regulation requires that all participant farms have their baseline nutrient leaching rates benchmarked, which represents a large upfront cost. Benchmarking in the Taupo scheme requires the farmer in question to collect data and evidence of their farming system for their best year between 2001 and 2005.[65] These data are run through Overseer by an independent consultant, the result then goes through an internal quality-review process at the WRC, and then, finally, it goes through an independent review by AgResearch to ensure that the Overseer estimation of baseline nitrogen discharging has been done in a consistent way across all farms. Farmers may also want to employ their own contractors to help with the initial collection of data and estimation of their best year.

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[64] Hania (2008) estimates the cost of benchmarking in the Taupo scheme at NZ$2,500–10,000. The Lake Taupo Protection Trust covered the cost of benchmarking for all farms greater than 20ha in size.
[65] Allocation is based on a farmer's highest leaching year during 2001–05 (see Section 2.4).

All of the costs of benchmarking, apart from the farmer's time, are covered by the Lake Taupo Protection Trust. Initial estimates of the cost of benchmarking predicted that it would take a contractor between 10 and 30 hours per farm, and that each farm would take between 10 to 50 hours for the regulator to process. These initial estimates put the cost of benchmarking between NZ$2,500 and NZ$10,000 per farm (Hania 2008). The wide spread of benchmarking costs is due to differences in the quality of farmers' records: if the farm has good records, then benchmarking can be done in a matter of hours; if it doesn't, benchmarking can take months. Graeme Fleming of the Lake Taupo Protection Trust suggests that there is a rough 50:50 split between those farmers who have the records on hand and those who don't. He illustrates the potential problem: 'An example of the difficulty … includes one farm where the manager had left and taken the records with them. Trying to set an allocation for a farm like this requires considerable research and discovery.'[66]

With almost all of the benchmarking completed, the trust estimates that to date they have spent NZ$2.5million on benchmarking, which would suggest that the average cost of benchmarking farms is at the high end of the NZ$2,500–10,000 range.[67]

While the full costs of the benchmarking process are covered by the trust, farmers have to pay for the final council approval stage of the set-up process. The Taupo cap and trade scheme relies on 'consents' to enforce compliance. These consents are the key regulatory tool for managing activities that may affect the environment in New Zealand (Rive 2012b). However, there are significant costs involved in the initial application and approval of consents, all of which are covered by farmers. The WRC implementation manager, Natasha Hayward, estimates that this costs farmers NZ$1,000–1,500.[68] A farmer we spoke to reported the dollar cost of his recent consent approval process as NZ$1,340. Additional to this one-off up-front cost, farmers have to pay an ongoing consent holder's fee of NZ$400 per year (Hania 2008). If all 180 participant farms face a similar cost, the total cost of consent applications to farmers in the catchment will be approximately NZ$240,000.

The final administration data we were able to collect relate to regulator staffing levels. These data cover only the staff running the programme, and not the far more significant costs of designing and implementing the scheme. During the final stages of benchmarking and implementation (late 2011), staffing levels at WRC were one manager and three full-time equivalent employees. In the future (by about 2014), this is expected to drop down to a half of a

[66] Personal communication, Graeme Fleming, 4 July 2012.
[67] Ibid.
[68] Personal communication with Natasha Hayward, 8 June 2012.

manager's time and two full-time staff. Assuming average wages, the annual wage costs of regulating the policy were approximately NZ$175,000 in 2011 and NZ$105,000 by 2014.[69] It is not clear what portion of this time is spent managing the trading scheme versus other regulatory roles that would be required regardless of the policy.

3.5. Innovation

One of the textbook attractions of nutrient cap and trading schemes is that they provide incentives for technology innovation and implementation (Tietenberg 2006). However, because nutrient reductions are estimated in the Taupo scheme rather than measured, as occurs in the textbook environmental trading market, it is not clear that innovation will happen in the same way as suggested by the literature. Below, we discuss the key differences between a traditional theory of innovation in environmental markets and what might be expected in a scheme such as Taupo, and consider whether changes to the measurement programme Overseer can be considered innovation. To date, the variation has led to a handful of innovative responses and catalysed ongoing research into alternative management practices. However, no new management practices to reduce nitrogen discharges have yet emerged and it remains unclear whether the trading system itself has motivated innovation thus far, or if innovative activity is a result of the introduction of the cap. Despite this, there is considerable evidence that profit per kilograms of nitrogen leached has improved since the introduction of the regulation. While it is not clear whether it is as a result of the trading scheme or the cap, this innovation is an important and heartening outcome of the policy.

