Section

4

4. Nutrient Loss Limits

Key Learning Objectives

After studying this section you should be able to explain:

1. The use of an economic instrument for improving water quality.
2. The concept of nutrient trading.
3. The information required to implement a nutrient trading programme.
4. How the success of trading programmes in controlling water pollution can be assessed.
5. The advantages of water pollution control using a nutrient trading programme compared to the method of control where each of the polluters is required to comply with mandatory limits on pollutants.
6. The possible reasons for some polluters not wanting to use a nutrient trading program to control water pollution.

Activities

Readings

Read the following notes on nutrient loss limits and nutrient trading (Section 4) before beginning Assignment C (Assignment C information will be sent to you as a separate document). Make additional notes where you think appropriate.

Introduction

Nutrient trading is a market-based approach to inland and coastal water pollution control in some overseas countries, especially in USA. A nutrient trading system allows two or more sources facing different nutrient control costs to shift pollution control responsibilities in order to lower the joint cost of control. In any lake or river catchment area there can be nutrient inputs (discharge) from industrial, urban or farm point sources (PS) and non-point source (NPS) diffuse runoff from urban and agricultural land. If the quantities of the PS and NPS discharges can be estimated and the cost of reducing those discharges to environmentally acceptable loads is known, then nutrient trading can take place among the parties responsible for each discharge. Trading may alter the pollution reduction responsibilities of each party, whilst achieving the same reduction in total nutrient discharge to the catchment. Trading may be done such that party A pays party B to undertake a greater than required reduction in nutrient discharge. The quantity of this extra reduction by party B should be equal to or greater than the nutrient discharge reduction that was required of party A. Thus, the required overall reduction in nutrient discharge to the catchment is still achieved.

The NZ government has embarked on a programme of action to ensure water quality, water allocation, and waterbody protection for future generations. Traditionally, regulatory agencies may take the pragmatic approach of setting out regulations, monitoring and negotiating with firms the enforcement of penalties. However, the use of nutrient trading programmes may potentially offer a way to introduce more flexibility and thereby reduce the cost associated with achieving environmental outcomes. For example, nutrient trading in Lake Taupo has been implemented and has required placing a cap on the amount of nitrate-N entering the lake from managed land. The Waikato Regional Council has used farm nutrient plans, created using the Overseer model, as the basis for benchmarking farm N leaching losses and allocating N allowances to farms around the lake. The benchmark N leaching losses were calculated using farm data averaged over the years 2001-2004. The average level of N leaching loss for the period 2001-2004 becomes the farm's grand-parented leaching allowance. If a farm can operate with N leaching below this allowance in future years it can gain N credits, but if it operates above this level it has to purchase N credits if they are available. This affects the current management practices being used by farmers around the catchment. In this section we summarise the current state of knowledge concerning the use of nutrient caps and nutrient trading, and considerations with implementing nutrient trading.

Economic instruments, such as nutrient caps and nutrient trading, are basically market mechanisms that are designed to address specific problems of environmental quality. Nutrient trading has generally been more effective where pollution is from point sources, such as pipes, than when emissions are from diffuse sources, such as farms. One of the main reasons is the difference in the feasibility and the cost of monitoring PS versus NPS (diffuse source) pollution. The most common type of nutrient trading in the USA is between PS and NPS. The idea here is to allow PS to sponsor implementation of NPS controls rather than install further costly controls of their own. In the USA, PS dischargers are generally the buyers of nutrient reduction allowances and NPS are the sellers. Legal and enforceable restrictions on the nutrient generating activities of NPS are necessary for nutrient trading between NPS and NPS (e.g. dairy and sheep farms) to occur. This trading would also open the possibility of two directional trades between PS and NPS; NPS could also purchase nutrient allowances from PS. Agriculture is the single largest cause of NPS pollution.

Example:

The Netherlands has experienced significant non-point source pollution problems. One important cause is the very intensive agricultural production (particularly livestock production) in the country. One of the approaches being used is the MINAS program. MINAS is essentially a tradeable permit approach for N and P applied as fertiliser on farms.

The system applies to pig, poultry, and mixed livestock and cattle farms with stocking rates above a set density (in total about 50% of Dutch livestock farms) and arable farms. Farmers in the MINAS program are required to prepare and submit a farm level mineral account (Nutrient Budget). The sum of P and N "surplus" from commercial fertiliser and manure sources is calculated in these accounts that are audited once a year. The allowable surplus has been revised downward over time. For instance, P limits have declined from 40 kg P/ha in 1998 to 30 kg P/ha in 2000 to 25 kg/ha in 2002. Farmers exceeding their surplus allowances can "trade" by giving excess manure allowances to farms that are under their surplus allowances. Those exceeding their quota are charged 2.5 guilder/kg/ha. The implementation of the program showed that 90% of farms do not pay charges because they supply manure allowances to arable crop farms with unused manure allowance capacity. One study found that the policy should decrease N use by 20% and P use by 30% (Principal source: Dwyer et al, 2002. Adapted from: MacDonald et al., 2004.)

Cost considerations

In the USA the main incentive for a PS discharger to participate in a trading program is compliance cost savings. Non-point source pollution controls usually cost less than point source controls. Therefore, trading between NPS and PS dischargers can save the PS discharger much of the cost of meeting water quality standards. Without differential pollution abatement cost, no trading would occur and no advantages would exist from creation of a nutrient trading system.

The costs to a PS discharger participating in a trade may include sizable transaction costs (the administrative costs of bargaining and initiating a trade, the cost of collecting data to accurately predict trading results), the cost of monitoring to ensure the trade conditions are met, and the cost of developing and implementing best management practice controls to reduce NPS discharge. For a trade to succeed, the total cost of all activities surrounding trading must be significantly less than the cost of implementing new technologies at the PS to meet water quality standards.

Because of the variability in nutrient concentration and flow of NPS streams a margin of safety often has to be incorporated into a trade that decreases the economic benefit.

Requirements to implement nutrient trading

Nutrient budgeting

Relationships between nutrient inputs to farms, farm management and transport of nutrients to water bodies are required to assess the impact of the farm activities on water quality. Some of this information can be obtained using nutrient budgeting software (e.g. Overseer).

Economic analysis

The costs of implementing best management practices and loss of farm production, if any, to achieve various levels of water pollution reductions need to be assessed. The cost savings for the PS discharger in not installing full or partial pollution control measures on their own to reduce nutrient entry to water bodies also need to be worked out. The cost savings for the PS should be higher than the cost of trading with the NPS for trade implementation.

Trading policy

In USA, the Environmental Protection Agency is authorised to look after these matters. The trade must be approved by the governmental authority before the transaction. The potential traders must be able to prove with reasonable assurance that the technologies for pollution reduction will work. The nutrient trading could become worthless if dischargers exceed their nutrient-loading limit without threat of enforcement.

Water quality standards

The governmental authority must establish water quality standards for each water body that will maintain or restore its designated use. The establishment of a meaningful and significant numeric nutrient discharge limit (a nutrient bubble or cap; see Glossary) is essential in order to create the demand for pollution cost control and monitoring the effectiveness of nutrient trading.

Monitoring water quality

The ambient water quality needs to be monitored at different points of time and location. This is more so for NPS than PS, because PS has a clearly defined and known effluent stream, whereas NPS, such as farms, have pollutants entering water bodies over a dispersed area rather than at fixed identifiable points. Furthermore, the loadings for NPS depend on random and episodic events, such as rainfall.

Monitoring management practices

Because it is technically difficult and costly to monitor water quality for assessing NPS pollution, the management practices adopted to reduce NPS pollution are commonly monitored to see whether the NPS is following the best management practices (BMP). The implementation of BMP sometimes takes a long time to show noticeable results in the local water quality. The residual effects of the previous management practices may still be contributing to the water quality for a while before the effects of the BMP become significant.

New Zealand water quality situation

For rural lowland water bodies in New Zealand, agriculture is considered to be the primary source of non-point source discharges. Materials used in agricultural production, such as fertilisers, and livestock activity allows sediment, nutrients, microbial contaminants to move with drainage and runoff from the soils into both surface and groundwater systems at higher rates than would be the case under natural systems.

Over the past 30 years, improvements in water quality have resulted from effective management and the reduction of PS discharges (e.g. adoption of land treatment of farm dairy effluent rather than discharge from treatment ponds to streams). However, the national and regional focus has shifted also to regulating and reducing NPS. A number of regional councils are requiring the use of the Overseer model to inform the process of predicting and auditing N discharge allowances. The following section provides three regional council case study examples.

1. Waikato Regional Council (Lake Taupo)

Problems with Lake Taupo's water quality are due to excess run-off of nutrients, particularly nitrogen. Scientific evidence shows that the health of the lake is declining as a result of nitrogen flowing from surrounding land, which accounts for about 94% of the ‘manageable’ nitrogen entering the lake. Wastewater from treated sewage and septic tank seepage contributes around 6% of the manageable nitrogen to the lake. Because much of the nitrogen inflows are via groundwater sources, there is a significant time lag between nitrogen inputs to the farmland and nitrogen entry to the lake. Therefore, the Lake is likely to continue to deteriorate for several decades before it improves back to its condition in 2000.

To protect the lake, the Waikato Regional Council proposed a variation to their Regional Plan. As of October 2004 they proposed that:

a) Nitrogen entering Lake Taupo will be maintained at the level that reflects the Lake's 2004 total annual load of nitrogen (1200 tonnes per annum) by 2080.

b) 20% of total annual manageable load of nitrogen leached from rural land uses and wastewater systems permanently removed from Lake Taupo catchments by 2019.

c) Nitrogen leached from land will be capped at 2001 -2004 levels.

In order to achieve these objectives, the regional council established a number of policies and methods that were first released in 2005. There are two policies that particularly affect farmers. Policy established capping nitrogen leaching from all rural land uses in the catchment. Capping was achieved by "grand parenting" farms a nitrogen discharge allowance (NDA) based on the Overseer model estimation of N leaching from their farm in the period 2001 to 2004. Capping at the nitrogen discharge allowance (NDA) avoids increases of nitrogen leaching from rural land use activities by placing limits on the annual average amount of nitrogen leached. For details on Policy, see:
http://www.waikatoregion.govt.nz/Council/Policy-and-plans/Rules-and-regulation/Regional-Plan/Waikato-Regional-Plan/
https://www.waikatoregion.govt.nz/Council/Policy-and-plans/Rules-and-regulation/Regional-Plan/Waikato-Regional-Plan/3-Water-Module/310-Lake-Taupo-Catchment/3105-Implementation-Methods-Land-Use-and-Discharge-Controls/

Trading of nitrogen (either "buy out" by the Lake Taupo Protection Tust or private trading) was considered for the Taupo catchment because it enhanced the flexibility of land use after the introduction of the Regional Plan Variation, which aimed to cap and reduce the discharge of diffuse source N into the lake. The RMA was amended to allow the transfer of discharge permits (this was amended in 2004, section 137 of the RMA). Legislative restrictions on the transferability of discharge permits previously had impeded regional councils using "cap and trade" arrangements to manage discharges. This made it possible for nutrient trading to take place. In the Taupo trading scheme, applications for the transfer of discharge permits needed to be lodged jointly, by both the current permit holder and the person to whom it is being transferred to.

