Climate change mitigation measures: Water quality benefits and costs

There is increasing evidence that the climate is changing, creating a growing need to respond locally by reducing greenhouse gas emissions to meet climate change objectives. Half of New Zealand's greenhouse gas emissions are attributable to agriculture. As farming continues to intensify, particular pressure is placed upon the agricultural sector to implement mitigation pathways. Some mitigation strategies offer additional environmental benefits such as enhancing water quality. Identifying these co-benefits is important in establishing an environment where appropriate measures are likely to be adopted and implemented.

Agricultural sources of greenhouse gas in New Zealand

The release of methane gas (CH_4) by ruminant livestock (sheep and cattle) accounts for two-thirds of greenhouse gas emitted by agriculture in New Zealand. The remaining third of the sector's emissions are from nitrous oxide gas (NO_2) which is mainly derived from livestock urine, manure and artificial fertiliser use.

Potential strategies to reduce greenhouse gas emissions

Although there are currently few options for mitigating livestock emissions, soil processes account for around 30% of agricultural emissions and offer mitigation potential. Achieving cuts in these emissions have associated water quality benefits. Some of the management strategies include:

Carbon sequestration: This is the process whereby carbon present in the atmosphere as carbon dioxide is 'locked-up' or transformed to other materials through the process of photosynthesis. Examples of sequestration include converting pasture into forest or extensive afforestation along the riparian zone.

Managing application of nitrogen to soils: NO_2 emissions can be reduced by nutrient budgeting and careful attention to fertiliser application.

Managing pasture soil conditions: Emissions can be reduced by avoiding low oxygen soil conditions that favour production of NO_2 by soil micro-organisms.

Alternative waste treatment techniques: Can be utilised to minimise uncontrolled release of methane. Waste management can include advanced treatment and capture techniques, followed by use of the recovered methane.

Climate change mitigation measures and water quality co-benefits

The interface between productive land and freshwater is one of the most fragile parts of the New Zealand landscape, with changes in land use closely linked to changes in stream quality. Implementing strategies such as afforestation, riparian planting, fertiliser control and alternative waste management provides opportunity to combat the effects of climate change and can jointly benefit water quality.

Extensive afforestation

Afforestation is the conversion of pasture lands back to forest. As well as allowing for carbon sequestration, there is considerable evidence from monitoring studies in New Zealand that forests improve water quality (Table 1).

Planting creates greater slope stability and reduces erosion of soils. This can directly improve stream quality and also decrease fertiliser requirements. The deeper roots in forests also increase nutrient uptake which can significantly lower the amount of Nitrogen and Phosphorus entering streams (Figure 1).

Afforestation can benefit aquatic food webs due to greater inputs of woody material and leaf litter to streams and rivers. Annual peak stream-flows are also substantially reduced due to interception and lower soil moisture under forest than pasture.

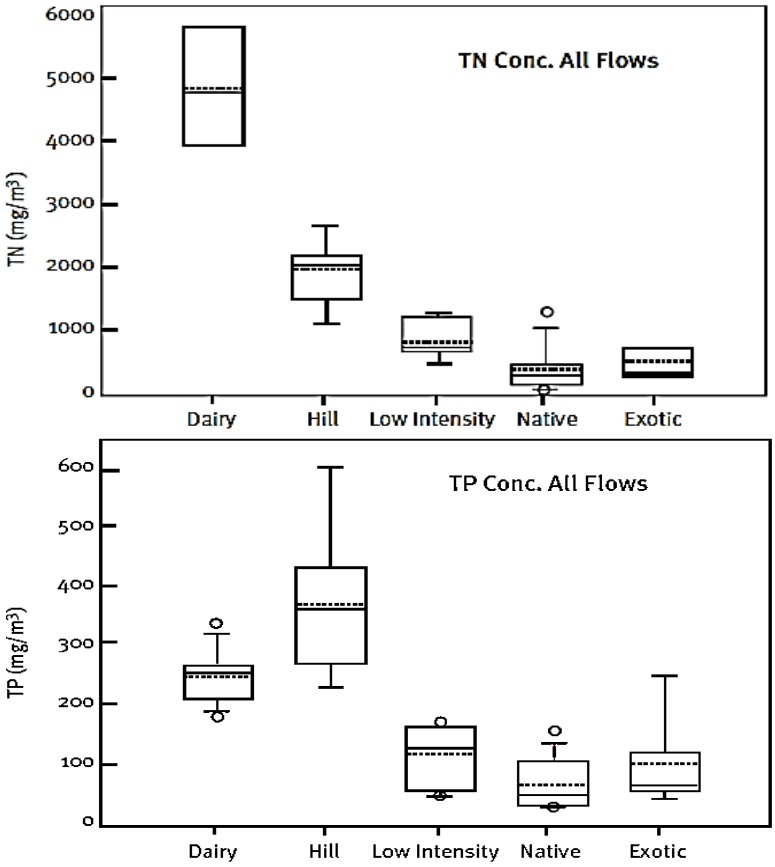


Figure 1: Summary of measured Nitrogen and Phosphorus concentrations in streams, from Elliott and Sorrell (2002).