The expected model of innovation in the Taupo trading scheme differs considerably from the standard literature description of innovation resulting from environmental regulation. The standard model, as described in Teitenberg (2006) or recent surveys such as Popp (2010), sees firms responding to the cost of pollution imposed by the environmental market, and investing in new technologies that will reduce their pollution and therefore their costs in the environmental market (where those costs equal the firm's measured pollution multiplied by the price of pollution allowances). Unfortunately, incentives for innovation are not as clear in a nutrient trading market such as the Taupo scheme, where pollution is based on estimated rather than measured pollution. Incentives for innovative mitigation techniques exist only if the techniques are recognised by the measurement tool (Overseer) and can therefore be rewarded within the trading scheme. As a result, a necessary (but not sufficient) condition for innovation will be that new mitigation methods can easily be incorporated into Overseer; we consider this

[69] These averages are calculated using 2011 median wages for 'Managers' and 'Clerical and Administration' using Statistics New Zealand income data for different occupations (ANZSCO2006).

before discussing the rise (or lack thereof) of new nitrogen mitigation techniques in the Taupo scheme.

To provide incentives to innovate, the incorporation of new mitigation methods into Overseer needs to be simple, fast and affordable. Unfortunately, ensuring that the science is robust is time-consuming; as a result, incorporating new mitigation methods into Overseer is difficult, time-consuming and expensive. This is especially true if a new technique is truly innovative and an evidence base has to be built from scratch. Even for well-researched and uncontroversial new science, the time taken to summarise and assess already completed research, receive input and feedback from referees, and finally incorporate this new science in Overseer is at least 18 months.[70] The incentives to innovate are complicated further by the fact that current nutrient trading policy specifies the use of a particular version of Overseer: even if a new mitigation method can be recognised by the measurement software, farmers will not be able to use it until newer versions of Overseer are recognised by the regulator. Working out how to recognise up-to-date versions of Overseer without re-legislating the entire policy is a current focus of regulators.[71]

3.5.1. Evidence of innovation

Given that innovative new mitigation methods will not yet be recognised within the scheme without development of Overseer, it is interesting to consider how Overseer itself has developed since the introduction of the nitrogen policy. Indeed, development and improvement of Overseer could be considered the major innovation resulting from the trading policy to date.

Estimation of nitrogen run-off within Overseer has been significantly improved over the past decade, which coincides with its introduction as a regulatory tool in Lake Taupo. However, the developers of Overseer do not believe that these upgrades of the nutrient run-off estimation occurred just as a result of the trading scheme, but rather that the development of the model is the result of a number of concurrent pressures, one of which was the use of the model in regulation. A number of the changes that have been made to Overseer to improve the nutrient estimation had begun before the Taupo scheme was implemented, such as the incorporation of nitrification inhibitors (dicyandiamide, or DCD). Other mitigation methods were potentially prioritised and included in Overseer earlier than they otherwise would have been without the

[70] Personal communication with Mark Shephard, David Wheeler and Ian Power, Overseer development team, 15 June 2012.
[71] Personal communication with Natasha Hayward, June 2012.

Taupo scheme, such as cut and carry lucerne, but it is difficult to draw clear lines of cause and effect.

The developers at Overseer suggest that the changes to the program that can be traced to the Taupo scheme have come through a more indirect route: the nutrient trading policy has focused attention and mobilised funding for new scientific research in the catchment, and this new science has allowed new methods to be incorporated into Overseer. Some of this science has been funded by the trust, which has dedicated up to NZ$5 million over its lifetime to research low-nitrogen alternatives appropriate for the Taupo catchment, but other sources of science funding are also present. Nitrogen mitigation options under investigation include nitrification inhibitors such as DCD, high-sugar grasses, and cut and carry lucerne. Research programmes of this sort include work looking at the effect of diuretics on nitrogen leaching, an innovative mitigation method that, if included in Overseer, will be based at least in part on research carried out in the Taupo catchment resulting from the implementation of the policy. However, these changes are not a direct result of the trading part of the policy, and are potentially just a result of the cap.

A key area of innovation resulting from the cap is changes in farm management to maximise profit per kilogram of nitrogen leached. This has allowed some farmers to increase profit whilst still farming within the environmental cap. As mentioned earlier, the trust improved the returns from decreasing nutrient discharges through afforestation by taking advantage of interaction with the NZ ETS. In addition to this, several farmers have begun to explore green marketing solutions in the hope of earning a premium from their products as compensation for the additional costs imposed by the scheme. One such example comes in the form of Taupo Beef, a project initiated by two farming families in the catchment. Differentiated from other beef as locally and sustainably produced, the Taupo Beef brand is available in a limited number of restaurants in Taupo. The fact that the Taupo Beef farmers are farming within a strict environmental cap is a critical source of credibility for their green claims; indeed, following petitions from the Taupo Beef farmers, the council created an official accreditation for farmers selling meat within the cap. Both the producing farmers and the restaurants serving Taupo Beef have received positive feedback from consumers, which has affirmed their initial belief that some consumers do value sustainably produced foods and are willing to pay a premium for such products (Barton and Barton 2011).[72]

[72] Interview with Mike Barton. See http://agriculturalemissions.blogspot.co.nz/2011/12/taupo-beef-story.html for an overview of the Taupo Beef project.