For an update visit the Waikato Regional Council web site:
https://www.waikatoregion.govt.nz/council/policy-and-plans/regional-policy-statement/regional-policy-statement-review/section32/

Policy establishes nitrogen offsets between properties. This allows higher nitrogen leaching from land only if the increase is offset by a corresponding reduction on another property within the lake catchment. This established the ability to purchase N credits, which has been implemented recently by the Lake Taupo Protection Trust.
Visit their website (https://www.protectinglaketaupo.nz/the-trust/) for more information on the Trust.

Benchmarking essential, says Lake Taupo Protection Trust

1 February 2008

Farmers in the Taupo catchment interested in selling land or nitrogen credits to the Lake Taupo Protection Trust need to get benchmarked before meaningful talks can begin and options can be explored. That's the message from the trust, which has already been approached by interested farmers. The Lake Taupo Protection Trust was established to protect water quality in Lake Taupo by permanently reducing the amount of nitrogen flowing into it. "This is the first environmental project of its type in New Zealand and it's set to make history," trust Chairman John Kneebone said.

2. Bay of Plenty Regional Council (Lake Rotorua)

The Bay of Plenty Regional Council (BOPRC) is the council charged with overall water quality and catchment management of Lake Rotorua. BOPRC adopted lake water quality targets in the 1980s. In the case of Lake Rotorua, this is based on the acceptance that the water quality in the 1960s did not give rise to significant public concern. At the same time, the decision was made to divert treated sewage away from the lake as it was contributing 50% and 25% of the total (sewage plus catchment) load of total phosphorus (TP) and total nitrogen (TN), respectively. Kit Rutherford, from the National Institute of Water and Atmospheric Research Ltd, prepared a draft report for BOPRC that reviews a number of studies to illustrate trends in the nitrate concentrations and to estimate nutrient loads entering Lake Rotorua. Rutherford's draft report clearly shows the increasing trend in TN load and a steady trend in TP load in the lake (Table 1). However, the author presented preliminary results and suggested that recommendations could change.

Table 4.1. Lake Rotorua nutrient inputs and water quality - loads and targets 1965-2002

	1965	1976-77	1981-82	1984-85	2002	Target	Reduction from 2002 to target
Population	25,000	50,000	52,600	54,000	69,000	-	
Phosphorus Input							
Raw Sewage (t/y)	5	18	30	47		-	
Treated Sewage (t/y)	5	7.8	20.6	33.8	1	3	
Stream (t/y)	34	34	34	34	34	34	
Internal (t/y)	ND	0	20	35		0	
Total (t/y)	39	42	75	103	35	37	nil
Nitrogen Input							
Raw Sewage (t/y)	34	100	170	260		-	
Treated Sewage (t/y)	20	73	134	150	32	30	-2
Stream (t/y)	455	485	420	415	660	405	-255
Septic tank (t/y)	50	80	15	10		0	
Internal (t/y)	ND	0	140	>260		0	
Total (t/y)	475	558	694	>825	692	435	257
Avg. Lake Quality							
Total P (mg/m^3)		23.8	47.9	72.6		20	
Total N (mg/m^3)		310	519	530		300	

In summary, Rutherford estimated that the 2002 annual catchments input is 35 tonnes of phosphorus (compared to a target of 37 tonnes) and 692 tonnes of nitrogen (compared to a target of 435 tonnes). However, this does not include raw sewage from septic tanks and internal loads to Lake Rotorua, which can be estimated at least half of the catchments loads. It also assumes that the inevitable population growth around the lake will not contribute any more nutrients. The nitrogen load has increased from 1965 to 1981 onwards probably due to increased nitrogen inputs from both the raw and treated sewage. The Trophic Level Index (TLI) is a "lake health" indicator that covers water clarity as well as phosphorus and nitrogen levels. In Lake Rotorua the TLI index does not show an overall increasing or decreasing trend from 1970 to 2002. It has not changed significantly since 1970, although some short-term variations can be seen with changes in sewage disposal and a long period of stratification in the lake over the summer of 1969-70.

Nutrient management in Rotorua Lakes Catchment

In response to National Policy Statement for Freshwater Management (NPSFM 2014) and regular science updates on lake water quality and catchment land use, the BOPRC have consulted the Lake Rotorua Stakeholder Advisory Group to develop an adaptive land management plan to reduce N loading into the lake catchment. The Proposed Rules (Plan Change 10) were notified in February 2016.
https://www.boprc.govt.nz/media/670433/appendix-8a-council-on-plan-change-10-clean-copy-version-plus-cover-page-dated-15-august-2017.pdf

In a manner similar to Lake Taupo, the Overseer model is to be used to estimate and benchmark individual farm N discharge and the root zone N load entering the lake. Based on historic farm productivity (grand parenting) in specified years, diffuse nitrogen discharge is calculated. Implementation of change to farm nutrient management and land use change become the main instruments for reducing nitrogen loss down to the Nitrogen Discharge Allocations.

Nitrogen trading also has been proposed and is summarised in a report, Nutrient trading in the Lake Rotorua catchment, http://www.rotorualakes.co.nz/vdb/document/896.
Currently Plan Change 10 hearings continue (see http://www.rotorualakes.co.nz/plan-change-10), whilst land owners with land holdings >40 ha were encouraged to become benchmarked and apply for resource consents, which were free of charge from July 1 to September 30, 2017.

Properties/farming enterprises that are considered controlled activities will be given a Nitrogen Discharge Allowance that they will need to meet by 2032 and will require a Nitrogen Management Plan that shows actions that manage the reductions.

The Lake Rotorua Primary Producers Collective is a diverse group of farmers aiming to influence policy and farm practice that enables profitable farming, a prosperous community and a healthy lake. Their website contains many readings and farmer videos that provide a background to the issues within the Lake Rotorua catchment. Refer to http://www.rotoruafarmers.org.nz/ to learn more about this collective and to gain an understanding of some solutions that are being farmer-led.

3. Horizons Regional Council (One Plan)

In 2007, Horizons Regional Council (Horizons), which manages the Manawatu, Rangitikei and Wanganui river catchments, proposed introducing legislation ("One Plan") designed to guide more sustainable resource use. The original "One Plan" was focussed at four problems in the region - water quality, water demand, hill country land use and threatened habitats. In some catchments, rivers and streams with elevated N and P concentrations have algal and weed growth problems that lead to deterioration in water quality; preventing recreational use. To minimise this problem, Horizons identified nitrate sensitive rivers and streams. Through the "One Plan" they proposed to reduce the N load entering these rivers and streams from intensively farmed land. Horizons employed consultants to use Overseer Nutrient Budgets to estimate the N leaching loss from all farm types in the nitrate sensitive catchments. They assumed that the N leached from farms contributed directly to the N loads measured in the rivers. Most of the N loss that has the potential to be managed was associated with dairy farms. Thus, to reduce the N load in the rivers, Horizons needed an instrument to reduce N leaching loss from the more intensively farmed land. Horizons proposed that the reduction in N load will be achieved by allocating N loss allowances based on land use capability class (LUC). The N loss allowance was proposed to decrease over 20 years (Table 4.2), with the goal of reducing the N load entering the rivers. LUC classes describe land of different production potential.

For example, LUC I is very good multiple-use land, low slope category, deep, easily worked, well drained soils. LUC VI can be stable hill country where soil erosion can be minimised by good pasture establishment/management, but can also be flat to rolling land with an erosion risk, or, with one or more of the following limitations that prevent safe cropping use: slight to moderate erosion hazard under perennial vegetation, very stony/very shallow soils, excessive wetness or overflow, frequent flooding with severe damage to pastures, low moisture holding capacity, severe salinity, moderate climatic limitations. LUC VIII is predominantly very steep mountain land not used for farming but often used for restricted to catchment protection and recreation. Horizons' view was that higher producing land (lower LUC class #) could be used more intensively and, therefore, have higher levels of nitrogen leaching loss. For the "One Plan" to provide for an economically sustainable future, it recognised that lower LUC class land needed higher N loss allowances. It also recognised that intensive management of lower LUC class land was in a better position to adopt management strategies to reduce N leaching than extensive management of higher class land. Accordingly, Table 4.2 shows the nitrogen loss allowances for each LUC class and the proposed reductions over a period of 20 years.

A brief example is given of how a proposed leaching allowance is calculated for an 88 ha dairy farm, based on the area of land it has in each LUC. National land resource inventory maps (LRI maps, scale 1: 50000) are available and are allowed by Horizons to be used by farmers to estimate the LUC coverage on their farm, using a desktop approach. Alternatively if the farmer has access to a landuse mapping expert then more detailed maps (scale, 1:10000) can be prepared from farm walks with references to the LRI maps of the district. The desktop approach should be less costly but will be less accurate.

Table 4.2. **Nitrogen loss allowances (kgN/ha/yr) according to land use capability class (LUC) (derived from table 14.2 One Plan)**

LUC	I	II	III	IV	V	VI	VII	VIII
Year 1	32	29	22	16	13	10	6	2
Year 5	27	25	21	16	13	10	6	2
Year 10	26	22	19	14	13	10	6	2
Year 20	25	21	18	13	12	10	6	2

(Source *The Farm Strategy Work Book* https://www.pdffiller.com/22651619--FARM-Strategy-workbook-13-04-07-Horizons-Regional-Council-)

In this exercise we examine the influence of allocating LUC classes to the farmland using the two approaches outlined above. The following two maps show differing LUC classification for the example farm. Map A shows the desktop, low cost LUC classing, at a scale of 1:50000, which is drawn from a "Land Resource Inventory" map, sourced from Landcare Research Digital Land Resource Inventory, IMS GIS server Massey University. The cost to source one of these maps for a farm is approximately $1500.

Figure 4.1. **LUC classification of the example farm, conducted using A, a desktop and B, a farm walk by an LUC expert. Yellow – LUC II; Maroon – LUC III; Blue – LUC IV; Orange – LUC VI; White-green speckle - gullies, reserves and wetlands.**

Map B shows a Medium Cost LUC classing, which was achieved from an LUC expert walking the farm and interpreting the landscape to draw more detailed map information at a scale of 1:10000. The cost of drawing one of these maps for a farm is $5000-$10000, depending on the size and location of the farm. A farmer may wish to spend extra money to obtain a more detailed map, such as the Map B example, to ensure that he/she has the largest leaching allowance possible.

Table 4.3. Land use class allocation to the example Dairy Farm using an expert farm walk. (Figure 4.1, Map B).

