

Restoring the waters: An examination of water quality and ecological restoration issues
surrounding New Zealand's Lake Omapere.

Program on the Environment Honors Capstone Analysis Paper

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Introduction

Fresh water is a fundamental need for aquatic and terrestrial organisms—including humans—to maintain life. Societies and individuals alike have long realized this and, as a direct result, water rights, water quality and water conservation are all at the forefront of discussion in environmental, policy and human rights circles. Due to uneven distribution and use, fresh water is in short supply on Earth. Most fresh water is in ice caps, while most liquid fresh water—nearly 99%—is in underground aquifers (Wetzel 2001). The amount of water that comprises the world's rivers, lakes and streams is paltry compared to the amount at the poles or far beneath the ground. When the amount of fresh water available for human use is calculated, 6,780 km³ per year, it becomes apparent how little of the world's water is open for human use (Jackson et al., 2001), emphasizing the importance of maintaining healthy fresh water bodies.

Because water is naturally scarce and world populations are consistently expanding, the quality of available fresh water is of growing importance. The 1971 passage of the Clean Water Act in the U.S. brought about a whirlwind of change in how freshwater systems were managed and cleaned up. Pollution from point sources—concentrated discharges from industry and urban areas—were regulated and dramatically reduced. Nutrient loads flowing through storm sewers were further reduced by bans on phosphorous (P) in detergents (USEPA, 2000). However, non-point source pollution, namely agricultural runoff and stormwater from urban and deforested areas, has replaced the point source discharges as the primary threat to U.S. freshwater bodies (USEPA, 2000). A similar trend exists elsewhere in the world: point sources have been cut, but non-point sources have grown and faced little regulation (Welch, 1992).

New Zealand, a nation of roughly four million people and with a landmass almost equal to that of Colorado, is often known for its 'green' reputation. Ironically, the environmental issue

I chose to study is one of the most widespread ecological problems in the world, and New Zealand, with an economy driven largely by agriculture (only behind tourism), suffers more than most nations. The degradation of water bodies by enrichment from nutrients, or eutrophication (sometimes called cultural eutrophication when caused anthropogenically) is inextricably tied to agriculture and stormwater in places where point sources have already been cut or never existed. Lake Omapere in New Zealand's Northland Region (Far North District) has been eutrophied for decades, but only in the last fifteen years have government agencies discussed restoration.

During my senior capstone project in environmental studies, I learned that, despite adverse economic conditions and the difficulty in satisfying multiple stakeholders, there may be hope for restoring Lake Omapere through carbon forestry schemes and bottom-up restoration planning. In theory, carbon forestry would provide an economic incentive for landowners to actively preserve and afforest riparian margins while community-driven planning would link stakeholders at the ground level rather than through government intervention. The contrasting reality however, is that the execution of these plans moves slowly, and with it the active restoration of Lake Omapere.

The Capstone Experience: Background

One thing that immediately struck me about New Zealand is the vast amount of water: lakes, rivers and streams of all sizes, glaciers, fjords and snowfields that all seem to tie the landscape together. I met Dr. Zuben Weeds in the summer of 2006 on a study abroad course exploring renewable energy across the New Zealand countryside. After seeing water-influenced landscapes across New Zealand I wasn't surprised when Dr. Weeds, a forest ecologist turned chemical engineer, mentioned that he would soon be entering the world of private consulting to work on potable water supplies, hydroelectricity and riparian ecology in New Zealand. In

autumn of 2006, he wrote me and extended an opportunity to study eutrophication and water quality as a part of his new company, Small Hydro Enterprises. Lake Omapere, a 1,200-hectare lake in New Zealand's Northland, had become heavily eutrophied from agricultural runoff. I would be assigned to research the ecological history of the lake, make some recommendations, and assess where and how agencies could begin restoring the lake. I accepted his offer with some apprehension—at the time I was enrolled in basic restoration ecology coursework and had almost no experience in aquatic/wetland ecology and chemistry.

Experience being a limiting factor, I designed a year's worth of independent studies for myself, following the advice of Dr. Kern Ewing and Dr. Jon Bakker. I spent the winter of 2007 pouring through literature and books on limnology, riparian buffers and riparian restoration, gaining as much background as possible. Simultaneously, I contacted the Northland Regional Council (NRC), which manages the water resources of New Zealand's Northland Region, and the National Institute of Water and Atmospheric Research (NIWA), which performs much of the monitoring around Lake Omapere. From NIWA and the NRC, I gathered numerous reports and documents about the trophic status of Lake Omapere and land use in the surrounding area. I contrasted their reports with case studies on the remediation of eutrophied water bodies and used the synthesis to gain a better idea of the scope of the eutrophication and the potential effectiveness of restoration efforts.