Research also shows that there is considerable differentiation between the efficiency of different farmers – in terms of profit per kilograms of nitrogen leached (Anastasiadis and Kerr 2013). The trading scheme places incentives that should encourage farmers to improve their nitrogen efficiency. While some remain sceptical that alternative management practices and green marketing will enable farming to remain viable within a nitrogen cap, these instances provide positive evidence for the future of farming in Taupo.

3.6. Environmental effectiveness

In the long run, the key measure of the Taupo cap and trade scheme's success will be whether it achieves, and continues to achieve, its environmental goal. Achieving the goal depends on compliance with the regulation, whether the science behind setting nutrient limits to achieve the water-quality goal was correct, and whether the policy is sufficiently economically and socially acceptable that it is sustained over the long term. However, due to the long lag times between nutrient release and its arrival in the lake, the environmental benefits of the policy will not be visible for a number of years. Despite this qualification, it is safe to assume that the policy has already had positive effects on lake water quality. The cap has limited further increases of nitrogen discharges in the catchment. Additionally, the trust has successfully purchased 128 tonnes' worth of nitrogen, equivalent to 14 percent of its 20 percent reduction goal. There has been no reported non-compliance with the scheme.

The scheme will also have had complementary environmental impacts. Due to complementarities between nitrogen mitigation and greenhouse gas mitigation, decreases in nitrogen discharges in the catchment will also result in decreases of greenhouse gas emissions (Kerr and Kennedy 2009). This will be augmented by the 5,002ha of afforestation that has resulted from policy; this land will sequester carbon in addition to decreasing agricultural greenhouse gas emissions resulting from land-use change.

In future assessments of the environmental effectiveness of the scheme, two potential negative environmental effects that should be monitored are nitrogen hotspots and the substitution of other harmful discharges in place of nitrogen. Hotspots occur when, as a result of trading, discharges shift and increase in one area (e.g. one stream of a catchment), which results in increased local pollution. As Lake Taupo has a residency time of approximately 15 years, localised hotspots are unlikely to occur unless one tributary dominates total nitrogen flows. Nevertheless, collecting data on the buyers of nitrogen allowances (and their location) would be good first step in monitoring the potential for hotspots without extensive scientific testing and associated undue expense. Another potential risk is that, as nitrogen is priced, farmers substitute other pollutants for nitrogen in their production. Such pollutants should be monitored to ensure that they do not increase as the trading scheme develops.

4. Conclusion

The Lake Taupo nutrient trading scheme is the first non-point-source nutrient cap and trade scheme in the world. We assess this policy by considering trading activity and policy documents, and by interviewing stakeholders. This allows us to analyse the impact of the cap on farm nitrogen discharges, and the cost-effectiveness of the trading scheme. We pay particular attention to the transaction costs faced by farmers participating in the trading scheme.

We find that while the introduction of a cap on nitrogen has worked to limit the nitrogen leaving agricultural land, it has also placed significant costs and restrictions on those affected. The cap has reduced farmers' ability to intensify production, has decreased land values, and has significantly increased administration and compliance costs. These economic costs have led to social costs: significant land-use change has resulted from the policy, which has resulted in a number of farmers leaving the catchment. This, combined with the uncertainty during the establishment of the policy, has negatively affected the social lives of farmers left in the catchment. The creation of the Lake Taupo Protection Trust to fund the decreases in nitrogen has significantly reduced the costs borne by farmers.

Although the trading component of the policy had been active for only three years by 2012, early evidence suggests that it is improving the cost-effectiveness of achieving the policy's environmental target. Trading to 2012 had included 19 trades with the public trust, which are evidence of nitrogen being reduced and retired where it is cost-effective to do so. The ten private sales to 2012 are evidence of the trading scheme facilitating a shift in nitrogen leaching to the most profitable uses. The three short-term leases of allowances provide evidence for the flexibility of the policy: trading is allowing participants to upscale or downscale their activities as they see fit. All of these trades suggest that the trading scheme is working well to facilitate the achievement of the environmental goal at low cost.

