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Modelling Waikato Farm Nitrogen Discharges for Policy Analysis

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Abstract

This study describes the development of bio economic models examining the economic and water quality impact of various proposed policy options in the Upper Waikato catchment. In the first phase nitrogen emissions are determined for representative farming systems using the Overseer nutrient budget model. These model components are integrated into an economic model, which predicts producer responses to various policy options. The second phase determines catchment wide costs and water quality impacts of riparian buffers by combining geographic information system, bio economic modelling and experimental data. The results of the study signals directions for policy initiatives and further analysis exploring policy design and all costs associated with production adjustment.

Key words: Riparian margins, Non point pollution, Nitrogen, Linear programming, and Environmental policy.

1. Motivation

1.1 Farming and Environment

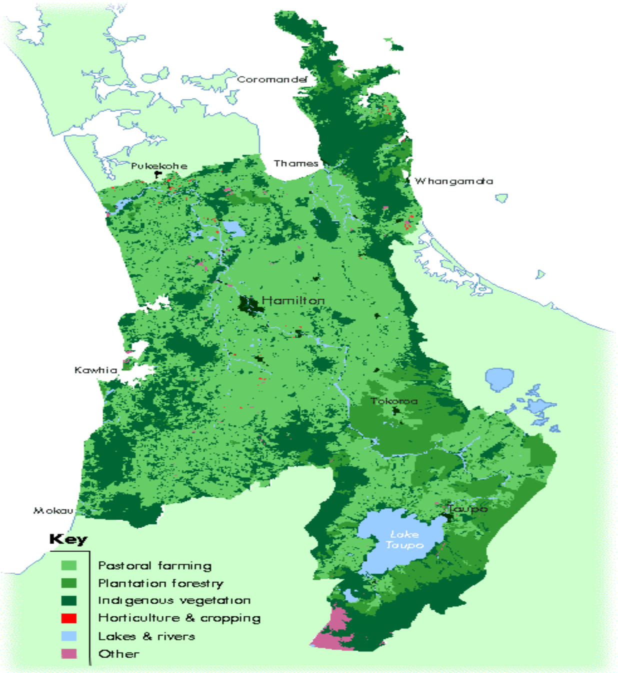
The environment is important for the welfare of the people. Intensified agricultural activities often have a significant harmful effect on the environment. Meanwhile agriculture still remains as the source of living for many people. Whereas most governments have by now included the objective of sustainable development in their political agenda, there is an urgent need to identify concrete policy measures that permit conservation of the environment without significantly affecting the economic viability of farming systems.

Within the Waikato nitrogen is the most widespread contaminant in water. Excessive nitrogen in water is a concern for both human health and the environment.

Excessive nitrogen levels in water are attributed to non point source of pollution from agricultural activities. According to Environment Waikato, 58% of the region's land is used for Pastoral farming (Figure 1), namely dairy and sheep/ beef farms Dairying is a significant agricultural land use in the Waikato Region. According to Dairy statistics 2001, dairying occupies 384,065 ha of land. Environment Waikato reported that 30% of nitrogen from dairy farms and 9% from sheep/beef farms, discharged into water. Vant (1999) found that the nitrogen yield in eight large Waikato catchments was strongly correlated with the stocking density of dairy cows.

The Waikato Region has multiple lakes and rivers with valuable scenic and aesthetic attributes. The character of Waikato's water bodies is reported to be diverse, reflecting the large variety of water types including the Waikato River, Lake Taupo, wild rivers, mountain streams and ground water. These water bodies have variety of uses and values such as domestic and community water supply, irrigation, drainage, electricity generation, waste assimilation and recreational use and fishing.

<u>Figure 1: Land Use Pattern in the Waikato Region</u>



Land cover data supplied by Terralink NZ Limited (from 1996 Waikato Land Cover Database); COPYRIGHT RESERVED.

1.2 Management of Non point pollution

Recently has been increasing concern regarding the effects of intensive land use on the quality of water in streams, rivers, lakes and wetlands. Various policy measures have been proposed to limit the nitrogen pollution namely standards, taxes on inputs and effluent and tradable emission permits.The current focus is to manage the non point source discharges in the Waikato region (Ritchie, 1999). Generally tradable emission permits have become established as the principal alternative to taxes as an efficient mechanism for pollution control. However empirical studies like (Weigngarten, 2001) reveal the cost efficiency of tradable emission permits depends on the institutional design of permit markets, market power and information flow and transaction cost. In this instance we have not included the tradable emission permits for analysis. Macdonald et al, (2004) have sited some examples of the limited success of tradable emission permit in their report for economic instruments for managing water quality in New Zealand.

Ritchie (1999) reported on following policy approaches to manage non point source of pollution; fencing of riparian margins, effluent application methods and efficient use of nitrogen inputs. Various technological options such as use of nitrate inhibitors, feeding pads and effluent disposal systems for cattle are being experimented in New Zealand by scientific research institutes like Agresearch and NIWA. Establishing riparian margins is reported to be an effective way to reduce nutrient losses through runoff (Collier et al, 1995). A riparian margin is a strip of land of varying width, adjacent to a waterway and which contributes or may contribute to the maintenance and enhancement of the natural functioning, quality and character of the waterway and its margins (Operative Waikato Regional Policy Statement, 2000)

The clean stream is a project launched by Environmental Waikato to establish riparian margins alongside of the rivers and streams in the Waikato region (Environment Waikato, 2004). Clean stream project intends to pay up to 35% of the cost of establishing riparian management works in priority areas.