In spring quarter of 2007, I wrote a review of my pre-departure research and gave a presentation at the University of Washington's Undergraduate Research Symposium about prioritizing riparian restoration actions around Lake Omapere. I synthesized my background research into a proposal to attract funding and the Garden Club of America sponsored my work with an Elizabeth J. Norweb Scholarship in Environmental Studies. To present my background

synthesis, I wrote a thesis entitled: “Prioritizing for riparian restoration surrounding a eutrophied lake: a pre-restoration analysis of riparian buffer potential and implications for New Zealand’s Lake Omapere.” I also completed a brief background report, compiling the environmental and ecological characteristics of Lake Omapere and the surrounding landscape for use in applied restoration activities. Lastly, I researched invasive species and typical native restoration plantings used in riparian restoration in New Zealand, familiarizing myself with the flora and fauna that I would encounter in any groundwork in New Zealand.

While designing an independent study curriculum, presenting background research and applying for funding were not the goals of my capstone work, they were deliberate activities that enriched my capstone experience and helped me to develop technical and professional skills required in most research-based professions. I was able to spend months reviewing literature, and became well-versed in the local ecology surrounding Lake Omapere, while simultaneously gaining practical communication skills in writing and public speaking.

Setting the Stage: Eutrophication, Lake Omapere and New Zealand’s Northland

Eutrophication, “an increase in enrichment that causes increased productivity in lakes, streams and estuaries,” usually caused by “an increase in the external nutrient supply rate (Welch, 1992),” is frequently a product of agricultural pollution. Such pollution comes from both non-point sources like crop production, pastoral erosion and point sources like livestock effluent a common byproduct of dairy operations. Eutrophication occurs worldwide in both marine and aquatic ecosystems; cultural eutrophication of freshwater bodies has been cited as “the most obvious, persistent, and pervasive global water quality problem at this time (Cooke, et al., 2005).” New Zealand’s Northland, a rural North Island region relies primarily on tourism, but has historically been economically driven by primary production industries—forestry, fishing

and aquaculture, and largely agriculture (NZ Dept of Labor, 2006). Dairy farming is among one of the most successful industries in the Northland, but with it comes associated water-quality risks tied to the disposal of livestock effluent (Smith and Wilcock, 1993) and the cultivation of unbuffered erosion-prone pasture (United States Department of Agriculture Forest Service, 1997).

Eutrophication occurs when phosphorus (P), and nitrogen (N) are introduced in quantities sufficient to alter the biochemical characteristics of the water. Phosphorus is the limiting nutrient in most aquatic ecosystems (Wetzel, 2001), so even seemingly nominal inputs of P may cause shifts in biomass quantity and structure. Most P enters aquatic ecosystems in sediment-bound forms while N can occur in various soluble forms, most commonly nitrates, nitrites and ammonia. The primary effect of eutrophication is increased primary productivity; a change that causes shifts in total in-lake biomass and species diversity. In the case of Lake Omapere, these shifts meant the local extinction of native aquatic biota and primary production dominated by toxic bacterial algae species. With increased biomass, dissolved oxygen is reduced as new plants actively respire at night and during winter. This change often reduces faunal diversity because dissolved oxygen levels usually limit faunal reproduction. In extreme cases of primary productivity, anoxia occurs; anoxia is a complete lack of oxygen in the water column that eliminates all aquatic animals.

Pastoral farming has taken place around the inland waters of New Zealand's Northland since before the turn of the century. The area's relative abundance of clean water made it suitable for irrigating pasture and watering livestock. Consequently, a majority of the Northland's wetlands surrounding inland lakes and rivers have been drained to create more pasture, reducing lake levels in some areas by as much as three meters (which occurred in Lake Omapere around

1900). In addition, farmers filled or drained wetland areas critical for surface and groundwater filtration (Mitsch & Gosselink, 2000). Grazing to the edge of water bodies and watering stock in rivers, lakes and ponds are common farming practices in pastoral systems. I observed both of these activities at a variety of pastoral sites in the Northland, including at Lake Omapere. In these practices, phosphorus and nitrogen are added to aquatic systems by stock through feces and urine, flowing into tributaries as surface runoff during precipitation events or being directly deposited into the water.

The lake was invaded by the noxious weed *Egeria densa*, an aquatic macrophyte—a plant larger than common algae living entirely in or on the surface of fresh water—that does not respond to fertilization (Mony et al., 2007). A fertilization response would entail increased rates of plant growth as nutrients are added. *E. densa* was found by Mony and others to not show this response (2007). *E. densa* stratifies the water column, preventing mixing and reducing dissolved oxygen levels at night when it actively respire (Wells and Clayton, 1991). It also serves to shade out competing aquatic producers, both native and adventitious.

Because of shading by *E. densa*, competing indicator species within the lake may not have been able to serve as ecological indicators of the lake's trophic level. In New Zealand, such indicator species may include *Chara fibrosa*, *Myriophyllum robustum*, *Hydatella inconspicua*, as well as shallow emergent vegetation such as rushes (*Juncus*), bulrushes (*Scirpus*) and sedges (*Carex*) (Tanner et al, 1986). As the *E. densa* collapsed, suspended sediment within the lake rose simultaneously, further shading out the development of other species (Gray, 2006). Soon after *Egeria densa*, a more problematic invader would manifest itself in Lake Omapere, one that gave much more insight into Lake Omapere's degraded condition.