We find that while transaction costs are low by international standards, they are still high enough to affect trading and decrease the cost-effectiveness of the policy. The choice of a cap and trade scheme will have reduced transaction costs relative to what would have been the case under a more common baseline and credit-type system. However, the requirement for *ex ante* trade approval and increased monitoring for participants who trade decreases the benefits of trading. This is likely to limit trading to large or long-term trades, as the transaction costs will outweigh the benefits of trading small volumes of allowances. Trading data provide suggestive evidence to support these conclusions.

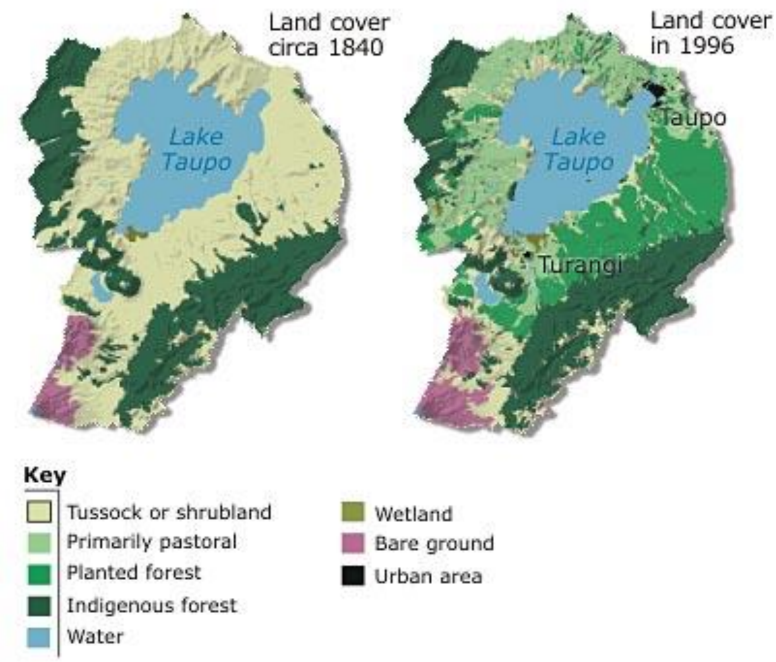
Looking forward, there are two key areas that should be focused on to improve the efficiency of the policy. The first is to recognise new versions of Overseer in policy so that innovative mitigation methods can be implemented by farmers. Second, regulators should continue to focus on reducing the transaction costs of trading, and in particular continue to attempt to minimise the administrative and time costs borne by farmers. Making allowance price information available to farmers would be a useful step, as would any policies that will increase the liquidity of the market in the future.

Overall, although the Lake Taupo cap and trade market is still young and our conclusions are provisional, we find that the trading system has provided useful flexibility for landowners and has decreased the cost of achieving the community's environmental goal. Additionally, the lessons and experiences gained by those involved in the development and implementation of the policy will be invaluable for those implementing similar schemes in the future.