Implementation of these pollution control measures is a costly exercise. It has economic repercussions on farming in terms of income loss. Meanwhile there is an administrative cost associated with the implementation. Therefore policies need to evolve in a way to maximise the net benefit to society.

Recent evidence to the Environment Court with regard to the proposed Waikato Regional Plan rules for non point discharges and livestock access to water bodies, shed light into the dimensions of the problem. Draft rules for the regional plan proposed by environmental groups were opposed by various land use groups, especially forestry owners as the rules impose significant costs on their current and future operations. There is contentious debate on the spatial dimension when implementing rules. Therefore tradeoffs associated with agricultural production and environmental protection needed to be quantified. Shortle and Horan (2001) revealed the use of economics to identify crucial issues of non point pollution control.

Empirical estimation of the impact of alternative environmental policies is important for effective policy development. In the absence of real world data convey the policy implications, research need to be based on simulation analysis rather than statistical analysis. An economic model based on mathematical programming, drawing on estimates of behavioral parameters from econometric studies, simulation models and scientific experiment could provide valuable insights.

The objective of this paper is to provide an initial model which allows analysis of the economic impact of the different Agri environmental policies on typical farming systems and consequent effect of on water pollution. A bio economic model, integrating mathematical programming model and nutrient budget simulation model the Overseer[1] is applied to estimate the changes in the level of nitrogen discharges and income on representative farms when different agri environmental policies are present.

2. Research Pathway

2.1 Linking Agriculture, Environment and Policies.

In examining the relationship between agricultural production and environmental pollution, there are two main categories of empirical model could be used namely econometrics and optimization. Optimization models have the advantage of providing the solution that best achieves the specified objective and allow detail specification of farm land activities (Weersink, Jeffrey and Pannell, 2002)

In order to investigate the relationship between possible policy intervention, land use decisions in the catchment and nitrate emissions, a modeling approach is adopted. This methodology has been widely used to the study of agricultural sources of pollution (Taylor et al, 1992 and Brady, 2003). Econometric methods could offer

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[1] Overseer is a decision support model for nutrient budgeting developed by Agresearch

useful estimations of functional relationship between variables, which could be used as inputs for optimization models.

Various methods are used to represent the catchment in modeling. Moxey et al, (1995) considered the catchment as a single, macro farm and developed a representative model accordingly. Chalmers and Crabtree, (1999) defined representative farms and aggregated them to the catchment level through weighting process. In our study to estimate catchment wide impacts, representative farms are fitted to the total extent of each farm categories.

An economic model is used to investigate the impact of different policies on farm profitability as well as nitrogen discharge. Cost effective nitrogen abatement measures are adjustment of production practices that reduce nitrogen discharge to certain level at the lowest possible cost.

2.2 Biophysical Relationships

The relationship between inputs, output and nitrogen discharge is a biophysical relationship. Detail of biophysical modelling accurately represents the production system. The data requirement of detailed biophysical modeling is great. The availability of biophysical simulators, such as the Overseer and feed budget models, contributes to data requirements and enhances the analysis.

The methodical approach combining a biophysical simulation model and an economic model is bio economic modeling. Bennett (2005) described bio-economic modeling as a mechanism for explaining and predicting the cause effect relationships in ecosystems and their economic consequences.

2.3 Spatial Dimensions

Agricultural land is heterogeneous in terms of productivity and pollution potential. A geographical information system (GIS) is an analytical tool that can enhance analysis, where spatial aspects are of particular importance. A geographic information system can be used to represent the spatial heterogeneity in terms of differences in soil type, land slope and production systems by overlaying available data. Yang and Weersink (2004) used an integrated economic, hydrologic and GIS modelling frame work to examine the cost effective targeting of land retirement for establishing riparian buffers in agricultural watershed. By means of GIS the data requirements for spatial optimization could be generated. By coupling, the results of GIS generated catchment wide land use information and the results of the mathematical programming, catchment wide impact of nitrogen discharge as well as the impact of various policy scenarios were investigated.

The cost effective targeting of riparian fencing is of paramount importance in Waikato context specially in terms of paying subsidies. Rather than paying a fixed subsidy for lands adjoining water bodies, cost effectiveness can be enhanced by targeting low cost, high environmental benefit locations. Yang and Weersink (2004) revealed another potential use of GIS i.e. the abatement cost estimated by an economic model and the sediment reduction estimated by hydrological model for riparian buffers could be linked together through a GIS model.