LUC Class	*N Leaching Allowance (Year 1)*	*Contributing Block*	*Area (ha)*	*Total Area for Class (ha)*	*Total N loss load (kgN/farm)*
I	32			0	
II	29	Block 1	14	57	1653
		Block 2	26		
		Block 3	17		
III	22			0	
IV	16	Block 4	11	11	176
V	13			0	
VI	10	Block 5	20	20	200
VII	6			0	
VIII	2			0	
Total				88	2029
N loss allowance					23 kgN/ha

The total N leaching allowance for this farm is calculated by multiplying the allowance for each class by the area for that class (Table 4.3), then dividing that number by the total area of the farm (i.e. 88). The N leaching allowance using this map is 23 kg/ha. In comparison, the N leaching allowance using Map A is 24 kg/ha, therefore, in this instance the farmer may wish to use the simpler, cheaper map as it gives them a larger allowance.

The farmer then conducts a full Overseer nutrient budgeting exercise based on the farms long-term average (e.g. 5 year) production plan to establish whether the farm complies with the LUC based leaching allowance. Non-compliance requires a management plan to be approved that will create reductions in N leaching and compliance with the reducing N allowance.

"One Plan" proposals scaled back after submissions to independent environmental commissioners

In the proposed "One Plan" (2007), dairy farms in sensitive catchments would have to comply with nitrogen leaching allowances, set by the FARM strategy work book, which depended on the land classification of their farm.

In hearings that ran from 2008 to 2010, this compliance was opposed by Federated Farmers and other groups, on the basis of the inapplicability of the land-use classification system on many land types. In addition, in the absence of proven nitrate leaching mitigation technologies, to reduce N loss required reduction in stocking rates, causing large financial penalties for farm businesses that had not been fully assessed. Fonterra and Dairy NZ preferred a non-regulatory, self-audited approach, which would allow farmers to employ best-practice techniques for nutrient application and effluent management to meet the provisions of the Clean Streams Accord and other industry initiatives.

In September 2010, the One Plan hearing panel of commissioners recommended a regulatory approach for the five most at-risk catchments that did not involve nitrogen loss limits based on land-use classification for existing dairy farms and new dairy conversions. Existing dairy farms in controlled catchments have to prepare a nutrient budget and management plan, and to implement farm management practices to minimise leaching. Straightforward activities such as culverts and bridges will be consented in the field by council staff. These regulations do not include horticulture, cropping and intensive sheep and beef farms.

In September 2016, Horizons Regional Council was taken to the Environment Court by Fish and

Game and the Environmental Defence Society. They claimed that the commissioner's recommendation meant that Horizons was going too easy on farms by allowing for high levels of nitrogen to be discharged and the One Plan leaching limits (Table 14.2) were not being enforced. The environment court ruled that Horizons Regional Council needed to implement the leaching limits. An appeal by Horizons in 2017 was not successful. Currently the Regional Council are reviewing their approach.

The Court's decision primarily affects Land Use (and associated discharge) consent applications that do not meet all of the requirements of the controlled activity rules of the One Plan. Consent applications for existing land use that do meet the N leaching requirements of Table 14.2 and meet all of the controlled activity requirements can still be processed as before. All other consent application processes will continue as per usual.

For further information on the One Plan refer to http://www.horizons.govt.nz/publications-feedback/one-plan

Recommended Readings

Delaware Department of Natural Resources and Environmental Control 2000. Watershed-based nutrient trading. One page fact sheet.

Wang, X., Zhang, W., Huang, Y., Li, S. 2004. Modeling and simulation of point-non-point source effluent trading in Taihu lake area: perspective of non-point sources control in China. *Science of The Total Environment 325*: 39-50.

Mackay, A., Clothier, B., Parfitt, R., 2008. Defining Nitrogen-Loss Limits within a water management zone using a natural capital valuation of the soil. *FLRC Workshop Proceedings, Massey University, Occasional Report 21*: 525-530.

Optional Readings

Crutchfield, S.R., Letson, D., Malik, A.S. 1994. Feasibility of point-nonpoint source trading for managing agricultural pollutant loadings to coastal waters. *Water Resources Research 30*: 2825-2836.

Faeth, P., Livernash, R., Hyacinth, B. 2000. Fertile Ground: Nutrient trading's potential to cost effectively improve water quality. World Resources Institute. Download report from: http://pdf.wri.org/fertile_ground.pdf (57 pages)

Jarvie, M., Solomon, B. 1998. Point-nonpoint effluent trading in watersheds: a review and critique. *Environmental Impact Assessment Review 18*: 135-157.

Horan, R.D., Shortle, J.S., Abler, D.G. 2002. Point-nonpoint nutrient trading in the Susquehanna River basin, *Water Resources Research 38*: 8-1 – 8-3.

MacDonald, H.D., Connor, J.; Morrison, M. 2004. Economic Instruments for Managing Water Quality in New Zealand. CSIRO Land and Water, Final Report for NZ Ministry for the Environment. Folio No: S/03/1393 (72 pages)

Glossary of nutrient trading terms

Discharge Allowance – specifies a quantity of nutrients that the discharger is allowed to release into a given body of water over a specified period of time.

Baseline - The numeric level of nutrient load at a particular point in time that serves to establish nutrient reduction goals and allowances.

Buyer - An entity that purchases nutrient credits.

Cap or Bubble - The total nutrient load that is allowed to be discharged into a given water body. The cap is the baseline minus the amount of load reduction needed to meet the goal. The cap is equal, or greater than, the sum of the discharge allowances.

Credits - The amount of nutrient load reduced below the discharge allowance.

Environmental Offsets – Environmental Offsets are actions taken to meet a standard (reducing pollution) at a site away from where the action causing an environmental externality occurs. The party causing the externality can either take the action themselves or pay for others to do it on their behalf. These actions are most often taken where environmental quality goals are only just been achieved, or there is non-attainment, and there is pressure to allow further development. In this approach it is possible to have further development that damages the environment, provided that works are undertaken to either offset or more than offset this damage.

Eutrophic - Describes an aquatic system with high nutrient concentrations. These nutrient concentrations fuel algal growth. This algae eventually dies and decomposes, which reduces the amount of dissolved oxygen in the water.

Eutrophication - The fertilisation of surface waters by nutrients that were previously scarce. Eutrophication through nutrient and sediment inflow is a natural aging process by which warm shallow lakes evolve to dry land. The most visible consequence is the proliferation of algae. The increased growth of algae and aquatic weeds can degrade water quality.

Impaired Waters (or Impairments) - Impaired waters are waters that do not meet water quality standards.

Non-point Source - A diffuse source of pollution that cannot be attributed to a clearly identifiable, specific physical location or a defined discharge channel. This includes the nutrients that runoff the ground from any land use - croplands, feedlots, lawns, parking lots, streets, forests, dairy-shed effluent etc. - and enter waterways. It also includes nutrients that enter through air pollution, through the groundwater, or from septic systems. Non-point sources of pollution are diffuse and spread across the landscape.

Nutrient Trading - The transfer of nutrient reduction credits, specifically those for nitrogen and phosphorus. Nutrient Trading is a tool used in watershed management to encourage pollution reduction.

Nutrient Trading Ratio - The ratio of the amount of nutrients in excess of the allowable limit released by an activity to that required elsewhere in the catchment to offset this excess. For example, a trading ratio of 2:3 implies that an activity that introduces 2 tonnes of phosphorus into a waterway would require 3 tonnes of phosphorus elsewhere in the catchment to be offset. Trading ratios are usually based on several factors, including the desired environmental improvement, the level of uncertainty about the environmental impacts, and the distance between the development and offset sites.

Nutrients - Compounds of nitrogen and phosphorus dissolved in water, which are essential to both plants and animals. Too much nitrogen and phosphorus act as pollutants and can lead to unwanted consequences - primarily algae blooms that cloud the water and rob it of oxygen critical to most forms of aquatic life.

Point Source - A source of pollution that can be attributed to a specific physical location; an identifiable, end of pipe "point". The vast majority of point source discharges for nutrients are from wastewater treatment plants, although some come from industries. Examples include municipal and industrial treatment facilities.

Riparian Area - Riparian refers to the area of land adjacent to a body of water, stream, river, marsh, or shoreline. Riparian areas form the transition between the aquatic and the terrestrial environment.

Riparian Forest Buffers - An area of trees, usually accompanied by shrubs and other vegetation, that is adjacent to a body of water which is managed to maintain the integrity of stream channels and shorelines, to reduce the impact of upland sources of pollution by trapping, filtering, and converting sediments, nutrients, and other chemicals, and to supply food, cover, and thermal protection to fish and other wildlife.

Sediment - Matter that settles and accumulates on the bottom of a body of water or waterway.

Seller - An entity that offers nutrient credits for sale.

Water Quality Criteria - Criteria are part of a water quality standard, and may be numeric or narrative. Criteria represent a quality of water that supports a particular designated use. When criteria are met, water quality will generally protect the use.

Water Quality Standards - A provision of governmental law consisting of a designated use or uses for a water body and the quantifiable criteria protective of the use(s). Standards may be annual or seasonal, depending on the designated use.

Watershed - A region bounded at the periphery by physical barriers that cause water to part and ultimately drain to a particular body of water.

Wetland - Low areas such as swamps, tidal flats, and marshes that retain moisture.

Reading 4.1

Delaware Department of Natural Resources and Environmental Control 2000. Watershed-based nutrient trading. One page fact sheet.

WATERSHED-BASED NUTRIENT TRADING

INTRODUCTION

Reducing the amount of nutrients that flow into the bays is an expensive endeavor. But, allowing the bays to remain polluted from nutrients also costs the community in terms of ecological resources and dollars. Elimination of nitrogen and phosphorus from point-source discharges may seem to be the easiest way to eliminate some of the problem. However, in the Inland Bays watershed, point sources only account for 8% of the nitrogen influx and 30% of the phosphorus loading. In some cases, it could cost 11 to 29 million dollars to reduce phosphorus by 15%. Non-point source contributions of nutrients (runoff) make up the majority of the nutrient loading into the bays. Controlling or regulating these non-point sources may be more effective at reducing nutrient levels in the bays and may be much less expensive. A nutrient-trading program may achieve the needed reduction in nitrogen and phosphorus.

DEFINITION

Nutrient trading is a way of allocating the assimilative capacity of the system—regardless of activity. These trades can take place among point sources; between point and nonpoint sources; or, among nonpoint point sources.

Trading alters the pollutant reduction responsibilities between parties. Trading may be done such that Party A pays Party B to undertake a greater than required pollution reduction. The amount of this reduction should offset (be equal to or greater than) the quantity of pollution reduction that they were required to implement. Thus, the same, or a greater, pollution reduction goal is met. These trades should occur within the same watershed and between sources in close proximity. Trading may also be accomplished through setting up "banks" where the nutrient reducing parties can sell their credits and parties requiring nutrient credits can purchase them. Many times purchasing ratios can be involved such that the purchase of nutrient credits cost 2 to 7 times that in nutrient credits. These ratios are believed to cover uncertainty in nutrient reduction achieved through nonpoint source use of best management practices.