5. Appendices

5.1. Key figures and tables

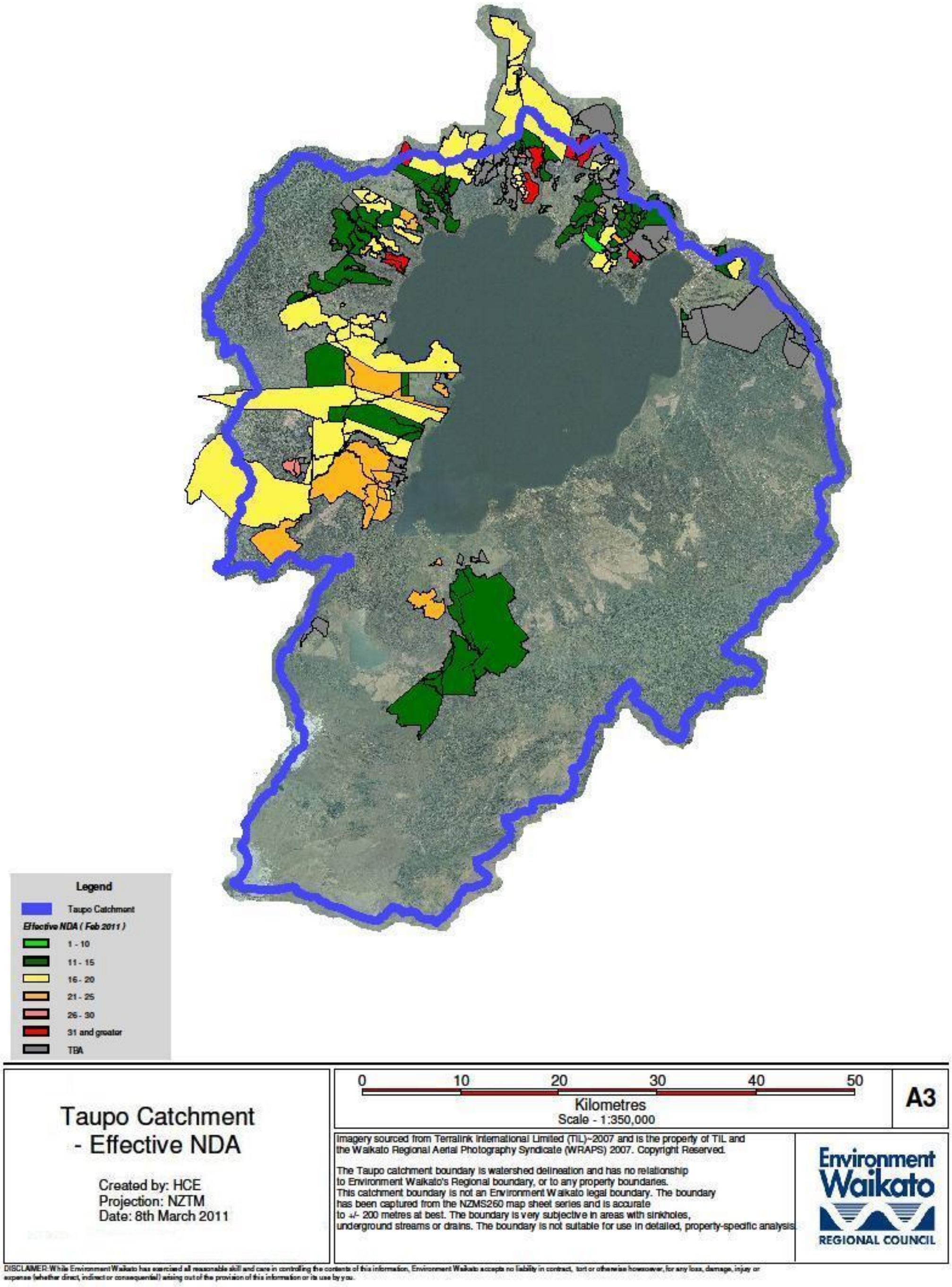
5.1.1. Map of Taupo catchment land uses over time[73]



Change in land cover in Lake Taupo's catchment
1996 Landcover data supplied by Terralink NZ Limited. COPYRIGHT RESERVED
1840's Vegetative information derived from Environment Waikato's Native Vegetation Inventory. COPYRIGHT RESERVED

[73] Source: Waikato Regional Council

5.1.2. Map of Taupo catchment highlighting nitrogen discharge allocations[74]



[74] Map courtesy of Waikato Regional Council.

5.1.3. Breakdown of land uses in the Taupo catchment and summary of pastoral properties

Property size	Number of properties	Total area (ha) (including retired land)	% of catchment land
<20ha	900–1,206	2638	5%
20–100ha	100	4,221	8%
>100ha	92–100	63,318	87%

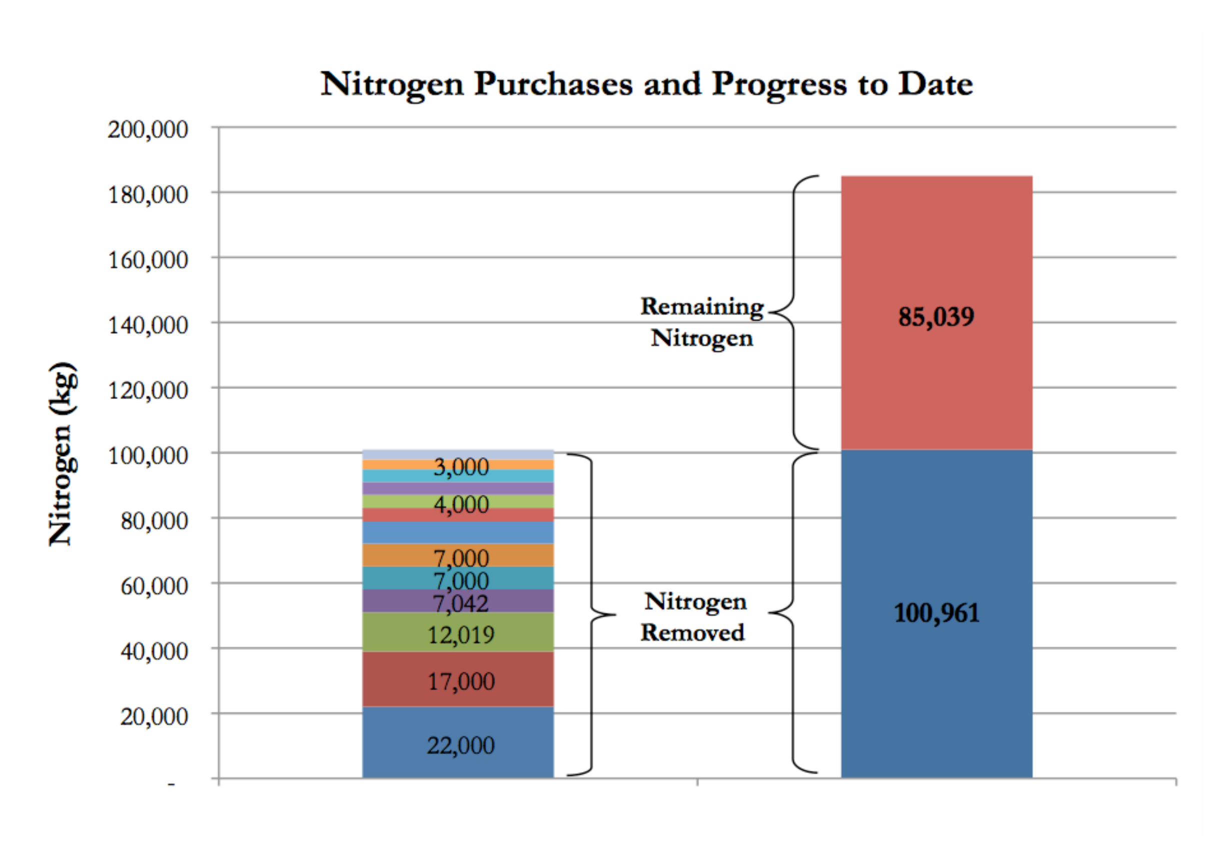
5.1.4. Timeline of important events in the development of Waikato Regional Council's Regional Plan Variation 5 (RPV5)