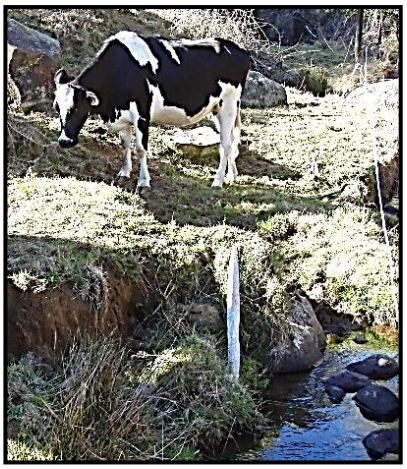
Table 1: Summary comparing water quality effects on receiving water, of pine in relation to pasture.

Water quality parameter	Typical reduction due to pine forestry (% of pasture value)	Degree of certainty	Comment
Nitrogen yield	10-50%	Moderate to high, uncertainty about residual effects of pasture soil fertility	Effect expected to be less/delayed if pine planted on pasture
Nitrogen concentration (stream)	15-50%	Moderate to high	Lower than for yield, as forest also reduces flow.
Phosphorus yield	10-50%	Moderate to high	Depends on erosion
Phosphorus concentration (stream)	20-100%	Moderate to high	Considerable variability
Sediment yield	10-100%	High	Considerable variability
Turbidity	Significant	Moderate	
***E. coli* concentration**	25-50%	Moderate	Depends on degree of pest control
Temperature	Significant	High	Variability based on stream size

Riparian forestry

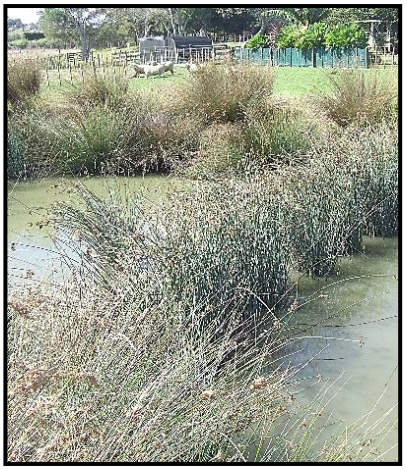
Riparian forestry involves planting or fencing along stream and river banks to create buffer zones. Farmers may be hesitant to put aside some of their most productive and valuable land for afforestation. However, riparian protection and planting can offer advantages for stock management and also provide water quality benefits such as:

- Significantly reduced nutrient and contaminant inputs to streams.
- Decreased impact of downstream flooding due to infiltration and interception of overland flow.
- Improved stream habitat due to lower water temperature extremes and fewer algal blooms as a result of shading.
- More stabilised stream banks, either directly or indirectly, from the exclusion of stock.



Improved Nitrogen fertiliser practices

Improved fertiliser practice can reduce inputs of nitrogen to waterways. Lowered nitrogen loading to land can be achieved through better management of fertiliser use, livestock waste products, overland flow paths, as well as timing fertiliser application to avoid oxygen-poor soil conditions. Other benefits include improved water quality through reductions in plant/algal growth in waterways and better public health outcomes where nitrate levels may otherwise approach potable water limits.



Alternative waste treatment

Anaerobic pond systems are commonly used for treating piggery and dairy shed wastewaters and can reduce farm runoff to streams. Such ponds produce significant methane emissions to the atmosphere. The requirement for greater storage to enable deferred application of effluent will increase methane emissions but this can be mitigated by capturing the gas and flaring the methane as carbon dioxide, which is a less potent greenhouse gas. NIWA research has shown it is practical to use the methane to generate electricity and heat, which can substantially reduce a farm's demand for external energy.

Climate change mitigation measures and water quality co-costs

Along with the range of water quality benefits that climate change mitigation measures offer some co-costs arise. Harvesting or clear-felling may reduce water quality in extensively afforested or riparian zones due to increased sediment load. Riparian forestry may also increase risks associated with localised flooding, including formation of debris dams at culverts as well as providing a habitat for pest species such as possums. Improvements in fertiliser practice may lead to more intensive grazing and therefore increased methane emissions. This may also increase faecal pollution of waterways.

Estimating water quality co-benefits and co-costs in physical terms

A number of modelling approaches are currently available to estimate the co-benefits and co-costs of climate change mitigation measures on farms. These models typically appraise the effects of environmental factors such as climate and soils on water quality and greenhouse gas emissions as well as enable the cumulative effects of mitigation measures to be studied at a variety of spatial scales. The OVERSEER Nutrient Budgets Model (http://www.overseer.org.nz/) is an example of an agricultural model widely used throughout New Zealand. It was developed by AgResearch and can assist in examining nutrient use and movement within a farm to optimise production and environmental outcomes.

Other ways of measuring cost/benefits is through experimental studies on the effects of land use change on water quality. Such experiments may take many years before meaningful results can be obtained, therefore comparative studies at a range of spatial scales may be more appropriate.

Further information

The full technical report *Climate change mitigation measures: Water quality benefits and costs* can be downloaded from www.climatecloud.co.nz/CloudLibrary/water-quality-benefits-and-costs.pdf