AN EXAMPLE

Numbers for illustration purposes only:
A plant contributes 10 pounds of nitrogen per day into the Bays. It will cost them $500,000 to remove that pollution discharge. They are required to reduce their discharge to 0. They need to purchase10 pounds of allocated nitrogen load, or 10 pollution rights, to continue their existing operations.

Ten farmers in the area contribute 20 pounds of N per day, together. Each farmer has 2 pollution rights. The farmers could eliminate 15 pounds of N per day by installing a new technology. This would cost $20,000 per farm.

The plant could then pay each farmer $21,000 for one of their pollution rights, giving the farmers, the money to purchase and use the new technology. This would cost the plant $210,000. The entire watershed would enjoy a reduction of 15 pounds of nitrogen per day. This is 5 pounds more per day than would have occurred without the trading.

TRADING PRINCIPLES

In order for trading to work within the current legal framework, a series of eight principles (written by EPA) should be followed:

1. Trading Participants must meet applicable Clean Water Act (CWA) technology-based requirements.
2. Trades are consistent with water quality standards throughout a watershed. Anti-backsliding and other requirements at the local, state and federal level still apply as well. *(Anti-backsliding* means that the pollution must be reduced overall, not increased.)
3. Trades are developed within a TMDL or equivalent analytical and management framework.
4. Trades occur in the context of current regulatory and enforcement mechanisms.
5. Trading boundaries generally coincide with watershed or water body segment boundaries, and trading areas are of a manageable size.
6. Trading will generally add to existing ambient monitoring since all parties require data.
7. Careful consideration is given to types of pollutants.
8. Stakeholder involvement and public participation are key components of trading.

ISSUES

- It does not make sense that a point source can trade for a pollution right from a non-point source where they use economic incentives and volunteerism to achieve pollution reduction—no enforcement mechanism.
- Requiring the use of technology-based standards may stifle innovation.
- If you require all parties to be using BMPs, then there would be no relief for any party through trading.
- Place the burden of proof that trading works on the party with initial burden of reducing the pollution.
- Pollution trading is flexible—managers can target areas for trading.
- Pollution trading is cost-effective.
- Trading allows for the opportunity to implement enhancement projects.
- The process of organizing a trading scheme identifies areas for trading and brings regulated and non-regulated community together.
- Can point sources enforce nonpoint source polluters' actions?
- Should enforcement actions be taken against the party that traded the point sources if nonpoint sourses do not comply?
- Can trading between point and non-point sources meet goals of CWA?

INLAND BAYS WATERSHED

This fact sheet was prepared by the Delaware Department of Natural Resources and Environmental Control's Whole Basin Team, at the request of the Inland Bays Tributary Action Teams, for citizens and stakeholders interested in one of Delaware's most environmentally and economically attractive areas—the Inland Bays and its surrounding lands, surface and ground waters.

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Delaware's good nature depends on you!

Reading 4.2

Wang, X., Zhang, W., Huang, Y., Li, S. 2004. Modeling and simulation of point-non-point source effluent trading in Taihu lake area: perspective of non-point sources control in China. *Science of The Total Environment 325*: 39-50.

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Modeling and simulation of point-non-point source effluent trading in Taihu Lake area: perspective of non-point sources control in China

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Abstract

The past decades have witnessed some efforts in point source water pollution controls in China. However, adequate abatement efforts have not been implemented on non-point source control, and non-point source contributions remain and have increased as a share of surface water degradation. It has been noted that conventional command-and-control regulations are ineffective for agricultural non-point source pollution, and watershed abatement trading between point and non-point sources may serve as a cost-effective way to deal with it. In this paper, the feasibility of point-non-point sources effluent trading in China and cost-effectiveness of the trading system on water pollution control are evaluated using a stochastic programming model and a combined probabilistic watershed simulation of a representative agricultural watershed in the Taihu Lake area. The method and model can be used to assess economic and environmental opportunities of trading in similar watersheds in China. The use of explicit emission target and reliability decision rules in the chance-constrained programming model is a practical simplification to convert a stochastic program into a solvable deterministic problem. Based on the simulation, suggestions on development and implementation of point-non-point sources abatement trading scheme in China were discussed.

Keywords: Non-point source control; Point-non-point effluent trading; Taihu lake; Watershed simulation; Uncertainty

1. Introduction

In recent decades with effective abatement of point sources pollution, non-point sources contribution has become a major cause of water quality degradation in China (State Environment Protection Administration of China, 2000). China is one of the largest producers and consumers of chemical fertilizers in the world, and the excessive nutrient loading from agricultural watersheds is considered to be the principal source of non-point sources pollution (Yan et al., 1999). With accelerated industrial development, there is an accompanying increase in pollutant loading of surface water, and the concentration-based discharge control on point sources is insufficient to attain water quality targets. Therefore, abatement of non-point sources is required.

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A tradable system for point and non-point sources is a market-based approach for environmental protection, which has long been advocated by economists. By providing flexibility to dischargers, a tradable system is potentially more cost-effective than traditional command-and-control regulation in attaining specific pollution reduction targets (Crutchfield et al., 1994; Malik et al., 1994; Zhang and Wang, 2002).

As a regulatory basis, mass loading control and wastewater/air pollutant discharge permits are elucidated in the *Air Pollution Prevention and Control Law of the People's Republic of China (2000) and the Water Pollution Prevention and Control Law of the People's Republic of China (1996)*. Since 1987, pollutant discharge permit systems have been put into trial implementation in 18 cities in China. As an initial legal statement in local regulation, Article 21 of the *Shanghai Regulation of Environmental Protection (1995)* states that permit trading can be a means to improve the environmental quality. The first trading case in China was performed in Shanghai in the early 1990s. In that case, a tin-plating plant called Minhang Tangwang Electroplating Facility was closed, and its industrial wastewater discharge permit of 10 metric tons per day was traded to the Shanghai Steel Facility. After decades of trial implementation and improvement, the regulatory and administrative framework to institute a tradable system for water pollution has been established in China. This lays solid foundation for developing point-non-point sources abatement trading scheme in China.

Several features of non-point source pollution complicate control practice. Firstly, non-point source emissions are influenced by stochastic events such as rainfall. Given current monitoring technology, the non-point source loads cannot be measured with certainty but in fact represent a probability distribution around the actual discharge load (Stephenson et al., 1998); Secondly, farmers were not traditionally responsible for the control of pollution caused by agricultural activities, and the current regulation is not designed for enforcement of agriculture pollution abatement. The conventional command-and-control regulation is, therefore ineffective for agricultural non-point sources, and economic incentive-based policies should be applied.

There is a large body of literature focusing on water emission trading systems in foreign countries, such as Malik (1990), Keeler (1991), Stranlund and Dhanda (1999), Malik (2002) and SanMartin (2003), etc. Literature on China's non-point source pollution management is also evolving. For example, Xia and Yang (2003) did a comprehensive study on non-point source pollution control in the Taihu Lake area; Guo et al. (2003) conducted a quantified study on nitrogen pollution from non-point sources in the Taihu Lake area. However, among Chinese studies, research on an empirical simulation model, considering uncertainty of non-point emissions, is rare. In our previous study, it was noted that pollution abatement trading may serve as a cost-effective way to deal with non-point source pollution in China, and a practical model of watershed point-non-point abatement trading with uncertainty of non-point source emissions was developed (Zhang and Wang, 2001, 2002). In this paper, our objective is to provide model simulation for point-non-point abatement trading in Dongtiao River watershed, a typical watershed in the Taihu Lake area. We assumed that the objective of decision-maker would be to maximize economic return in the watershed, subject to environmental quality targets. The simulation results were then used as a basis to analyze the cost-effectiveness of point-non-point trading in the Taihu Lake area. Furthermore, suggestions were provided for further implementation of the trading system in China.

2. Background of the study site

2.1. Introduction of Taihu Lake area

Taihu Lake is situated between 30°5′–32°8′N and 119°8′–121°55′E, in the eastern part of China (see Fig. 1). It is the third largest freshwater lake in China, with a catchment area of 36 500 km^2, a water surface area of 2338.1 km^2, and an average water depth of 1.9 m. The annual average air temperature is 14.9 °C–16.2 °C. The annual mean precipitation is 1000–1400 mm, and the annual mean runoff into the lake is 4100 million m^3.

Fig. 1. Location of Taihu Lake.

Taihu Lake area is one of the most densely populated and urbanized areas in China. Along the lake, there are seven large and medium size cities (including Shanghai, Suzhou, Wuxi, Jiaxing, Huzhou, Changzhou, Kunshan, etc.) and 31 counties. This area is also one of the most developed agricultural areas in China. With high fertilizer utilization and high agricultural output, the chemical fertilizer consumption in Taihu area accounts for 1.3% of the whole nation. Because of the development of township and village industries, the opportunity cost of labor was increasing, and the conventional organic fertilizer was increasingly replaced by large amount of chemical fertilizer. In recent years, besides the wastewater from industrial sources, agricultural non-point emission was growing to be a major pollution source. The chemical fertilizing structure with high nitrogen concentration promoted the loss of nitrogen from farmland, and contributed significantly to the eutrophication of the Lake (Ma et al., 1997; Lu, 1998a; Li et al., 2000).

Taihu Lake is one of the three key polluted lakes (Taihu, Chaohu, Dianchi) under the control of the State Council and State Environmental Protection Administration (SEPA). In 2001, SEPA issued the *Management Method of Pollution Discharge Permit in Huaihe River and Taihu Lake Catchment*, which stipulated all the facilities that discharge wastewater into the water body, municipal WWTP and central industrial WWTP must apply to the local EPB for a wastewater discharge permit. According to the *Tenth Five-Year-Plan for Water Pollution Prevention and Control in Taihu Lake Catchment* issued by the State Council in 2001, a mass loading quota was allocated to each river/stream watershed within the Taihu Lake area.

The current non-tradable permit system in the Taihu Lake area lays a good foundation for a shift to a tradable one in terms of institutional capacity for discharger identification and management.

2.2. Feasibility of the trading scheme

It is generally recognized that the following basic criteria are prerequisite for a watershed to develop and implement a trading scheme between point and non-point sources:

- In the watershed, non-point source pollution loading must be significant and contribute as a large share to the water pollution.
- The abatement of non-point sources should be feasible and effective; and
- The abatement cost of non-point sources should be lower than the cost of further point source abatement on a per unit basis.

Gauged by the above criteria, Taihu Lake area is considered to be suitable for a point-non-point trading trial in China.

Firstly, eutrophication is the major environmental problem of Taihu Lake, and is mainly caused by nutrient losses from agricultural non-point sources. According to the statistical data from the Management Bureau of Taihu Lake Catchment, Ministry of Water Resources, nitrogen pollution from the agricultural non-point sources accounted for 77% of the total nitrogen discharged into Taihu Lake, and phosphorous pollution from the agricultural non-point sources accounted for 66% of the total. From 1987 to 2000, major pollution indicators (COD_{Mn}, TN and TP) in Taihu Lake showed increasing trends.