1955	160km² of catchment land in developed pasture
1973	470km² of catchment land in developed pasture
2002	525km² of catchment land in developed pasture[75]

1998	WRC enters Memorandum of Understanding with Tuwharetoa Maori Trust Board (TMTB)
2000	Start of technical investigations into land-use impacts on lake water quality; key stakeholders notified of impact of land use on lake water quality[76]
September 2000	'Issues and Options for Managing Water Quality in Lake Taupo' circulated to determine public attitudes towards water quality options[77]
September 2001	WRC resolution to 'maintain water quality by reducing nitrogen output from existing land uses and preventing further land-use intensification[78]
February 2001 – February 2005	35 consultative meetings held between WRC, Taupo Lake Care (TLC) and farm systems experts[79]
9 July 2005	Notification of RPV5
9 February 2007	Lake Taupo Protection Trust established[80]
15 March 2007	WRC decision released
May – June 2008	Environment Court hearings
12 November 2008	Environment Court releases interim decisions
17 June 2011	Finalisation of RPV5 in Environment Court
7 July 2011	RPV5 fully operative
7 February 2012	All farmers must have applied for resource consents with WRC
2018	Reassessment of 20 percent nitrogen reduction target[81]
July 2034	Common expiration of all NDAs[82]

[75] Young (2007: 7).
[76] Young (2007: 5, 14).
[77] Waikato Regional Council (2000); Young (2007: 15).
[78] Young (2007: 15).
[79] Young (2007: 20).
[80] Young (2007: 24).
[81] Environment Court (2011: 14).
[82] Environment Court (2011: 10).

5.1.5. Lake Taupo Protection Trust nitrogen purchases, 2009 – June, 2012



5.2. Rules determining whether land use is 'permitted' or 'controlled'

The WRC's RPV5 sets out whether a property will be determined to be 'permitted' or controlled (Environment Court 2011). Rule 3.10.5.3 classifies nitrogen-leaching farming activities as controlled activities. Note that lands converting from non-pastoral to pastoral uses after July 2005 must apply either as a permitted activity under rule 3.10.5.1 as a low nitrogen-leaching farming activity, or as a controlled activity under rule 3.10.5.3 as a nitrogen-leaching farming activity. Following the finalisation of RPV5 on 7 July 2011, farmers had until 7 February 2012 to complete the benchmarking process and apply for a resource consent. As of July 2011, 97 percent of farms had completed the benchmarking process.