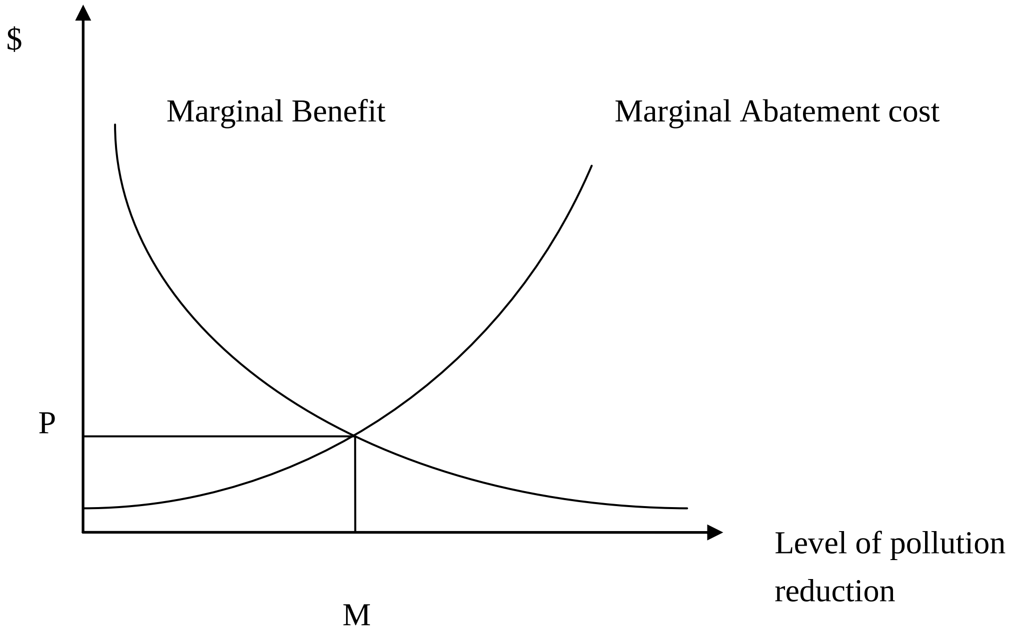
Hydrological models are used to model the biophysical relationship of nutrients and their transportation from source to water bodies. Hydrological models need to be integrated with economic models to estimate optimal width of riparian buffers (Yang and Weersink, 2004). Riparian buffers of various widths could be incorporated into a linear programming problem as activities. This would permit the calculation of series marginal cost of sediment abatement by parametrically varying the nitrogen discharge limit.

3. Theoretical frame work

A simple static model can theoretically explain the efficient level of non point source pollution. An efficient level of emission is one that maximises the net benefits from pollution, where net benefits are defined as pollution benefits minus pollution costs. Figure.2 shows the marginal abatement cost (MC) and marginal benefit of pollution control. Marginal abatement cost is positively sloped since the cost of pollution control increases at increasing rate. Marginal benefit is negatively sloped to capture the trend that benefits of pollution control increases at decreasing rate. The socially optimal level of pollution control is where the marginal cost equals the marginal benefit (Hanley et al, 1997).

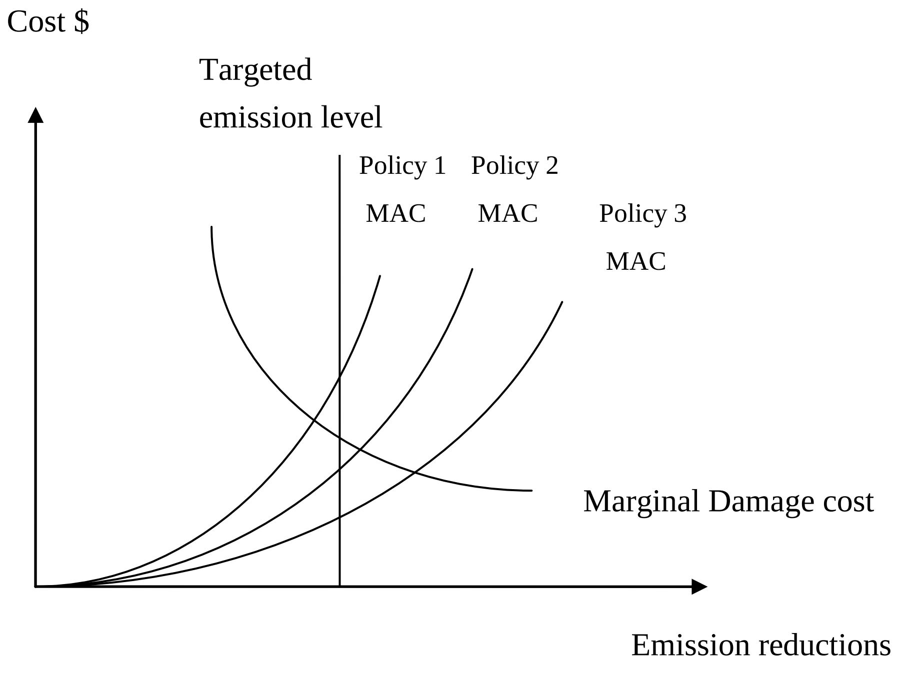
The application of this theoretical framework has many challenges because of difficulties in identifying the damage function and stochastic nature of agricultural pollution. These difficulties can partially be overcome by use of externally specified pollution levels. The implications of such specified limits on the level of pollution and farm income needed to be evaluated in ex ante manner. The limits on pollution level can be integrated as constraints into farm models to calculate opportunity costs. The estimate of opportunity cost under various pollution levels and by various means provide guidance in formulating policies.

Figure 2: Efficient Level of Pollution Abatement



Exogenous specification of pollution levels and the cost efficiency of achieving this under various policies are graphically illustrated in figure 3. When the level of emission dwindles the marginal external cost becomes lower. Mean while the marginal cost of abatement tend to increase at increasing rate at higher levels of pollution abatement.

Figure 3: Cost Efficiency of Policies



4. Modeling

The modeling framework is used to evaluate different policies in the Waikato region. Modeling could be represented as 3 major sub models namely Overseer model, representative farm and the linear programming model.

4.1 The Overseer Nutrient Budget Model

Technical coefficients representing nitrogen into water for alternative production practices were derived using the Overseer decision support model for nutrient budgets. The estimate of nitrogen into water is determined primarily from calculation of the amount of nitrogen inputs and outputs from farming system. According to this model nitrogen discharge is calculated based on stocking rate/unit, animal productivity, slope of the land, soil type, soil nutrient status, fertilizer application and timing, feeding and effluent administration.