When *Egeria densa* was eradicated from the lake in the mid 1990's, the level of trophic disturbance became apparent as cyanobacteria (blue-green algae) of various classes moved in to take advantage of the newly available light resources. These bacteria, predominantly *Macrocystis* species, unlike *E. densa*, do respond to fertilization and quickly came to dominate the enriched lake. These cyanobacteria, not only further stratified the water column, but also produced poisonous macrocystin toxins that render the water undrinkable. Lake Omapere was the water supply for the nearby town of Kaikohe through the 1980's and early 1990's. Omapere also served as the water source for the same cattle that had enriched the lake during those times, but was effectively worthless post-eutrophication except as a nursery for algae. Poisoned and depleted of oxygen, recent fish surveys have shown only two species, juvenile goldfish and short-fin eels, neither of which were originally native to the lake. When Lake Omapere suffered trophic disturbance from eutrophication, seemingly nothing was left untouched, from the local people to native aquatic vegetation to cows.

The macrocystin toxins that poison Lake Omapere are not merely limited to the lake, as their effects are felt downstream all the way to the Tasman Sea. Downstream in Hokianga Harbor, a large shellfishery has been closed in recent years due to bioaccumulation, the concentrating of toxic substances within an organism at a rate faster than they can be lost, of macrocystin toxins in mussels, clams and scallops. The Utakura River, Lake Omapere's sole outflow, is often unavailable for watering crops, cattle or people after severe rain events flush Lake Omapere, sending a deluge of enriched water to Hokianga Harbor, toxins included. The village of Kaikohe and surrounding rural areas now rely on drinking water from tanks that collect rainwater during the winter. Shortages are common though, because the Northland has a modified Mediterranean climate with minimal summer rain. The village of Mototi, south of the

Utakura River, relies on upslope mountain streams for water, but faces the same dry season shortage as rainwater collectors when streams are low.

In New Zealand's Northland, there are two types of cattle farming, dairy and beef—and both have contributed to water quality decline. Beef farming can be done in more arid environments, as the goal is to grow animals, rather than milk and/or milk fats. In dairy farming, water is required to irrigate pasture so that cows produce more milk fats. Dairy farmers often take manure from the paddock, mixing it into a slurry with water and then reapplying it as fertilizer. When effluent is not used, inorganic fertilizers are mixed with water and applied to pasture by air or tractor. The cycle consists of water being added to nutrients of some form and then being applied to pasture to enhance grass productivity. The more calories in grass or forage that cattle eat during calving, the higher their milkfat content will be, earning higher prices per liter from the processor. This cycle often coincides with shifts in market prices for dairy commodities: the higher the market price for dairy products, the higher the rate of fertilization. The same trend occurs where marginal (seasonally inundated or erosion-prone high-slope) land is increasingly cultivated as dairy or beef prices rise. A common side effect of beef cattle cultivation on drier lands is the denuding of vegetation. Once the top layer of grasses is eaten and soils are compacted by treading, then the surface soils become increasingly vulnerable to soil erosion and less likely to support future vegetation (Porteous, 1993).

Insert Figure: Dairy Farming and Nutrient Budgets

Goals: Where Naivety and Pragmatism Meet

After completing the aforementioned pre-departure work and arriving in New Zealand, I began to revise my goals for what I wanted to accomplish in the Northland. I had reviewed the

literature on Lake Omapere, limnology, riparian ecology and agricultural buffers, and was ready to apply this knowledge in a field setting. Originally, I aspired to collect baseline data on soil nutrient levels around Lake Omapere and its inflowing streams and I wanted to quantify species composition and disturbance regimes from grazing, and then eventually restore a portion of Lake Omapere's shoreline. After a week in New Zealand and a few visits to Lake Omapere, I realized that the socio-political climate was not ready for work around Lake Omapere.

My first lesson in New Zealand was that when addressing complex environmental problems, the temporal scale required to provide a solution might be longer than desired, leading to shifts in goals for the immediate timeframe. I legitimately thought that during my time in New Zealand, I would, in part, actually restore Lake Omapere. I believed that my pre-departure work had prepared me to begin a restoration project and that the people around Lake Omapere, government, landowners and stakeholders, would be receptive. I was wrong about this, but fortunately I was able to shift my goals.

Rather than planning and implementing a restoration project, I decided that researching potential incentives for riparian buffers would provide longer-term, sustainable possibilities for future restoration work. I began to look at carbon forestry, specifically using *Leptospermum scoparium*, a prolific shrub that is endemic to New Zealand and Australia. Not only does *L. scoparium* have a prolific growth rate—ideal for sequestering carbon—but it is also used in apiculture, or bee cultivation. I wondered, was there a possibility that land owners around Lake Omapere and other degraded water bodies could make a profit from honey and carbon credit production on their riparian buffers? How could such a scheme be created and displayed, selling its benefits to the landowner and the local ecology?