Secondly, agricultural non-point sources have larger abatement potential and relatively lower cost. The average nitrogen fertilizer utilization per ha is 501.6 kg in the northern Taihu Lake area (located in Jiangsu Province), and 1125 kg in the southern Taihu Lake area (located in Zhejiang Province). Under this level of applied fertilizer, the average crop output per kiligram nitrogen is only 8.2 kg, and the fertilizer effectiveness is only 27%. The surplus of nitrogen in soil causes significant contribution of nitrogen to the lake. According to a study by Cui et al. (2000a), in northern Taihu Lake area, the fertilizer applied to paddy-field, considering both the crop production and the ecological benefit, should be 221.5 kg nitrogen per ha. In a research project conducted by Zhejiang Agricultural Science Institute, 150 kg per ha was suggested as a proper amount of nitrogen fertilization (Lu, 1998b). The current level of nitrogen fertilization is far beyond the proper level and reduction of nitrogen fertilizer would be beneficial.

Thirdly, as a result of continuous attention on point source pollution control in recent years, regulations on point pollution control have been issued and measures have been implemented successfully in the Taihu Lake area. During the period between 1996 and 2001, 1035 major pollution facilities were identified and pollution abatement measures were implemented. By the end of 2001, the following achievements on point pollution control had been made: 70% of the industrial wastewater discharged met the standard; 25 wastewater treatment plants for treatment of sanitary wastewater had been constructed and commenced operation; and Detergents containing phosphorous had been replaced by non-phosphorous detergents in the cities surrounding Taihu Lake. However, agricultural non-point source pollution is still out of control.

3. Method and model

The watershed optimization model with the objective of minimizing total abatement costs and constraint of emission target has been provided in our previous work (Zhang and Wang, 2002). The expression is:

$$\text{Min} \quad C = c_p(q_p) + c_n(q_n) \text{s.t.} \tag{1}$$

$$P\{[e_p(q_p) + e_n(q_n)] \le e^0\} \ge \alpha \tag{2}$$

Where,

C = total abatement cost

q_p = point sources abatement

q_n = non-point sources abatement

c_p = abatement cost of point source, defined in term of q_p

c_n = abatement cost of non-point source, defined in term of q_n

e_p = point source emission, assumed as linear function of q_p

e_n = non-point source emission, $e_n = e_{n0} - \gamma q_n$, where e_{n0} is the initial emission of the non-point source (given as average, long-term value); γ is the random variable representing the stochastic events that influence non-point source emission; q_n is non-point abatement.

e^0 = watershed emission constraint of nitrogen

$P\{[e_p(q_p) + e_n(q_n)] \le e^0\}$ represents the probability by which $[e_p(q_p) + e_n(q_n)] \le e^0$ can be satisfied. a(0 < a < 1) is the minimum allowable probability of satisfying the emission constraint. That is, the acceptable risk of violating the constraint is 1 − a.

One convenient approach for solving this stochastic optimization model is to use chance constrained programming approach developed by Charnes and Cooper (1964). This method makes it possible to replace the probabilistic pollution constraint with its deterministic equivalent. It is convenient to analyze the impact of uncertainty, and how the variance of emissions affects the optimal solution using the deterministic equivalent (detailed description on the chance constrained programming approach and comparison with other approaches can be referred to Bystrom et al., 2000). According to the chance constrained programming method, the deterministic equivalent of Eq. (2) is:

$$e_p + E(e_n) + k_\alpha[\text{var}(e_n)]^{1/2} \le e^0 \tag{3}$$

Where k_α is the standard normal variable such that $\Phi(k_\alpha) = \alpha$ (Φ is the sign of standard normal distribution). For any given α, the value of k_α can be obtained from the standard normal cumulative distribution. In Eq. (3), the first two terms on the left-hand side represent the expected emissions from point and non-point sources, and they are considered to be deterministic. The third term

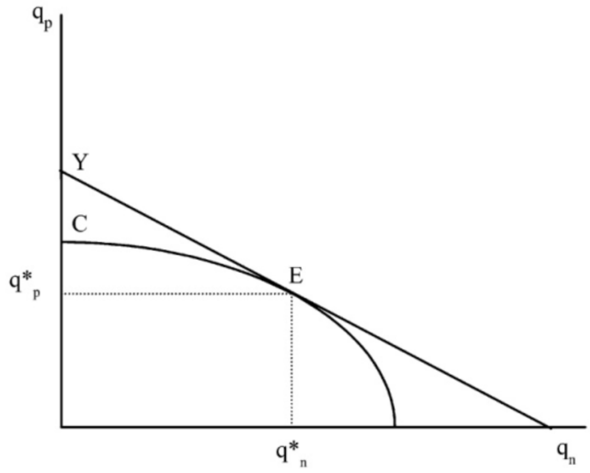

Fig. 2. Trading equilibrium and optimal abatement allocation.

represents the variance of non-point source emission, and k_α is the weight attached to the variance in order for the abatement target to be reached with a probability α. Overall, the left-hand side of Eq. (3) represents the aggregate emissions from point and non-point sources. By using the chance constrained programming approach, the probabilistic constraint is simplified to its deterministic equivalent and the probabilistic optimization model can be written as:

$$\text{Min} \quad C = c_p(q_p) + c_n(q_n)\text{s.t.}$$

$$e_p + E(e_n) + k_\alpha\left[\text{var}(e_n)\right]^{1/2} \le e^0.$$

The optimal solution to the above watershed trading model, and also the trading equilibrium and optimal abatement allocation is illustrated in Fig. 2. In Fig. 2, the horizontal and vertical axes measure, respectively, the levels of abatement of point and non-point sources (q_p and q_n). The Y curve represents aggregate emissions from point and non-point sources as depicted in Eq. (3) (assuming $f\ (q_n)$ is linear in q_n). Total abatement cost is denoted by the C curve, which describes all combinations of point and non-point source abatement that yield a constant total cost (it can be proved that the C curve is decreasing and concave in the coordinate of $q_p - q_n$ by taking the first and second derivative of q_p with respect to q_n). The slope of the C curves is equal to the relative marginal abatement cost between point and non-point sources, holding the total cost constant. The trading equilibrium and the optimal abatement allocation are given by the tangent point between the C curve and Y curve, as is denoted by point E in Fig. 2.

The trading ratio is defined as the units of pollutant reduced, per unit credited to a discharger (Jarvie and Solomon, 1998). For example, the ratio 1:1 allows a point source to purchase one unit of a non-point source's reduction to avoid reducing its own loadings by one unit. A ratio larger than 1:1 can provide a much larger environmental improvement and safety margin. In this paper, the trading ratio is the number of units of non-point source reduction that can substitute for a unit reduction from the point source satisfying the probabilistic constraint, denoted as t, where:

$$t = \frac{\mathrm{d}y/\mathrm{d}q_p}{\mathrm{d}y/\mathrm{d}q_n} = \frac{e'_p}{\left(-E(\gamma) + k_\alpha\left[\text{var}(\gamma)\right]^{1/2}\right)f'(q_n)} \tag{4}$$

The value of $E(\gamma)$ and $\text{var}(\gamma)$ can be obtained from long term statistics of non-point emission, or from mathematical models simulating surface runoff and soil erosion progress (Milon, 1987). In Eq. (4), k_α serves as the weight attached to the variance of non-point emissions. Since the abatement effort of non-point source increases its variance, a higher reliability requirement would result in a larger trading ratio.

4. Data

In this paper, Dongtiao River watershed, a typical watershed in the Taihu Lake area was selected for the simulation of point-non-point trading. Experiences and data from the existing non-tradable permit system, along with further analysis carried out for this study were used to estimate the cost and benefit of point-non-point trading system in Taihu Lake area.

Dongtiao River watershed is located in the southwest of Taihu Lake area (see Fig. 3). This river is mainly designated for industrial and agri-

Fig. 3. Location of Dongtiao River watershed.

cultural water utilization. The watershed is an intensive paddy cultivation area and one of the major sources of nitrogen and phosphorus in Taihu Lake. In this paper, nitrogen fertilizer reduction is proposed as a method of agricultural non-point source abatement. Features of agricultural non-point sources in Dongtiao River watershed are summarized in Table 1.

In our study, the targeted pollutant to be reduced is nitrogen, and the point sources are mainly municipal wastewater treatment plants and facilities discharging wastewater with a high concentration of nitrogen. According to the *List of Key Pollution Industries in Taihu Lake Area*, there are 40 industrial polluters located in this watershed. The annual average nitrogen discharge from point sources is estimated to be 5767 metric tons. Non-point sources are mainly from agricultural land, which has a total area of 166 829.78 ha, including 147 940.65 ha of paddyfield. Annual average nitrogen discharge from agricultural non-point sources is 4095 metric tons (Jin et al., 1999).

Due to the unavailability of first hand pollution control information, most of the pollution reduction options and associated costs were derived from secondary data. Major information sources were existing research reports, environmental impact statements, feasibility study reports, and government guidelines for best practical environmental protection technologies. The information provided a reasonable approximation of cost reduction for the individual dischargers involved in the study. Cost estimation of point sources abatement was based on the operational cost of nitrogen treatment equipment (refer to Cao and Wang, 1997). Non-point sources abatement cost was estimated based on the market price for paddies, paddy production per kilogram of nitrogen fertilizer utilization, and market price of nitrogen fertilizer (refer to Cui, 2000b). Data used to simulate the trading in Dongtiao River watershed are summarized in Table 2.

5. Simulation and sensitivity analysis

Applying the above mentioned trading model, targeted with the minimum of total abatement cost and constraint by the abatement objective of nitrogen, simulation of pollution abatement trading between point and agricultural non-point sources was conducted, and the results are summarized in Tables 3–5.

To show how reliability constraints influence the array of optimal solution, the model addresses eight different levels of reliability such that the variance receives different weight in the pollution constraint.

The optimal allocation between abatement in agricultural non-point sources and point sources

Table 1
Characteristics of agricultural non-point sources in Dongtiao River watershed

Total agricultural land	166 829.78 ha
Nitrogen fertilizer applied (1995)	302 527 t
Average nitrogen loss	0.101 kg/kg nitrogen fertilizer
Variance coefficient	0.014
Market price of crop	2.0 RMB/kg
Market price of chemical nitrogen fertilizer	5.43 RMB/kg
Average production of nitrogen fertilizer	8.5 kg/kg nitrogen fertilizer

Sources: Zhang et al., 2001; Jin et al., 1999; Cui et al., 2000a

Table 2
Pollution abatement and cost data of Dongtiao River watershed

	Point sources	Agricultural non-point sources
Nitrogen abatement target	8313 t/year	
Current nitrogen emission	5767 t/year	4095 t/year
Key pollution sources	Dying plants, textile mills, chemical industries, fertilizer production, food plants, municipal waster water	Paddyfield
Control strategies	Wastewater treatment through biologic, membrane, and denitrifying process, etc.	Land use controls, land management and chemical fertilizer reduction, etc.
Abatement cost (10 thousand RMB)	$C_p = 0.14q_p^{1.5}$	$C_n = 1.16q_n$
Marginal abatement cost (10 thousand RMB)	$C_p' = 0.21q_p^{0.5}$	$C_n' = 1.16$

Sources: Cui, 2000b; Lou, 1999; Yang and Wang, 1998; Xu, 1996; Cao and Wang, 1997

varies with the level of reliability specified. Table 3 shows that the level of required certainty has a substantial impact on the results. As α increases, the monitoring of the uncertainty of discharges becomes increasingly important. An increase in the reliability requirement would raise the optimal trading ratio (see Fig. 4), and the abatement effort would shift toward the point source. Table 3 also shows that imposing reliability requirements is costly. Raising the reliability level from 60 to 90% decreases the cost saving more than seven times. At the highest level of reliability (95%), the trading is no longer cost-effective.