4.2 Representative Farm

Environmental economic modeling involves aggregation. The diversity of farms within the catchment presents a number of problems for modelling the response of farms to policy initiatives. To achieve the first best solution each individual farm need to be considered as a separate unit. Since the data availability is problematic within the time span, representative farms are chosen as a starting point for analysis in the present study. Representative farms for the Waikato region are selected from MAF Farm monitoring reports 2004. The representative farm types are Dairy and Sheep/Beef. Pumice is assumed to be the soil type which is a predominant soil type in the Upper Waikato region. The representative farms are described in the table 1. The economic impacts of various environmental policies on representative farms are simulated.

Table 1: Generalized Description of Two Representative Farms

Dairy farm*		Sheep/Beef farm#	
Extent of land	101 ha	Effective area	300 ha
No of milking cows	272	Breeding ewes	1215 hd
No of heifers	56	Hoggets	355 hd
Stocking rate	2.6	Other sheep	50 hd
		R1 yr cattle	200 hd
		R2 yr cattle	150 hd
		Other cattle	80 hd
		Stocking rate	11.2/ha
		Total stock units	3358 su

[*] 2004 Dairy Monitoring, MAF

[#] 2004 Sheep and Beef Monitoring Report, MAF

4.3 Linear Programming Model.

The response of agricultural producers to alternative nitrogen policies is simulated in the economic model. The primary function of the economic model is to allocate the available land area and feed resources among available production alternatives.
The model developed for analysis is a linear programming model, which links changes in agricultural production practices to changes in nitrogen discharge. The model for net revenue maximization was formulated as an optimization matrix, the rows in this matrix were linear mathematical equations representing objective functions and nitrogen discharge and other production constraints with respect to livestock production. The columns are the decision variables, representing animal production activities. These activities are defined as the combination of stocking rate and nitrogen in order to reflect the biophysical interactions associated with nitrogen discharge simulated using nutrient budget model. It is assumed that proposed scenarios would not bring any change in the fixed cost.

The objective function of the model maximizes net revenue π, which is the gross margin from the production activities. Gross margins of production activities are derived from the data of MAF farm monitoring reports for 2004. Production variable $X_{j,}$ represents the area (number of hectares) of each production activity. The solution to the problem is the choice of production practices that maximize profits given exogenous production and environmental variables. It is solved using the Lindo 6.1 modeling software.

The section below provides a mathematical description of the model.
Objective function

$$Max \quad \pi = \sum_{j=1}^{j} \left\{ P_j - F_j (w + t^N) - \alpha_j c^N \right\} X_j$$

P_j - Gross margin of ha of j^{th} production activity excluding the cost of nitrogen.
w - Unit cost of nitrogen fertilizer
F_j - Amount of nitrogen used in the j^{th} production activity
t^N - Tax on nitrogen fertilizer-
α_j - Nitrogen discharge from the j^{th} activity
c^N- Charge on nitrogen discharge
X_j - Production activities

β_j - Feed demand for the j^{th} activity

δ_j - Feed Supply from the j^{th} activity

The objective function is maximized subject to following constraints

Land constraint $\sum_{j=1}^{j} X_j \le L$

Emission constraint $\sum_{j=1}^{j} \alpha_j X_j \le Z^A$

Feed demand and supply constraint

$$\sum_{J=1}^{j} \beta_j X_j \le \sum_{j-1}^{j} \delta_j X_j$$

Feed demand and supply activities are linked through feed transfer activities.

The modelling approach adopted here is aiming to quantify the functional relationship between the level of emission and the net benefit of the farming system and find out the least cost policy measure to achieve a set emission target. The economic and environmental impacts of these policies are determined by comparing modeling results with the baseline solution. The baseline solution reflects the current production setting and estimates economic and environmental outcomes in the absence of new water quality policies. Changes in farm income, stocking rate and nitrogen use are predicted for each policy scenario.

It is necessary to be cautious when interpreting the financial results from the analysis. In this preliminary study, cash farm surpluses reported in the MAF farm monitoring reports 2004, were considered as average to simulate high intensity and low intensity farms using the information derived from literature regarding the biophysical relationship between nitrogen and production variables. The base run of the economic model selected high intensive and high income farming activities. Therefore the net revenue figures are much higher than the Waikato average. Cash farm surplus figures could have been replaced with inflation adjusted economic farm surplus. Similarly, science based livestock and pasture simulation models could have been used to derive the activities of different intensity.

A tax on nitrogen is incorporated in the model by increasing the variable cost of each production activity i. e. nitrogen use in each production activity is multiplied by the sum of the input costs and input tax. The charge on nitrogen into water is incorporated into the objective function by deducting the nitrogen discharge cost of each production activity. i. e. nitrogen discharge from each management practice is multiplied by the charge.

Standards are per hectare specific and overall. For overall standards, the nitrogen constraint is set to be a certain percentage of the base line discharge level. This would permit exceeding the standard limit in one part of the farm provided the overall discharge is not exceeded the limit. Per hectare specific standard ensures uniform nitrogen discharge through out the farm.

Technical coefficients for the LP model were obtained from published experimental data. The nitrogen discharge coefficients are generated using the nutrient budget software the Overseer. The Overseer nutrient budget model is used to simulate the effects of different production activities on nitrogen discharge. Output from the Overseer is incorporated into the economic model. Solutions to the economic model specify the profit maximizing combination of production activities under different restrictions on nitrogen discharge.