Ameliorating a degraded lake, like many of the environmental issues that I've studied, involves addressing the social, political, economic and ecological issues that led to the current situation. I set up visits and interviews with stakeholders to gain a better understanding of local opinions on the matter, proposed a carbon forestry-funded riparian buffer scheme and visited with local government to understand their obstacles in rehabilitating Lake Omapere.

Stakeholder Groups and Desires

Lake Omapere is a 1,200-hectare lake with a troubled history; eutrophication aside, this history includes illegal drainage, biological invasions and nearly constant disputes over water rights and uses by agencies and local peoples. During my capstone I was working for Small Hydro Enterprises, a private engineering firm that consisted of two full-time employees and myself. They had been contracted by the Far North District Council to examine freshwater resources in the Far North District that could be used as water supplies for the area's rural communities. This project put Dr. Weeds and myself in touch with the stakeholder who was most interested in potable water supplies: the local Maori.

The Maori in Northland generally live together in small communities far from the political and economic centers of the region; due to the isolated nature of these communities, natural resource management often comes from a bottom-up approach. Maori in New Zealand, like Native Americans in the U.S. is a blanket term for a diverse set of indigenous peoples. Maori in various geographic locations draw distinction based on tribal heritages. In the Northland there are several tribes and each has its own Iwi and Hapu, the elders and executives. Often the positions of power given in these circumstances go back to family lineage and or location within the tribe's region. The Iwi and Hapu make all the decisions for a tribe, although they may take into account the consensus opinions. Dr. Weeds was working with Te Rarawa,

one of five Iwi in the Far North District; all of these Iwi have claims to land which drains from Lake Omapere, or are in possession of fishing rights in the Hokianga Harbor. The Maori have sporadically spoken out about the condition of Lake Omapere due to these downstream affects, but since no Maori own land along Lake Omapere, they cannot actively implement restoration without landowner permission or a requirement imposed by government.

The landowners around Lake Omapere, who are all farmers, have historically had exclusive control of land use around the lake, but they have been the least likely to participate in restoration activities. The farmers, although suffering from the unusable state of Lake Omapere, are currently taking very few steps to restore the lake unless they receive funding from the government (NRC). One major reason is that the markets for their products are growing and prices are rising, encouraging increased production and discouraging land-use changes away from agriculture. Farmers, while often owning large expanses of land, have very little financial return on their investments, often breaking even in good years and relying on government subsidies during bad times. With a perceived dawn of 'good' economic times, farmers around Lake Omapere are resistant to changes that reduce their productivity and potential opportunities for profits.

While landowners have little incentive to take ecologically sound actions, government's regulatory framework is inconsistent and not designed for cohesive ecosystem management. The Northland Regional Council (NRC) is responsible for the management of water resources in their region while the Far North District Council (FNDC) manages land resources. These smaller government organizations, have goals that overlap but management and regulatory obligations that are exclusive to one another. Their policies simply fail to incorporate the management of land into maintaining water resources and vice versa. Since the economy of Northland is largely

powered by primary production industries, action on the part of these agencies is often slow if it adversely affects agriculture or forestry.

The NRC has undertaken the Lake Omapere Restoration and Management Project (LORMP, or ‘the project’ herein), an attempt to begin a dialogue between farmers and government to encourage the sustainable management of farms. This entails outlining proposed nutrient budgets with farmers, even though they’re not obligated to follow them, and providing consultation on the upgrading of farm infrastructure such as paddocks and drains. The NRC also sponsors an environment fund that can be used to pay for as much as half of riparian fencing that excludes cattle. Although these efforts would theoretically improve the lake, the lack of compliance enforcement and lack of a scientific basis for prioritizing areas makes the NRC’s project efforts less effective. Figure I below shows a summary of all major stakeholders involved in the eutrophication and restoration of Lake Omapere.

Organization or Group	Role	Urgency and Authority
Local landowners and Farmers	Control the land required to undertake Restoration efforts	Unless financially harmed by legislation or farm practices, unlikely to advocate restoration.
Northland Maori	Largely bears the burden of downstream effects; rural communities may have lost their water supply	Lack authority since they don’t currently own any of the farm lands producing agricultural pollution.
Northland Regional Council	Manages water resources in the Northland Region; began the LOMRP to address the issue formally.	May lack power and ability to implement policy or plan restoration.
Far North District Council	Manages land resources in the Far North District of the Northland Region	May lack power and ability to implement policy or plan restoration.
Small Hydro Enterprises	Consulting firm contracted by Te Rarawa Maori group.	Advisory role; no power to affect legislation or undertake restoration.
Ministry of Agriculture and Forestry	Advisory body for primary production industries across New Zealand; partial collaborator on carbon forestry initiatives.	Detached from the problem, manages farms, not necessarily off-farm adverse ecological effects.
Department of Conservation	Manages parks and refugia across New Zealand	Since Lake Omapere is not a critical conservation area, but a degraded one it receives little attention