The impact of reliability constraints on abatement costs can be visualized in Fig. 5. In Fig. 5, the reliability constraints influence the cost of point sources reduction significantly. Point source costs for 80 and 90% reliability constraints are 1.2 times and 1.5 times of the costs for 60%, respectively.

Sensitivity analysis for the impact of abatement cost on the trading result is presented in Tables 4 and 5. In Table 4, the impact of non-point source abatement cost is illustrated by a 10% cost fluctuation under certain reliability constraints. The impact of point source abatement cost is summarized in Table 5. It can be learned from the sensitivity analysis that the cost fluctuation has significant influence over the abatement allocation between point and non-point sources. Increase of non-point abatement cost will reduce the abatement percentage of non-point sources at the trading equilibrium; while increase of point abatement cost will cause an increase of non-point source abatement percentage, and vice versa. In terms of cost

Table 3
Simulation results and cost savings under different levels of reliability

Reliability level$^{\alpha}$	Trading ratio	Abatement of point sources (t)	Abatement of nitrogen fertilizers (t)	Percent of point abatement (%)	Abatement cost of point sources (10^4 RMB)	Abatement cost of non-point sources (10^4RMB)	Cost saving (10^4RMB)
0.6	11.2	3684.98	51 833.87	44	31 316.99	60 127.29	2946.45
0.65	11.4	3817.76	51 245.77	46	33 024.82	59 445.09	2511.49
0.7	11.6	3952.89	50 577.29	48	34 793.64	58 669.66	2108.77
0.75	11.8	4090.37	49 827.03	49	36 624.52	57 799.36	1738.87
0.8	12.0	4230.20	48 993.58	51	38 518.52	56 832.55	1402.34
0.85	12.4	4516.92	47 071.45	54	42 500.20	54 602.88	831.68
0.9	12.8	4813.03	44 799.62	58	46 747.22	51 967.56	401.32
0.95	13.6	5433.46	39 161.76	65	56 071.56	45 427.64	−20.40

Table 4
Impact of cost fluctuation -non-point abatement cost changes by 10%

Reliability level[α]	Trading ratio	10% changes of non-point abatement cost	Abatement of point sources (t)	Abatement of nitrogen fertilizers (t)	Percent of point abatement (%)	Abatement cost of point sources (10^4 RMB)	Abatement cost of non-point sources (10^4RMB)	Cost saving (10^4RMB)
0.6	11.2	0.9	3103.44	58 376.97	37	24 204.32	60 945.55	5948.30
		1	3684.98	51 833.87	44	31 316.99	60 127.29	2946.45
		1.1	4636.00	41 203.47	56	44 191.98	52 575.63	949.48
0.65	11.4	0.9	3192.97	58 195.41	38	25 259.21	60 756.01	5509.52
		1	3817.76	51 245.77	46	33 024.82	59 445.09	2511.49
		1.1	4769.74	40 273.45	57	46 117.98	51 388.93	731.54
0.7	11.6	0.9	3307.75	57 904.31	40	26 633.45	60 452.10	4977.44
		1	3952.89	50 577.29	48	34 793.64	58 669.66	2108.77
		1.1	4941.21	39 007.30	59	48 627.05	49 773.31	495.95
0.75	11.8	0.9	3428.84	57 528.40	41	28 109.21	60 059.65	4451.90
		1	4090.37	49 827.03	49	36 624.52	57 799.36	1738.87
		1.1	5122.09	37 584.31	62	51 321.47	47 957.58	298.97
0.8	12.0	0.9	3580.71	56 960.61	43	29 997.30	59 466.88	3842.42
		1	4230.20	48 993.58	51	38 518.52	56 832.55	1402.34
		1.1	5348.97	35 676.87	64	54 768.74	45 523.69	123.86
0.85	12.4	0.9	3781.90	56 050.25	45	32 560.63	58 516.46	3116.03
		1	4516.92	47 071.45	54	42 500.20	54 602.88	831.68
		1.1	5649.50	32 947.78	68	59 448.82	42 041.36	9.61
0.9	12.8	0.9	4072.75	54 432.00	49	36 388.09	56 827.00	2218.94
		1	4813.03	44 799.62	58	46 747.22	51 967.56	401.32
		1.1	6083.98	28 613.85	73	66 436.97	36 511.28	68.23

saving from the trading scheme, increase of non-point abatement cost will reduce the cost saving and make the trading less feasible and profitable, while increase of point abatement cost will make the trading more feasible and profitable, and hence the cost saving will be added.

6. Suggestions on further implementation

In China, non-point source pollution was not given adequate attention during the past decades. Therefore, challenges exist for the design and implementation of the point-non-point abatement trading scheme, including a baseline database, initial allocation, social impact, institutional framework, enforcement and management. Based on the investigation in the Taihu Lake area and model simulation, suggestions on further implementation of point-non-point effluent trading in China are presented below.

1. The lack of appropriate water quality standards and regulations is the key obstacle to water pollution control in China, and establishment of watershed quality objectives and regulations are essential to ensure successful implementation of the trading. There should be sufficient water quality monitoring in place to support loading estimates from point and non-point sources. Adequate data will provide confidence in understanding relationships between pollution control measures and water quality improvements, and ensure water quality standards are being met.
2. To identify, design and implement trading projects, two sets of data are necessary: (1) effectiveness of control measures; and (2) background information of watershed and economy. Data limitations exist extensively for point and non-point source trading. In China, the effluent load data for most point sources are available from regular monitoring, but the load data for non-point sources are rarely available. Typically, non-point sources loads are available only for whole tributaries in the form of annual

Table 5
Impact of cost fluctuation -point abatement cost changes by 10%

Reliability level$^{\alpha}$	Trading ratio	10% changes of point abatement cost	Abatement of point sources (t)	Abatement of nitrogen fertilizers (t)	Percent of point abatement (%)	Abatement cost of point sources (10^4 RMB)	Abatement cost of non-point sources (10^4RMB)	Cost saving (10^4RMB)
0.6	11.2	0.9	4730.13	40 148.68	57	40 990.24	46 572.47	713.62
		1	3684.98	51 833.87	44	31 316.99	60 127.29	2946.45
		1.1	3166.45	57 670.87	38	27 439.74	66 898.20	6200.99
0.65	11.4	0.9	4866.59	39 172.69	59	42 776.70	45 440.32	533.27
		1	3817.76	51 245.77	46	33 024.82	59 445.09	2511.49
		1.1	3257.80	57 458.54	39	28 635.64	66 651.91	5725.35
0.7	11.6	0.9	5041.54	37 846.65	61	45 103.98	43 902.11	342.25
		1	3952.89	50 577.29	48	34 793.64	58 669.66	2108.77
		1.1	3374.91	57 127.34	41	30 193.57	66 267.72	5149.66
0.75	11.8	0.9	5226.09	36 359.35	63	47 603.19	42 176.84	188.06
		1	4090.37	49 827.03	49	36 624.52	57 799.36	1738.87
		1.1	3498.46	56 708.39	42	31 866.60	65 781.73	4582.37
0.8	12.0	0.9	5457.57	34 369.63	66	50 800.69	39 868.77	60.67
		1	4230.20	48 993.58	51	38 518.52	56 832.55	1402.34
		1.1	3653.42	56 085.52	44	34 007.08	65 059.20	3926.47
0.85	12.4	0.9	5764.21	31 528.83	69	55 141.70	36 573.44	0.005
		1	4516.92	47 071.45	54	42 500.20	54 602.88	831.68
		1.1	3858.69	55 100.37	46	36 913.04	63 916.43	3148.28
0.9	12.8	0.9	6207.51	27 028.11	75	61 623.55	31 352.61	117.79
		1	4813.03	44 799.62	58	46 747.22	51 967.56	401.32
		1.1	4155.44	53 370.46	50	41 252.13	61 909.74	2194.69

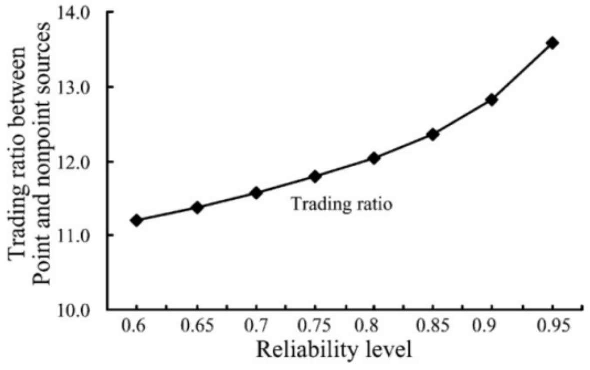

Fig. 4. Impact of reliability level on trading ratio.

average values. Reliable estimates of expected load reductions from non-point sources are important to evaluate trading effects on water quality improvements. These data can be obtained from research reports, environmental impact statements, or published literatures.

3. Normally point and non-point sources trading may shift the location of pollutant reductions from point source areas to non-point areas. It is important to understand the spatial distribution of potential trading participants and their characteristics within a trading area. Maps, with the aid of GIS technology, can be simple but powerful tools to help water quality managers visualize potential trading scenarios. Knowledge of local topography and soil conditions, as well as precipitation, is also important.
4. In China, the potential non-point sources are numerous but vary significantly. Spatial, temporal, and chemical differences between point and non-point sources emissions pose challenges to understand and predict effects of point-non-point trading. Accommodating these differences can help to attain environmental objectives. Several approaches are available to account for differences between point and non-point source emissions. As used in the simulation in this study, long-term average loads for both point and non-point sources allow the emission of each to be compared over time periods where variance is acceptable. Determining proper trading rate, which reflects known and unknown differences in effects, taking the uncertainty of non-point emission into consideration, and providing a safety margin, are essential in trading programs.
5. In China, the potential non-point source partners are numerous, but the abatement capacity from individual non-point sources may be low. Transaction costs associated with point-non-point sources trading emerge. To facilitate trading, the involvement of local governments and agencies in non-point source pollution management can help to reduce transaction costs by supplying both point and non-point sources with information on potential trading partners. Additionally, watershed planning, environmental investigation reports, and other information may help to identify unaddressed non-point source pollution problems, and can provide trading opportunities.