4.4 Catchment Wide Impact

An attempt has been made to estimate the catchment wide impacts of riparian margins in reducing nitrogen into water. Catchment wide impacts of riparian margins are modeled as follows. We have assumed the filtering potential of 10 m width of riparian margin is 25% of nitrogen into water, based on the literature (Parkyn, 2004), in which various experimental studies have been sighted with varying potential nitrogen reduction ranges from 11% to 90% . Study by Williamson, et al, (1996) on Riparian margins of Lake Rotorua revealed that the riparian margins were capable of reducing 26% of particulate nitrogen. A geographic information system is used to find information of water as bodies running through the pastoral land and the distribution of farms in the upper Waikato sub region, specifically the length of water margin under pastoral land. Estimations for the establishment cost of riparian margin were from Environmental Waikato. The farms are assumed to be similar to representative farms.

5. Results and Discussion

In the baseline scenario production practices are chosen to maximise the net revenue without considering nitrogen discharge. The baseline scenario selects the high intensive farming activity in both farming systems (Tables 2 and 3). In reality farmer's optimal choice, may differ from the optimal solution because of cash constraints, management constraints and risk aversion, farm specific physical resources and individual preferences. Changes in net revenue as a result of parametrically restricting the amount of nitrogen into water are presented in figure 4. It maps out the functional relationship between nitrogen and farm revenue for

different farm activities at different levels of nitrogen into water level. As nitrogen into water is restricted high stock density and high level nitrogen use activities are systematically substituted by low stock density and low nitrogen use activities.
The marginal abatement cost is derived from net revenue function, tends to rise exponentially consistent with the theory in the dairy farm model (Figure 7). This exponential rise of marginal abatement cost is not observed in sheep/Beef model beyond 30% reduction of nitrogen into water (Figure 8). The probable reason for this phenomenon is at lower stocking rates nitrogen discharge is indifferent between 0 N and 9 kg N per ha fertilizer application. As a result further restriction on nitrogen discharge beyond 30 % from the unrestricted level leads to shrinkage of farming activity (Table 3). The results indicate the cost of small reductions in nitrogen level is relatively low, while drastic reduction is relatively costly. When nitrogen is restricted more and more pasture land become idle in Beef Sheep farms. Net revenues in the base scenarios are higher on both types of farms.

In considering the relationship it is important to recognise that the model does not incorporate the changes in the fixed cost. As a result the marginal cost tends to be over estimated as the level of abatement increases. Especially this is going to be a concern in the case of establishing new pastoral farms such as pine to pasture conversions. In tailor made farms, the fixed cost component could have been reduced through thoughtful planning.   Dairy farms produce the highest nitrate output.

5.1 Impact of Various policies

The environmental policies were analyzed according to their impacts on total quantity of nitrogen applied and stocking rates across the farm. Analysis of the effect of various environmental policies on both farms is listed in table 4 and 5. Standards applied are hectare specific and overall. Hectare specific standards ensure nearly uniform discharge of nitrogen across the farm but the cost to farmers is higher than the overall standards. Overall standards render greater flexibility in choosing production activities. Overall standards are more cost effective than hectare specific standards for nitrate emissions.

Even though results show that the emission charges are more cost effective than input taxes, the efficiency of theses taxes need to be explored in the presence of compliance and transaction costs. Kampas and White (2002) revealed that the input tax was more efficient than emission tax in the presence of transaction costs.

Standards appear to be cost effective when compared to incentive based policies such as taxes on inputs and effluent charges. In dairy farms up to 450% levels of nitrogen input tax enterprise mix remained unchanged despite the decline in net revenue as the tax rises. This result is consistent with many studies. Similar results were found in the study of (Swinton and Clark, 1994), where the enterprise mix was unchanged between 121% to 780% of nitrogen input tax. Apparently, relatively high tax rates would be required to induce dairy farmers to substantially reduce nitrogen use. Giraldez and Fox, 1995, estimated the cost of a nitrogen ceiling and a tax on the reduction of certain level of nitrogen. The cost of a nitrogen tax and ceiling were $49.7 /ha per year and $1.81/ ha year respectively. Martinez and Albiac (2004) empirically estimated the effectiveness of environmental policies. In their study nitrogen standards outperformed nitrogen taxes, 1.20 Euro/kg of nitrogen tax resulted in 21.5 million euros quasi rent and 990 tons of nitrogen leaching. Meanwhile nitrogen standard resulted in 23.8 million euros quasi rent and 634 tons of nitrogen leaching. Empirical studies suggested that fertilizer use is very inelastic to price changes. Wu et al, (1995) estimated income loss of 16% under nitrogen standards and 49% under a tax regime to reduce nitrogen losses by 25%. They found elasticity of nitrogen losses with respect to nitrogen price of less than 0.1. Hopkins, et al (1996) stated standards may be more appropriate to reduce diffuse pollution. A study by Taylor et al (1992) implied that the elasticity of nitrogen losses with respect to nitrogen price as 0.034. In case of sheep/beef farms nitrogen reduction occurs at 350 % nitrogen input tax. Differences in effectiveness between farms partially reflect the differences in utilization rates of nitrogen.

The relative efficiency of taxes and standards in the presence of spatial heterogeneity depend on relative slopes of the marginal pollution cost and marginal profit and correlation between marginal pollution costs and marginal profit. A combination of steep marginal cost of fertilizer and flat marginal profits can favour uniform standards (Wu and Babcock, 2001). The steeper cost curve is attributed to low fertilizer use efficiency. This demonstrates the importance of accurate biophysical modeling in the evaluation of environmental policies. Non effectiveness of lower nitrogen taxes can be attributed to lower own price elasticity of demand of fertilizers. Hertlel, et al (1996) estimated the price elasticity of demand for nitrogen fertilizer as -0.2.