Permitted activities are those whose nitrogen discharges are so minimal as to not require formal approval, benchmarking or measurement. These include farming activities as specified by rule 3.10.5.1 that leach less than 8kgN/ha/year and stay within certain stocking and fertiliser application limits. It is estimated that there are approximately 900–1,200 such lifestyle farming blocks, together accounting for only 5 percent of all pastoral land in the Taupo catchment. Rule 3.10.5.2 applies to non-farming activities such as indigenous vegetation, forestry and golf courses, conditional on certain nitrogen fertiliser application limits. It assumes background leaching of 2kgN/ha/year for unimproved land and 3kgN/ha/year for plantation forestry. Low nitrogen-leaching activities resulting from the development of undeveloped or forestry land are classified as controlled activities under rules 3.10.5.4 and 3.10.5.5 and are subject to slightly different regulation. These rules permit the development of Maori and non-Maori lands by allowing landowners to exceed predetermined background nitrogen leaching rates by 2kgN/ha/year for a collective total of 11,000kgN and 3,100kgN, respectively. Non-complying activities as specified by rule 3.10.5.9 are those not defined as either permitted or controlled activities by rules 3.10.5.1 to 3.10.5.8.

Rule 3.10.5.7 provides flexibility for offsets (trades) among high nitrogen-leaching farming activities deemed controlled activities by rules 3.10.5.3, 3.10.5.6 and 3.10.5.9. Note that rule 3.10.5.6 refers to the division of high-leaching farms. RPV5 also allows for previously low nitrogen-leaching farming activities to expand production and apply for a resource consent under rule 3.10.5.3, so long as they purchase nitrogen from a willing seller to offset their increase in nitrogen.

5.3. Additional background on overall policy development and impact

5.3.1. Single best year benchmarking standard

Historical allocation requires that all farms be allocated a nitrogen allowance, or NDA, consistent with their recent nitrogen output, a requirement that introduced a variety of theoretical and practical challenges.[83] It was initially assumed that each farm would be benchmarked based on average nitrogen discharges between July 2001 and June 2005, which are assumed to vary with climate and weather variations. During the submissions stage, Taupo Lake Care, an organisation of farmers within the catchment, launched a successful challenge against this benchmarking standard. TLC argued that farmers should be free to establish a benchmark based on any single year period within that timeframe, and thus be given the appropriate maximum allowance for which their farm had been established and investments had been made. TLC argued that to establish an NDA based on an average value would force a reduction in production in the best of years, while climate and weather conditions would naturally enforce additional reductions in the worst of years.[84] From a scientific standpoint, benchmarking based on the single best year would contribute an estimated extra 162tN each year, with a moderate adverse effect on lake quality.[85] Other landowners expressed frustration at seeing this advantage

[83] NDA requirement is not applicable to low nitrogen-leaching farms as permitted activities under rule 3.10.5.1.
[84] Interview with Mike Barton, 14 July 2011.
[85] Vant (2008: 23) and Ledgard (2007: 19).

so readily granted and at seeing some farmers benefitting from windfall gains from a generous allocation.

5.3.2. Proposed alternative allocation methods

Forestry groups such as Carter Holt Harvey (CHH) proposed as alternative allocation mechanisms averaging or delayed averaging. Under these mechanisms, all landowners would be held accountable to the same catchment-wide average nitrogen discharge limit, either immediately or some years in the future. These mechanisms would allocate excess nitrogen to forest owners and leave farmers with a nitrogen deficit, which would require them to either downscale or purchase additional nitrogen to continue operations. Although this would have had unequal distributive impacts, CHH considered it a fair way to enforce the polluter pays principle.[86] However, just as the use of the term 'polluter' proved ultimately toxic and inappropriate as applied to farmers exercising best practices in the catchment, similarly WRC determined to apply a grandparenting mechanism as the most equitable scheme that would cause the 'least social disruption'.[87]

5.3.3. Appropriateness of Overseer

Another practical challenge facing the establishment of individual allowances was to select an accurate means of modelling the relationship between past management decisions and the resulting nitrogen discharge. As mentioned before, Overseer was determined to be the best tool for taking various inputs to model expected nitrogen output on a case-by-case basis. Overseer demonstrates high performance in terms of a close correlation between measured and modelled nitrogen leaching and facilitates comparisons between different management practice options.[88] However, the use of software to model nitrogen output presents several ongoing challenges. Its success relies on the accurate and complete disclosure of farm-specific information. For those farms with incomplete data, conservative default measures would be assumed, which could underestimate the nitrogen leached by an individual farm.[89] Other farm management styles do not closely align to Overseer's assumption, for example, those farms running a two-year rotation or changing animal stocking numbers throughout each year.

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[86] Counsel for the Waikato Regional Council (2008); see p.60 for a summary of delayed averaging argument.
[87] Counsel for the Waikato Regional Council (2008); see pp.50–68 for a discussion of allocation alternatives. Young (2007: 37).
[88] Ledgard (2007: 19).
[89] Hania (2008: 18).