This paper serves as an initial discussion of point-non-point trading scheme in China. Various problems and obstacles need to be identified and solved, from the institutional level to implementation level, as well as monitoring and management level. At this point, a trial trading program would be feasible and helpful in a sub-catchment of the Taihu Lake area, such as the Dongtiao River Catchment. One facility that contributes significant nutrient loadings to surface water, however, has difficulty in meeting its mass loading target may be selected to trade with the surrounding agricultural property owners, which discharge nutrient

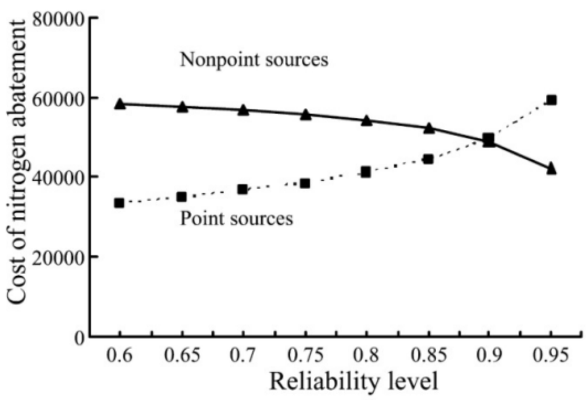

Fig. 5. Impact of reliability level on abatement cost.

loadings to the same water body. To reduce transaction cost, the agricultural property owners can be organized as one unit, i.e. village or town. The trading program can be monitored and managed by a management committee jointly attended by village/town leaders, facility leaders and third-party personnel. Before the trading program is implemented, nutrient discharge quota for agricultural property owners should be set.

7. Conclusions

From the above discussion, it can be concluded that the trading scheme between point and non-point sources is feasible in the Taihu Lake area. The model simulation illustrated that the optimal allocation between abatement in agricultural non-point sources and point sources varies with the level of reliability specified. An increase in the reliability requirement would raise the optimal trading ratio, and the abatement effort would shift towards the point source.

In addition, abatement cost fluctuation also has significant influence over the abatement allocation between point and non-point sources. For example, an increase of non-point abatement cost will reduce the cost saving and make the trading less feasible and profitable, while an increase of point abatement cost will make the trading more feasible and profitable, and add to the cost saving.

Considering the fact that current level of nitrogen fertilizer utilization is far beyond the appropriate level, the nitrogen abatement cost of agricultural non-point sources would be less than the theoretical data adopted in the model. The numerical simulation and cost-benefit analysis show that the point-non-point trading in the Taihu Lake area can be a cost-effective method to achieve the abatement goal.

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References

Bystrom O, Andersson H, Gren I. Economic criteria for using wetlands as nitrogen sinks under uncertainty. Ecol Econ 2000;35:35–45.

Cao D, Wang J. Economics of Chinese industrial pollution. Beijing: China Environment Science Press, 1997. (in Chinese).

Charnes A, Cooper WW. Deterministic equations for optimizing and satisficing under chance constraints. Oper Res 1964;11:18–39.

Crutchfield SR, Letson D, Malik AS. Feasibility of point-non-point source trading for managing agricultural pollutant loadings to coastal waters. Water Resour Res 1994;30(10):2825–2836.

Cui YT, Cheng X, Han CR. The economic and ecological satisfactory amountof nitrogen fertilizer using on rice in Tai Lake Watershed. Acta Ecologica Sinica 2000a;20(4):659–662 (in Chinese, with English abstract).

Cui YT. Fertilizer and Eco-environmental Protection. Beijing: Chemical Industry Press, 2000b. (in Chinese).

Guo HY, Wang XR, Zhu JG. Quantity study of nitrogen pollution from non-point sources in Taihu Lake Catchemnt. J Agro-Environ Sci 2003;2(22):150–153 (in Chinese, with English abstract).

Jarvie M, Solomon BD. Point-non-point effluent trading in watersheds: a review and critique. Environ. Impact Asses Rev 1998;18:135–157.

Jin XC, Ye C, Yan CZ. Comprehensive treatment plan for key polluted regions of Lake Taihu. Environ Res 1999;12(5):1–5 (in Chinese, with English abstract).

Keeler AG. Non-compliant firms in transferable discharge permit markets: some extensions. J Environ Econ Manage 1991;21(2):180–189.

Li RG, Xia YL, Wu AZ. Pollutants sources and their discharging amount in Taihu Lake area of Jiangsu province. J Lake Sci 2000;12(2):147–153 (in Chinese, with English abstract).

Lou JS. New technology and design for water pollution treatment. Beijing: Ocean Press, 1999. (in Chinese).

Lu Y. Agricultural non-point source pollution and agriculture sustainable development in Taihu Lake area, Jiangsu. Environ Prot 1998b;2:1–4 (in Chinese).

Lu Y. Non-point pollution of nitrogen in agricultural ecosystem. Agro-environ Prot 1998a;17(1):35–39 (in Chinese).

Ma LS, Wang ZQ, Zhang SM. Pollution from agricultural non-point sources and its control in river system of Taihu Lake, Jiangsu. Acta Scientiae Circumstantiae 1997;17(1):39–47 (in Chinese, with English abstract).

Malik AS, Larson BA, Ribaudo M. Economic incentives for agricultural non-point source pollution control. Water Res Bull 1994;30:471–480.

Malik AS. Further results on permit markets with market power and cheating. J Environ Econ Manage 2002;44(3):371–390.

Malik AS. Markets for pollution control when firms are non-compliant. J Environ Econ Manage 1990;18(2):97–106.

Milon JW. Optimizing non-point source controls in water quality regulation. Water Res Bull 1987;23:387–395.

SanMartin R. Marketable emission permits with imperfect monitoring. Energy Policy 2003;31(13):1369–1378.

State Environment Protection Administration of China. Report on the state of the environment of China. Beijing: China Environment Science Press, 2000 (in Chinese).

Stephenson K, Norris P, Shabman L. Watershed-based effluent trading: the non-point source challenge. Contemporary Econ Policy 1998;16:412–421.

Stranlund JK, Dhanda KK. Endogenous monitoring and enforcement of a transferable emissions permit system. J Environ Econ Manage 1999;38(3):267–282.

Xia LZ, Yang LZ. Research on non-point source pollution control in Taihu Lake region. Environ Sci 2003;1:45–50 (in Chinese, with English abstract).

Xu YT. Nitrogen and phosphors treatment in wastewater. Shanghai: Press of Hudong Normal University, 1996. (in Chinese).

Yan WJ, Yin CQ, Zhang S. Nutrient budgets and biogeochemistry in an experimental agricultural watershed in Southeastern China. Biogeochemistry 1999;45:1–19.

Yang JT, Wang JN. Changes and design of pollution charge system in China. Beijing: China Environment Science Press, 1998. (in Chinese).

Zhang W, Wang XJ. Modeling for point-non-point source effluent trading: perspective of non-point sources regulation in China. Sci Total Environ 2002;292:167–176.

Zhang W, Wang XJ. Theoretical study of point-non-point source pollution abatement trading. Acta Scientiae Circumstantiae 2001;21:748–753 (in Chinese, with English abstract).

Zhang ZJ, Dong L, Zhu YM. The dynamic characteristics and modeling of nitrogen in paddy field surface water and nitrogen loss from field drainage. Acta Scientiae Circumstantiae 2001;21(4):475–480 (in Chinese, with English abstract).

Reading 4.3

Mackay, A., Clothier, B., Parfitt, R., 2008. Defining Nitrogen-Loss Limits within a water management zone using a natural capital valuation of the soil. *FLRC Workshop Proceedings, Massey University, Occasional Report 21*: 525-530.

DEFINING NITROGEN-LOSS LIMITS WITHIN A WATER MANAGEMENT ZONE USING A NATURAL CAPITAL VALUATION OF THE SOIL

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Abstract

Current nitrogen (N) loadings in the Upper Manawatu River and Mangatainoka are more than twice the water quality standard set for each Water Management Zone (WMZ) by Horizons Regional Council after consultation with the communities. Horizons have good data sets on the contribution of point-source N loadings to these two rivers. Generally these are now minimal. However, in a recent study of "Farm strategies for contaminant mitigation" for Horizons by SLURI, a direct link between land use and management decisions was established between N losses from farms and loadings in the Upper Manawatu river. SLURI found significant reduction in the N loading could be achieved by a focus on intensive land uses.

By limiting policy to existing intensive land uses, improvements to water quality would only accrue if there was no further expansion of intensive land uses in the balance of the catchment. Any policy approach would therefore need to consider all lands in the catchment from the outset, and range from capping nutrient losses from current production systems, calculating an average nutrient loss limit for each hectare of land in the catchment, or allocating a nutrient loss limit based on the biophysical potential provided by the natural capital value of the soil.

Of these various approaches, allocating a nutrient-loss limit based on the natural capital of the soil in the catchment offered the best basis for developing policy that is linked directly to the underlying natural biophysical resources in the catchment. It is independent of current land use and places no restrictions on future land-use options. It also provides all land users in the catchment with certainty by defining a nutrient-loss limit based on the suite of soils they own.

We consider that this natural capital based approach for managing nutrient is a new methodology that should be at the forefront of sustainable development.

Introduction

Current nitrogen (N) loadings in the Upper Manawatu River and Mangatainoka are more than twice (744,000 and 518,000 kgN/yr, respectively) the N limits (341,000 and 238, 000 kgN/yr, respectively) set based on recommended standards for the notified standards in the One Plan. Horizons Regional Council has good data sets on the contribution of the major point source N loadings to the river. Remedial actions have been successful. In a recent study conducted by the

Sustainable Land Use Research Initiative (SLURI) team, the contribution of non-point source N loading from dairy and sheep and beef in the Upper Manawatu catchment were established. In that study the N loss in the river from the average dairy farm was found to amount to 15.4 kg/ha/yr and for sheep and beef the N loss was 3.9 kg/ha/yr (Clothier et al., 2006). Over 90% of the total N in the river is from these two non-point sources, with dairy contributing about half of the N loading in the river, despite only representing 16% of the land use in the catchment.

The N loss from the average dairy farm calculated using OVERSEER® in the Upper Manawatu catchment was found to be 31 kgN/ha/yr, and for the average sheep and beef farm 7 kgN/ha/yr. By establishing a N transmission co-efficient of 0.50 for both dairying and sheep and beef operations, a direct link could be made between land use and management decisions as it influences N losses and loadings in the river.

In the short-term, significant reductions in the N loading in the river could be achieved by a focus on intensive dairy operations, as existing mitigations options offer the potential to reduce N losses. While this approach offers a short-term policy option, it is based on the assumption that there will be no further conversion of sheep and beef to more intensive land uses (e.g. cropping, market gardening, dairy), or any further intensification of sheep and beef sector, all of which have the potential to increase the N loading in the river. Any policy approach will therefore need to consider all land owners in the catchment from the outset for a long-term water management action plan to achieve the goals of the community.