The riparian margin is the low cost policy option in both farm types. The adequacy of riparian margins alone to curtail the nitrogen discharge is questionable as it is only capable of limiting surface and sub surface nutrient movements. Estimated catchment wide impact of riparian margin at Upper Waikato is given in table 6. The cost of establishing riparian margin in Sheep/ Beef farms is assumed to be higher due to higher material cost and relatively rough terrain.

Table 2: Optimal Solutions under Different Nitrogen Restriction Scenarios (Dairy model)

	Base	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**
Net Revenue	161600	153867	146135	137239	127906	114554	99869	82848	55233
Nitrogen into water	6666	5999.4	5332.8	4666.2	3999.6	3333	2666	1999.8	1333.2
Activities (ha)									
SR 3.4 225N	101	56.56	12.12						
SR 3.0 175N		44.44	88.88	63.7	12.4				
SR 2.6 125N				37.3	88.6	71.29	32		
SR 1.8 50N						29.71	69	95	63.4

Table 3: Optimal Solutions under Different Nitrogen Restriction Scenarios (Sheep/Beef model)

		Reduction of nitrogen into water				
	Base Solution	**10%**	**20%**	**30%**	**40%**	**50%**
Net revenue	116400	109950	103500	94275	82080	68400
Nitrogen into water	4500	4050	3600	3150	2700	2250
Activities (ha)						
SR 14 36N	300	150				
SR 12.6 18N		150	300	75		
SR 9 11.2				225	270	225

Figure 4: Impact of Limiting Nitrogen into Water

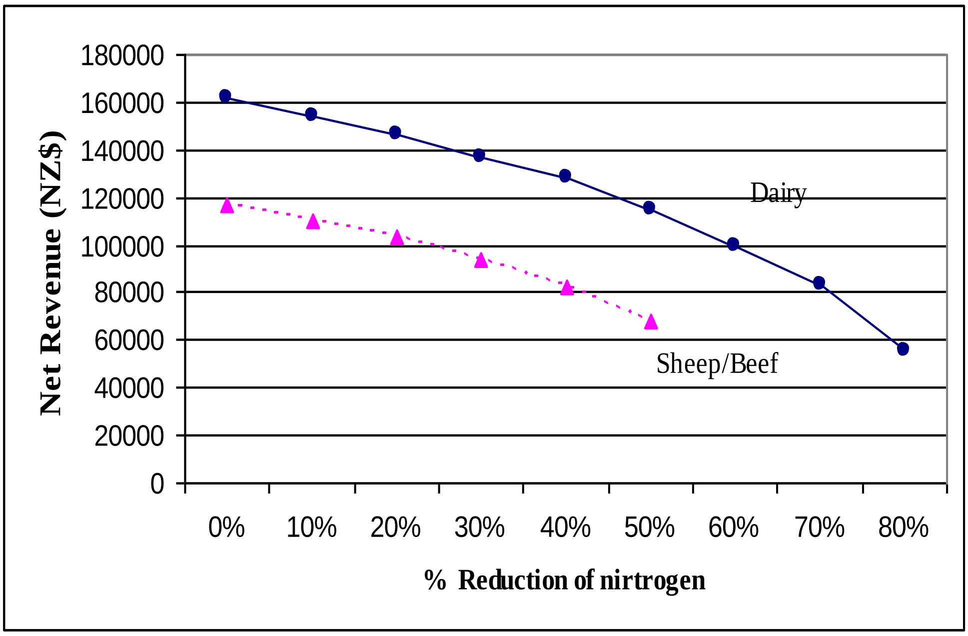


Figure 5: Marginal Abatement Cost of Reducing Nitrogen into Water (Dairy farm model)

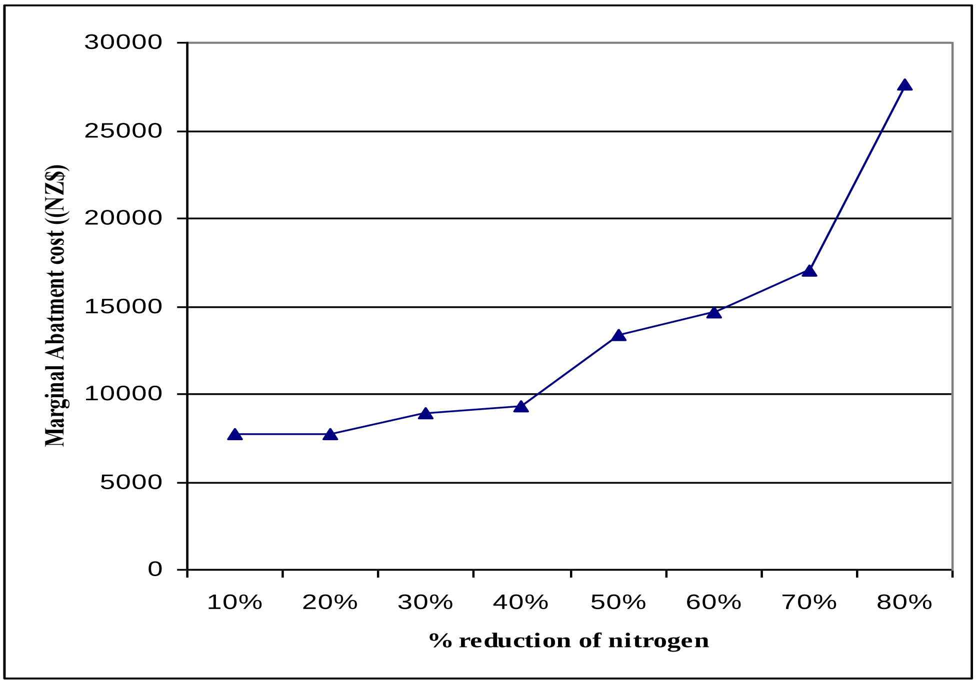


Figure 6: Marginal Abatement Cost of Reducing Nitrogen into Water (Sheep/ Beef farm model)