Figure I: Stakeholder roles and authority around Lake Omapere

A brief meeting at Lake Omapere with Bruce Griffin of the Northland Regional Council helped to illustrate the difficulties of managing restoration on Lake Omapere. We met Mr. Griffin at a farm entrance that appeared to be a boat slip. The lake had flooded after recent rainstorms and was two meters higher than its usual level. We were standing next to paddock, land that would in times of normal flow be thought of as farm, not riparian zone or wetland. As we slogged along on what passed for high ground, Bruce explained that even knowing the correct approach for watershed (ecosystem) management, the NRC lacked the power to do anything. The socio-political winds were blowing too heavily in favor of farming, and no legally-binding policy could be made.

Mr. Griffin further explained that the Lake Omapere Management and Restoration plan had involved lots of publicity but very little action thus far. While often flooded, marginal farmland is still private land, and not open to voluntary restoration projects as a park or preserve might be. The NRC took the initiative to bring together the LORMP, but could do little to implement actions towards the goals without dramatic changes in land use, public acquisition of private land, or passing laws requiring nutrient budgets and riparian buffers. As Dr. Weeds and I looked out to dozens of flooded acres, we wondered how the lake could ever be restored with such land use practices

The Ministry of Agriculture and Forestry (MAF) and the Department of Conservation (DOC), both government agencies, are the primary government stakeholders at the national level. The DOC is in charge of creating and managing areas of natural heritage and ecological importance as well as creating public green spaces for all of New Zealand. The MAF also works to serve the larger primary production industries, giving economic prospects to farmers, horticulturists and foresters. MAF also serves the country's farmers and foresters by providing

research and development on numerous aspects of farming and forestry, including best management practice for riparian zones (MAF, 2007).

Central government and regional agencies have done very little surrounding Lake Omapere in terms of mandating best management practices. Because the area has a small population and relatively low income levels, it does not have much political clout at the national level. Currently there seems to be minimal development of stakeholder dialogues outside of individual consultations between groups. Both of these circumstances are unfortunate; Lake Omapere will require substantial federal funding not only to undertake restoration, but also to establish stakeholder dialogues on the public record.

The Maori have probably the most urgent claims to restore the lake as they have been directly affected by Lake Omapere's degradation. Sadly, the Iwi and Hapu have the least authority on the issue, but as I found during my travels, still support the restoration of the lake through conservation corps activities and regular meetings. I was able to attend a planting day in which a Lake Omapere-area farmer allowed a stretch of land formerly invaded by gorse (*Ulex europaeus*) to be planted with the native Kanuka (*Kunzea ericoides*). The crew consisted of Maori youth who used the experience to get landscaping and horticultural certifications while giving back to their traditional lands. This event was isolated and the area of land planted was based on farmer permission, not on the area required to effectively remediate pastoral nutrient flows.

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Potential for Change: Riparian Buffers

Restoring a lake is no small task, and there is no simple procedure that can restore pre-eutrophic conditions to a degraded lake. In lake restoration, most managers implement a triage approach in which minimizing new nutrient input takes precedent (Cooke et al 2005). This can be done by either capping point sources such as dairy effluent, industrial waste or sewer systems. For example, Lake Washington, once a highly eutrophied lake, was cleaned up by the elimination of municipal point sources of waste water while phosphorus-based detergents were phased out under the Clean Water Act (Edmondson, 1991). Only after reducing potential sources of new nutrient inputs, can existing in-lake nutrients be addressed.

Lake Omapere is a non-point source problem, with nutrients coming from across the landscape—there is no capping of the problem. Given this fact, an ecosystem-scale approach must be taken if the lake is to be restored. This approach should utilize planted riparian buffers or retention wetlands to remove as many nutrients flowing across the landscape as possible. This would involve the participation of all stakeholders, but action only on the part of farmers in the watershed—something that is perceived as unfair by local farmers. Disappointingly, no nutrient budget for Lake Omapere has ever been taken at the watershed scale, so it is difficult to know whose farm is contributing the most nutrients and where riparian buffering actions would be most effective. Until a quantity of nutrients can be associated with a property, there is no way to

request action. Lake Omapere, like many agricultural lakes, does not have the regulatory mechanism of banning and/or capping point source nutrients; non-point sources of P and N from across the landscape must be reduced. Planning for this begins with nutrient budgets and on-site surveys, both of which are currently absent.

Riparian buffers and cattle exclusion have been shown to be the first and most effective steps in reducing non-point source runoff from agriculture (Cooke et al, 2005, Dosskey, et al 2002). In a field trial in southern along the Sherry River in New Zealand, Davies-Colley and Nagel (2004) found that 246 cattle were capable of producing 35.2 kilograms of suspended solids and 1,448 g of total N. In addition, Dosskey and others (2002) found that planted riparian buffers removed statistically significant quantities of N and P from surface runoff when such runoff was not channeled across the landscape. Numerous studies support Dosskey's findings at farm-sized scales (Cook et al, 1996; Inamdar, 2002; Schmitt, et al. 1999; Lee, et al. 2000; Borin et al. 2005).