Options for achieving the water quality standard

There are a number of approaches that could use to achieve the water quality standard, including;

1. **Capping** current production systems and nutrient (e.g. nitrogen) losses. Then there would be a managing down regardless of N losses from individual farms, as is the case currently under consideration for the Taupo catchment.
2. **Place a limit on the losses of nutrient (e.g. N) from intensive land uses**. This would place restrictions of any further intensification and requires mitigation practices as an integral part of any ongoing land development.
3. **Calculate a nutrient (e.g. N) leaching loss limit for each ha**. This could result in the use of OVERSEER® to achieve the water quality standard and apply them equally to each land owner. For the Upper Manawatu WMZ this would be 6.5 kgN/ha (Calculation =341,000 kgN/yr divided by 130,000 ha Transmission co-efficient =0.50). At current loading the average loss per ha is 15 kgN/ha.
4. Allocate a nutrient (e.g. N) **loss limit based on the** biophysical potential of natural capital of the soils.

Option 1 favours, on one hand, the existing intensive land users, and penalises land owners as yet not fully developed. It locks in the current land use pattern, and has the potential to limit future land use change. Option 2, like 1, has a focus on limiting/controlling N loss by regulating land use, and it would require a tight definition of intensification and a detailed description of each land use. Option 3 fails to recognise that soils differ in their properties and functioning. Some soils will have very low N leaching losses because of physical limits to production and climatic constraints.

Option 4 does not target a land use, intensity of use, or place a limit on production. Rather it allocates a nutrient (e.g. N) loss limit to each landscape unit based on the biophysical potential of natural capital of the soils.

Natural capital based approach to allocation of a nutrient loss limit.

Allocating a nutrient loss limit based on the natural capital of the soil in the catchment offers an approach for developing policy that is linked directly to the underlying natural biophysical resources in the catchment. This is not too dissimilar to the concept of a water-use take limit. It is independent of current land use and places no restrictions on future land use change or options. It does provide all land uses in the catchment with certainty by defining a nutrient loss limit, beyond which mitigation will have to be part of any further development.

The nutrient (e.g. N) loss limit is defined as the amount of N lost by leaching from the soil growing a legume-based pasture fixing N biologically, which is under optimum management (optimum grazing practice, Olsen P in optimum range, etc), before the introduction of additional technologies (N fertilisers, effluent and manures, intensive cropping, drainage, irrigation, etc). A legume based pasture system is self-regulating biological process with an upper limit on the amount of N that came be fixed and made available for plant growth and the environment. Potential production therefore reflects the underlying biophysical capacity of the soil to produce with resilience.

To calculate the N loss limit for a given landscape unit, the potential animal stocking rate that can be sustained by this legume-based pasture fixing N biological, under optimum management, before the introduction of additional technologies, is listed in the extended legend of the LUC worksheets "Attainable potential livestock carrying capacity". These can be transformed to pasture production and used in OVERSEER® to calculate N leaching loss under a pastoral use.

By linking N loss limits to each landscape unit, the difficulties associated with having to define land use is avoided. This approach recognises soils differ in their productive capacity. Technologies used to lift production beyond that of a legume based pasture (N fertiliser, irrigation, supplements, etc.) would require the use of mitigation practices to prevent any further increases in N leaching losses. Another potential advantage of Option 4 is that in catchments with no water quality problems at the present time, land owners can be provided with an indication of the level of production and associated nutrient losses they can reach, before mitigation practices would have to become an integral part of ongoing farm development.

Case study: Upper Manawatu Water Management Zone

The landscape in the Upper Manawatu Water Management Zone is dominated by Class VI, with sheep and beef the dominant land use, in particular in the catchment above Weber Road, which is approximately in the centre of the water management zone (Fg.1).

In this case study the natural capital of the soils in the catchment, is calculated from the potential stocking rate that could be sustained by a well managed legume based pasture. This information on each soil in the catchment is available from the extended legend of the LUC worksheets "Attainable potential livestock carrying capacity". In this study the information is taken from the LUC worksheets for the North Island.

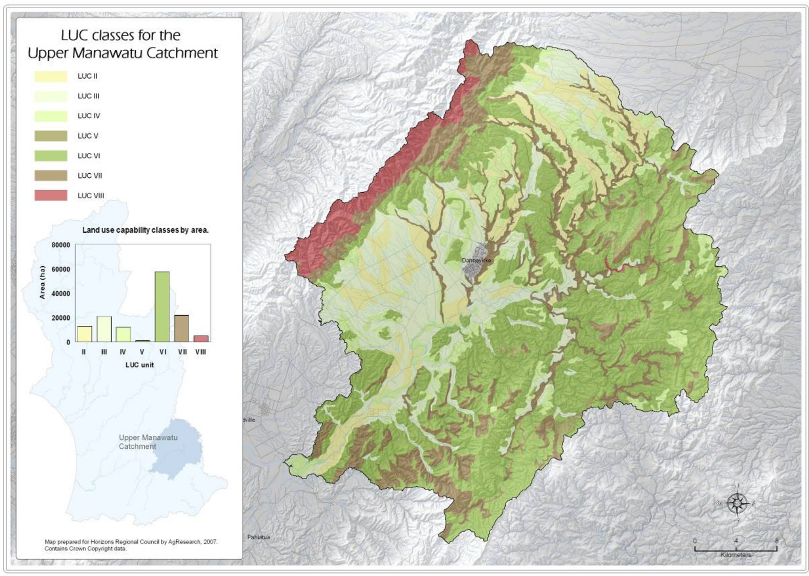

Fig.1 LUC classes for the Upper Manawatu Water Management Zone.

The potential livestock carrying capacities were transformed to pasture production and used in OVERSEER® to calculate N leaching losses under pastoral use. The N losses by leaching calculated from OVERSEER® summarised for the soils in each of the LUC class I-VII for the North Island and used in the Upper Manawatu Water Management Zone are presented in Fig. 2. As the limitations to use of the soil increase (i.e. Class I to VII) the underlying capacity of soil to sustain a legume-based pasture system declines, as does the potential N loss by leaching.

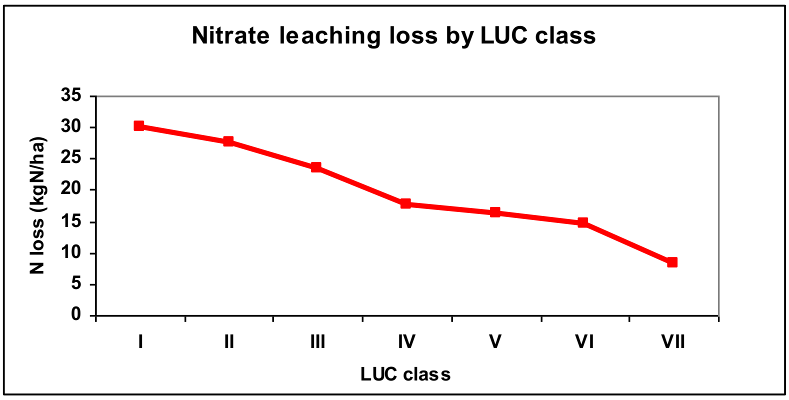

Fig.2 Average Nitrate leaching loss calculated using OVERSEER® (Developed dairy operation, Annual rainfall 1200 mm) associated with the potential livestock carrying capacity for each soil in LUC class I-VII listed in the extended legend of the LUC worksheets for the North Island.

The calculation in Table 1 was limited to the use of the potential for the "average" soil in each LUC class. The approach offers the potential to utilise site-specific information, including soil type, drainage class, landscape type (e.g slope) and geo-spatial position, along with rainfall to inform OVERSEER®. This would increase the accuracy of the calculated values.

LUC class	Area (ha)	N Loss based on potential production (kgN/ha/yr)	Fraction of potential	Nitrate Loss limit kgN/ha/yr	Transmission Co-efficient	Total N loading in river (kgN/yr)
II	12424	27.4	0.9	24.7	0.5	153348
III	20257	23.5	0.9	21.1	0.5	213978
IV	11508	17.5	0.9	15.8	0.5	90729
V	907	16.3	0.9	14.7	0.5	6666
VI	57254	14.5	0.9	13.1	0.5	373897
VII	22108	8.3	0.9	7.5	0.5	82431
VIII	5180	0.0	0.9	0.0	0.5	0
Total	129638					921049

Table 1 Area of soils in each LUC class, calculated N loss associated with the potential productivity of the soils in each LUC class using OVERSEER® and the contribution of the soils in each LUC to the N loading in Upper Manawatu river and average N loss per ha per yr if the soils in each LUC Class are farmed at 90% of potential.

If all the soils in the Upper Manawatu water management zone were farmed at 90% of potential as listed in the extended legend, and assuming a transmission coefficient of 0.5 for all land classes, the N loading in the river would be 921 tonnes annually. This is higher than current loadings in the river.

When the fraction of potential production for all soils is limited to 75% on all LUC classes, the N at the farm scale and the resulting N load in the river are reduced to 768 tonnes N, very close to the present loading. The major strength of this approach is that in calculating the limit it considers the whole water management zone. With the long-term goal to reduce the current N loading in the river, an adjustment can be made to the fraction of potential production that is permissible, before a mitigation strategy must be initiated. The approach also offers the opportunity to engage directly and in a very transparent way with land owners and the wider community in setting the targets, without being prescriptive.

Calculating the N loss limit on-farm

At the farm scale, the N loss limit could be calculated using the information in the NZLRI, or from information obtaining from on-farm mapping. Recognising the NZLRI was designed to provide an indication of the distribution of soils at the district, rather than the paddock scale, it could be used as a first approximation, with the land owner having the opportunity to obtain a more detailed soil map and calculating N loss limits from the paddock scale information, along with local rainfall data if available.

Conclusions

The approach of allocating a **nutrient loss limit based on the natural capital of the soil in the catchment** offers a basis for developing policy that is linked directly to the underlying natural biophysical resources in the catchment, irrespective of current land-use or future options. We stress that this is independent of current land use and places no restrictions on future land use options. It provides all land users in the catchment with certainty by defining a nutrient loss limit based on their suite of soils. The approach offers the opportunity for innovation and to engage directly and in a very transparent way with land owners and the wider community in setting the targets

Finally we consider that this natural capital based approach to managing nutrient is a new methodology that should be at the forefront of sustainable developments. We believe that the resilience of our future land-use production systems will be measured on their sustainable exploitation of natural capital, whilst minimising external costs to the environment. This approach achieve wins both way: productivity and protection.

References

Clothier, B., Mackay, A., Carran, A., Gray, R., Parfitt, R., Francis, G., Manning, M., Deurer, M., Green, S. 2007. Farm Strategies for Contaminant Management. A report by SLURI for Horizons Regional Council, March 2007. pp 58