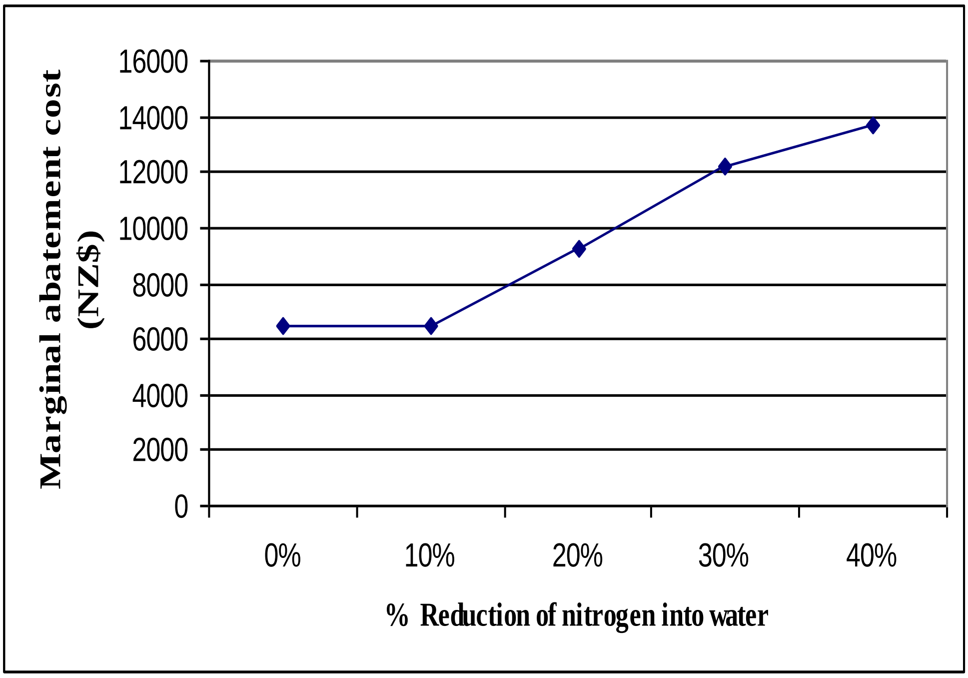


Table 4: Cost Effectiveness of Policy Instruments to reduce Nitrogen Discharge (Dairy)

				Activity (ha)				
	Net Revenue	Nitrogen Discharge	Cost of reduction	SR 3.4 225N	SR 3.0 175N	SR 2.6 125N	SR 2.2 100N	SR 1.8 50 N
			$/KgN					
Unrestricted	161600	6666	Non reduction	101				
Charges on Nitrogen discharge								
$11/kg N	88274	6666	No reduction	101				
$12/kg N	82214	5151	52.4		101			
$20/kg N	48884	3838	39.9			101		
$14/kg N	71912	3838	31.7			101		
$23/kg N	39087	2121	27.0					101
$24/kg N	39087	2121	27.0					101
$22/kg N	41208	2121	26.5					101
Charges on Nitrogen discharge & Tax on Nitrogen input								
$10 kgN+50% tax/KgN	82416	5151	52.3		101			
$8 kgN+100% tax/KgN	82820	5151	52.0		101			
500% tax	68579	3838	32.9			101		
$11 kgN+100% tax/KgN	69185	3838	32.7			101		
$10 kgN+100% tax/KgN	73023	3838	31.3			101		
450% tax	75548	3838	30.4			101		
Hectare specific N standards								
Nitrogen into water = < 33KgN per ha	106959	3030	15.0				101	
Nitrogen into water = < 46KgN per ha	125644	3838	12.7			101		
Land retirement								
10% of the land	145440	5999	24.2	90.9				
Riparian margin (10 m width)								
3 % land + 3000 m water margin fencing @25% filtering potential	151100	4851	5.8	98				
Overall N standards								95
Nitrogen into water= < 19.8 kg	82849	2000	16.9					
Nitrogen into water =< 26.4 kg	99869	2666	15.4			32		69
Nitrogen into water =< 33 kg	114554	3333	14.1			71		30
Nitrogen into water =< 39.6 kg	127906	4000	12.6		12	89		
Nitrogen into water=< 46.2 kg	137239	4666	12.2		64	37		
Nitrogen into water=< 59.4 kg	153867	5999	11.6	57	44			
Nitrogen into water =< 52.8 kg	146135	5333	11.6	12	89			

Table 5: Cost Effectiveness of Policy Instruments to reduce Nitrogen Discharge (Sheep/Beef farm)