Even though riparian buffers have been proven effective in site-specific studies, their efficacy has been questioned at the watershed scale. Research in a Canadian watershed has shown that the effectiveness of buffers at cleaning agricultural runoff is diminished unless implementation is watershed-wide (Yates, et al 2007). Therefore, Lake Omapere's entire shoreline should be excluded from grazing and then planted in native vegetation to remove excess P and N. The lake serves as a collecting basin for all of the surface water on surrounding pastures, so continuity of the buffering is undoubtedly important. Needless to say, cattle would also need to be excluded from the riparian plantings so that buffer efficiency is maximized.

I found that while most government agencies, including MAF, DOC, NRC and FNDC encouraged riparian fencing and buffering, there were no active laws mandating cattle enclosures

or riparian planting to prevent water degradation. Landowners around Lake Omapere face several constraints to initiating riparian buffering, chiefly a lack of money. MAF actively supports farm improvement demonstrations and research through the Sustainable Farm Fund (SFF) and the NRC through the aforementioned 'Environment Fund'. However, SFF grants have been allocated for riparian buffer schemes in the Northland. Dr. Weeds and I realized early on that a cost-effective, chemically monitored buffer demonstration could be used to encourage riparian buffering around Lake Omapere, but it would first require landowner interest and engagement.

Carbon Forestry and Funding Riparian Buffers

A significant portion of my time in New Zealand was spent brainstorming and researching potential methods to fund riparian restoration activities. All the land around Lake Omapere is private land in dairy, sheep or beef production; there is currently a large market for the product being produced—milk fats and dried dairy products for export. Fonterra, the New Zealand national dairy co-op has recently tapped markets in Southeast Asia and the prices being paid to farmers for milk and milk fats are at all-time highs. Figure II (shown below), illustrates the profitability trends for Dairy farms in Northland (MAF, 2006).

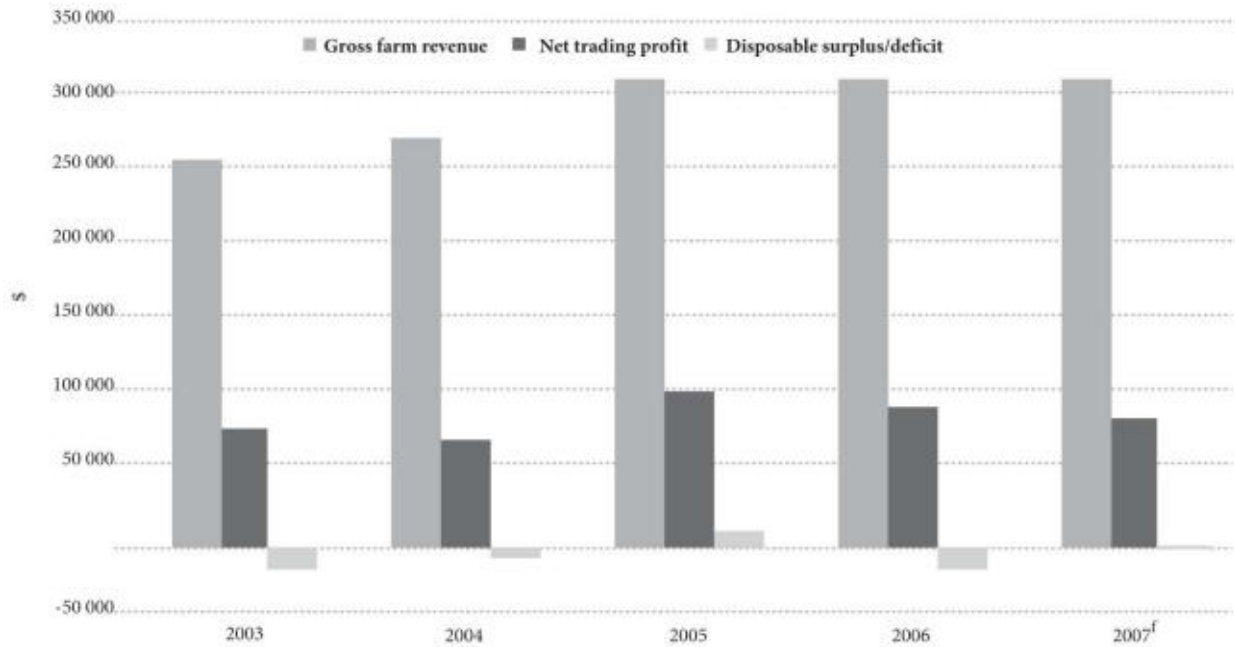


Figure: Dairy profit trends show an increase in dairy profitability from 2003 to projections for 2007 (Taken from MAF 2006).