5.3.4. Lingering concerns and future challenges

Although implementation progress to date has been positive, there remain several challenges that will impact the success of the policy in the long run. As more scientific data is gathered and our understanding of the impact of land-use activities on water quality improves, it could be that a higher reduction target is required. Since it will be a long time before the adequacy of the 20 percent target is confirmed or invalidated, environmental groups such as the Environmental Defence Society remain convinced that a higher target is already justified.[90] Any increase in the reduction target necessarily implies additional social and economic costs, and it remains to be seen how these will be distributed and how the regulation will be redesigned to accommodate any such changes.

Similarly, the possibility of spatial variation of the impact of nitrogen presents an additional future challenge. It could be that the spatial movement of nitrogen around the catchment would have adverse environmental consequences, even if the total amount leached remains the same. For example, 'hotspots' of high nitrogen concentration could develop in bays near intensively farmed areas. While spatial considerations were initially dismissed because of fairness and equity concerns, it may be that future policy versions need to consider spatial variation by introducing different regulations for sub-catchments or trading ratios that allow trading while accounting for spatial variation. However, such additional features could increase the complexity and transaction costs of making a trade, which could have the adverse effect of discouraging trading activity.

5.3.5. Ngati Tuwharetoa perspective

From an environmental perspective, some Tuwharetoa stakeholders in the catchment would have liked to see a greater commitment to responsible stewardship of Lake Taupo, particularly in the form of a higher nitrogen-reduction target. Acknowledging that nitrogen reductions do not come easily and usually come at a cost to business, George Asher defends that protection of the lake nevertheless presents a 'challenging obligation on everybody' and that 'nobody should shun their responsibility for responsible stewardship'.[91] Tuwharetoa landowners themselves have made land-use decisions in order to protect the lake deliberately, often at the expense of potential commercial gain. Potentially productive lands, especially on the eastern side of the lake, were instead planted into forestry with the goal of reducing negative environmental

[90] Environmental Defence Society (2004) and phone conversation with Gary Taylor of the Environmental Defence Society, 15 August 2011.
[91] Interview with George Asher, 8 August 2011.

impacts on both lake and land. As Asher explains, 'commercial gain didn't enter the picture', saying that for Tuwharetoa landowners, the 'perspective is quite different from a normal landowner perspective'.[92]

5.3.6. Farming perspective on forest conversions

As with the conversion of whole farms into forested lands, the conversion of attractive and productive farmland into forestry has provoked negative psychological reactions from some landowners, who question the benefits of planting in forestry and express concerns over the long-term future of farming in the catchment. While many have come to see the necessity of the policy, accept its limitations and seek the opportunities it could provide, others remain sceptical about the general approach of converting land into forestry, hoping that future hindsight will not provide a sense of regret to have lost productive farmland in exchange for plantation forests. Furthermore, this option remains more feasible for those farms with marginal lands available for conversion, but may not as readily apply to smaller farms limited by space and by the number of carbon credits they could offer to carbon credit-seeking companies.

5.3.7. The trust: success factors

Several factors, both by design and by chance, have facilitated the success of the Lake Taupo Protection Trust thus far. First, the trust has committed to providing business consultants and encouraging prospective sellers to consider the implications of their choice thoroughly. Second, offering payments over time has enabled farmers to reduce stock numbers gradually rather than having to make sudden and costly changes.[93] Most significantly, the introduction of synergy with the NZ ETS allows farmers to earn income from selling both nitrogen allowances and carbon credits. Both of these factors have made selling nitrogen an attractive opportunity from a business standpoint. While the purchase of entire farms was neither financially sustainable for the trust nor positively received by those farmers disappointed to see their neighbours go, management practice changes that allow farmers to continue their operations and sell only excess nitrogen to the trust provide a more favourable alternative, and we are seeing an increased occurrence of such deals over time.[94]

[92] Ibid.
[93] Interview with Graeme Fleming, 15 July 2011.
[94] Ibid.

5.3.8. The trust: outlook

Despite substantial progress towards its reduction goal, the trust faces a considerable challenge going forward. While the NZ$72 million actual endowment of the trust remains a fixed pool of money, an increase in the targeted reduction sparked concern about the funding available to finance remaining nitrogen reductions.[95] It was initially assumed that 153tN would need to be removed, but completion of benchmarking including the single best year standard has necessitated that an additional 30tN be removed. Because the trust receives its funding in NZ$6 million yearly increments, there is a limit to the number of deals that can be paid for at any one time.[96] The trust has decided to initiate a community engagement exercise to generate innovative ideas and strategies for the final 85tN that need to be removed. As an example, smaller blocks could pool nitrogen reductions together to reduce the legal costs per kilogram of transacting with trust compared to those that would be incurred from individual transactions.

[95] NZ$72 million represents the committed NZ$81.5 million less GST.
[96] Kneebone (2009) and interview with Graeme Fleming, 15 July 2011.

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