				Activity (ha)				
	Net Revenue	Nitrogen Discharge	Cost of reduction $ kg/N	SR 14 36N	SR 12.6 18N	SR 11.2 9N	SR 9.8 18N	SR 8.4 18N
Unrestricted	116400	4500	No reduction	300				
Charges on Nitrogen discharge								
$21/kg N	28200	3000	58.8			300		
$15/kg N	49500	3600	74.3		300			
Charges on Nitrogen discharge and Tax on Nitrogen input								
$8 kgN+100% tax/KgN	68700	3600	53		300			
$17 KgN+ 100% Tax/kgN	36900	3000	53			300		
450% tax on fertilizer nitrogen input	82200	3600	38		300			
350% tax	88200	3600	31.3		300			
Hectare specific N standards								
Nitrogen into water = < 10KgN per ha	80100	3000	24.2				300	
Nitrogen into water = < 9KgN per ha	68400	2400	22.9					
Riparian margin (10m) 3 % land + 7000 m water margin fencing @25% filtering potential	112520	3240	3.0	290				
Overall N standards								
Nitrogen into water=< 7.5 kg	68400	2250	21.3			225		
Nitrogen into water= < 13.5 kg	109950	4050	14.3	150	150			
Nitrogen into water =< 9 kg	82080	2700	19.1			270		
Nitrogen into water =< 12 kg	103500	3600	14.3		75	225		
Nitrogen into water =< 10.5 kg	94275	3150	16.4		300			

Table 6: Catchment Wide Impact of Riparian Margins

	Dairy	Sheep/Beef
Estimated extent (ha) under riparian margin	90,201	70,913
Length of riparian margin (Km)	2,567	2,038
Total land lost under riparian margin protection (@10m width)	2567 ha	2038 ha
Cost of Establishing riparian margin	$1.90 /m	$2.54/m
Total cost of riparian margin (NZ$)	4.90 million	5.2 million
Potential nitrogen into water (KgN)	3427638	709130
Nitrogen into water with riparian margin (@25% filtering potential) (KgN)	2570729	531848
Reduction of nitrogen discharge (KgN)	856909	177282

6. Implications for Policy and Management

The results presented indicate the potential of using a modelling exercise in developing guidance for policy formulation. The empirical models presented here are based on simple two representative farms. More realistic estimates could be achieved through refinement of the empirical model.

Restrictions on nitrogen discharge have a substantial impact on production decisions and farm profitability. The implications of this need to be considered when developing policies for restricting farm nitrogen preventive measures.

Taxes on nitrogen input have to be set relatively high to reduce nitrogen discharge. Therefore policy makers may have difficulty in imposing these high tax rates. This does not necessarily suggest that tax policies unwarranted, provided tax revenue is channelled to research leading to environmental improvement and productivity enhancement. Bearing the upfront cost of adopting the new technology may be an effective way of extending the financial assistance to farmers. Implementation of polices may incur high transaction costs. These transaction cost need be considered and incorporated into the model.

The potential of offsetting the reduction of farm profitability through the intensive use of nitrogen rich feed supplements may be possible in face of attractive market prices for dairy products. Therefore the complex interaction of stocking rate and individual animal discharge needs to be considered. Regulating the stocking rate may be a solution to this problem as animal are the major source of nitrogen.

Even though this kind of analysis provides sub optimal solutions, there may be a desire from policy makers for simple and uniform policy instruments due to lower administrative cost. Therefore, there is a real need for cost effectiveness analysis of different environmental policy schemes at the more aggregate level, especially to support the choice among uniform policies.

7. Implications for Modeling

The model presented in this study does not incorporate risk of the production systems. Likewise it has not addressed the issue of spatial heterogeneity. Thus an important extension of this study is to include these aspects into the regional water quality policy analysis.

Management decision interact with the agro ecosystem in a dynamic way and effects may build up over times, thus affecting sustainability of the farm enterprise from environmental and economic point of view. Therefore dynamics need to be incorporated into the model.

Various technological options such as use of nitrate inhibitors, feeding pads and effluent disposal systems for cattle are being experimented in New Zealand by scientific research institutes like Agresearch and NIWA. Impact of these technological innovations can be possibly integrated into the analysis.

Inclusion of greater detail of variability in agricultural production technology is important to reflect the reality (Brady, 2003). This would better equip the model to capture substitution effects and tradeoffs between the different measures available for reducing emissions. Since timeliness of agricultural activities and various management practices have an impact on nitrogen discharge. These factors need to be modeled (Ekman, 2005).

The estimates of compliance cost and transaction cost of different policy measures need to be incorporated into the model. Effect of other policy tools like tradable emission permits can be included into the model. Damage cost of nitrogen water pollution need to be estimated and incorporated for the completeness.

8. Conclusion

This paper develops and applies a preliminary analytical frame work to evaluate alternative environmental policies. The framework integrates a representative farm, nutrient budget model, the Overseer and an economic model. The Overseer is used to simulate nitrogen into water under different production practices. The economic model is used to analyze the response of agricultural producers to alternative environmental policies. Catchment wide impacts are estimated by integrating geographic information.

Restricting nitrogen discharge has a significant impact on farm income. The abatement cost of pollution is high at higher levels of nitrogen discharge reduction. Analysis indicates standards are preferred to incentive based policies like input taxes and effluent charges. However this depends on the biophysical relationship between production and pollution variables. The impact of a nitrogen input tax is not the same on dairy and sheep/beef farms. Riparian margin is the cost effective solution for both farms. The transaction costs of these policies, the damage function of pollution and the effectiveness of other potential policy tools such as tradable emission permit need consideration in future analysis. To account for the spatial heterogeneity, time path and non linear relationships of production and pollution function, this model need to be further extended.

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