We theorized that if riparian restoration were to become feasible, it would have to produce a return to land owners similar to their current land use (pastoral agriculture for dairy/beef/sheep). Because New Zealand ratified the Kyoto Protocol, it has a formal agreement to reduce greenhouse gas emissions to their 1990 levels by 2012. I therefore asked myself, “Can we fund ecological restoration and riparian planting with carbon forestry?”

Carbon forestry is a relatively new concept that has quickly developed as Kyoto nations undergo assessments of their carbon sinks and sources. Carbon forestry (CF) uses growing trees to sequester carbon dioxide (CO₂) from the atmosphere. The amount of carbon sequestration can often be calculated in algorithms used to predict the current amount of carbon in a tree based on diameter. This data can be further analyzed to predict carbon sequestration through the life of the tree, and the life of entire stands based on mathematical models. For example,

Leptoserium scoparium has been modeled, showing that it may sequester 1.9 to 2.5 tons of carbon per hectare, per year when reverting on marginal pasture land (Trotter, et al. 2005).

I began to research the Emissions and Biodiversity Exchange (EBEX) initiative and the Permanent Forest Sink Initiative (PFSI)—two carbon forestry initiatives sponsored by the Ministry of Agriculture and Forestry (MAF). The EBEX and PFSI initiatives serve as incentives to encourage new forest plantings to sequester carbon from private land. Under these initiatives, the New Zealand government administers assessments of all post-1990 forests to quantify current and potential carbon storage. If landowners agree not to cut most of their trees in the future, then they are paid up front for the carbon predicted to be sequestered in their trees between 1990 and 2012. New Zealand may then use these carbon credits as offsets for industrial emissions when quantifying carbon budgets for Kyoto purposes. Below in figure III is a chart from Carswell, et al 2003, that shows the process by which EBEX pays forest owners/forest planters for their credits:

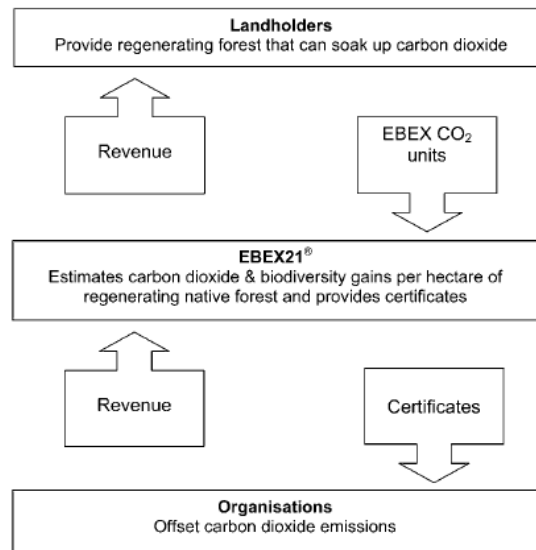


Figure III: The pathway through which EBEX increases non-harvested indigenous forest (carbon) sinks.

Carbon forestry currently favors faster growing pioneer species that accumulate carbon (and profits) at a higher rate initially than slower growing late-successional species. I learned in

my background research that Manuka (*Leptospermum scoparium*), an evergreen prostrate shrub that flowers four times annually, producing vital seed four times a year. The high rate of seeding and germination indicated that *L. scoparium* is also an easy plant to cultivate *in situ*. Dr. Weeds and I decided to look into the research surrounding Manuka to evaluate its suitability as a carbon forestry crop and ecological restoration planting.

Fortunately, our observations and premonitions were supported by the scientific literature surrounding *Leptospermum scoparium*. The scientific literature showed that *L. scoparium* is a common riparian plant with a fast growth rate (Trotter et al., 2005) that serves well as a nurse crop (Burrell, 1965; Allen, 1988), erosion control planting (Allen, 1988), and pioneer species (Fountain, 1991; Dodd and Power, 2007). Observations and farmer interviews told us that the shrub naturally reverts on pasture with gorse and is not eaten by cattle. Dodd and Power (2007) support this claim, also showing that using cattle to trample seeds into pasture actually helps them to germinate.

Restoring Lake Omapere: A proposal

Synthesizing my research and turning it into an ecological restoration project was the next step in my capstone. Dr. Weeds and I began to work on a Sustainable Farm Fund (SFF) Grant from the Department of Conservation. We proposed that a landowner could receive half the funding involved in project costs from SFF to afforest his or her riparian zone. They could use seed or seedlings of *Leptospermum scoparium* because they out compete invasive weeds in early stages and serve as a nurse crop for wind and bird distributed later-successional species. This scheme would be monitored for tree growth, tree establishment under the canopy as well as soil, surface and groundwater nutrient changes post-afforestation. The EBEX initiative would provide income for all plants that grew within the allocated buffer zone, covering the other half

of the cost of the buffer. In theory, this would allow the buffer to pay for itself using upstart grant money and eventually paying the rest off in EBEX carbon credits. The only problem was, no private land owner wanted anything to try our scheme.

Gridlocked: Constraints to Riparian Restoration in New Zealand

To introduce our proposed initiative to local farmers and begin a dialogue about riparian buffering and carbon forestry, I found myself attending numerous events that were attended primarily by farmers. One evening, the New Zealand Farm Forester's Association hosted a social with an expert on plantation forestry and truffles. After the speech I sat and talked about the aim of our project to numerous farmers, gauging their reactions and trying to see how they felt. While many people felt that water quality in Lake Omapere (and other lakes) was important, they were not readily willing to change the way they farmed if it meant losing profits. They also seemed relatively unconcerned about remedying their farming's downstream affects.

Another constraint was that the farmers had no interest in growing native species—something mandated in the EBEX 21 scheme, and part of our *L. scoparium* plan. Douglas fir (*Pseudotsuga menziesii*), Sitka spruce (*Picea sitchensis*) and radiata pine (*Pinus radiata*) are the most heavily cultivated forest crops in New Zealand, with native forestry being only five percent of all wood production—mostly for firewood. With the current paradigm being replacing native forests and scrub with pasture and then eventually non-native species, shifting to a native carbon forestry scheme will take some work informing farmers. This mentality may change as the idea of accumulating standing biomass supercedes the idea of raising valuable timber, pulp and paper crops.

The third perceived problem with riparian afforestation was the perception, that the process of establishing carbon credits was prohibitively expensive and inflexible to harvest. For

example, the EBEX 21 scheme requires initial analysis and then periodic audits performed by Landcare Research. However, such analyses do not necessarily cost the landowner more money than having his or her timber appraised for sale in current plantation practices. Similarly, just because one has his or her forest audited, does not mean that they are required to never harvest from it. If markets shift and timber becomes more valuable than carbon credits, then landowners can cut their trees, sell them and then pay back the difference to the government (Carswell et al, 2003).

However, the largest obstacle to our plan was simply the dairy product market. If a riparian setting garners a set amount of profits as pasture and that amount rises with dairy prices, then the farmer increases his profits. If he has afforested his riparian area and can't graze it due to carbon forestry, then he is locked into making the market price of carbon—something currently less than dairy returns and predicted dairy returns (Chicago Climate Exchange, 2007). While these concerns have merit, they're biased towards the current paradigm that involves more certainty. Match this with a perception that less capital expenditure is required to run pastoral farms than plant forests, and there is significant opposition. I found that most farmers, people who generally struggle to turn profits, would rather substitute their guaranteed dairying returns for a perceived costly and potentially risky return that happened to improve water quality.

Beyond Omapere: Water Rights, Water Quality and Restoring Riparian Areas in a Changing World

In New Zealand, I was introduced to water quality issues surrounding degraded water bodies as well as to some of the ecological restoration techniques used to remedy their waters. However, beginning such restoration work proved to be extremely difficult. Seeing the connections between land and water was difficult enough, as I learned through my discussions

with various farmers. Even more challenging was convincing people to act after seeing the connections between potential income, environmental improvements and global climate change. The stakeholders around Lake Omapere have very little power to affect change. The government, while trying to bring carbon forestry online, is struggling with the reality that they cannot match free market prices for other commodities that require environmentally degrading land use. The economically struggling farmers have future prospects for intensifying production and increasing profits. They do not however, have an interest in doing anything that costs them money initially or does not return an immediate profit.

After seeing the various processes at work in Lake Omapere, I left New Zealand feeling that the solution of water quality problems may come in various forms, none of them quickly. Economic incentives and/or a shift in market price are the only two real drivers that seemed that they would have an immediate effect on farmers' perceptions of the problem and solutions. Government agencies, while aware of problems were tied up with too many other projects and a lack of support staff and funds. Government mandating water quality regulations on agricultural lands did not seem to be the answer; such a law would be unpopular, and few politicians will risk his or her career for a degraded lake.

Although Lake Omapere is not going to be restored in the immediate future, I saw several positive signs. Many of these signs are parallel to environmental perceptions in America, and probably have global implications. Bottom-up management is often an impetus for action, as I saw with Terarawa and Small Hydro Enterprises. They had a need for potable water in their rural community, so they addressed their internal issues of water supply. They mobilized and researched and began to implement alternative solutions. The non-agricultural public is fervently environmentally aware in New Zealand. If they were to be made aware of the

happenings at Lake Omapere, perhaps they would begin to lobby government and request action to improve water quality.

The restoration activity that I saw on the planting day around Lake Omapere was also the most inspiring and prophetic act I encountered in New Zealand. Two-dozen teenage Maori with spades and a truck of plants actively planted almost a thousand Kanuka shrubs. These shrubs, like Lake Omapere's restoration will begin growing slowly. As the Kanuka gain resources, light, water and nutrients, they will grow like Lake Omapere's restoration will as it gains resources: political awareness, financial assistance and conservation easements. In Lake Omapere's restoration and the Kanuka, the going is slow early on. But once both establish, they will take root and grow by complex processes, into bigger things that may not have been imaginable at the time they were planted.

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