Economic resilience and environmental performance of dairy farms in the upper Waikato region.

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Abstract

Dairy farming has impacts on receiving water bodies that have increased in New Zealand during the past two decades due to the intensification and expansion of the industry. As a result the industry has implemented a number of voluntary initiatives to address its environmental impacts. However, declining ecosystem health in the Waikato region means that these initiatives alone are unlikely to retard further decline. Farm system reconfiguration will be required to reduce diffuse nutrient, sediment and pathogen losses. This change will have to occur without significant disruption to farm profit and economic viability. To date most studies have considered single mitigations and the cost of change associated with each. The common notion held by farmers and industry is that if they are constrained by nitrogen leaching caps, business will become less viable.

This study examined economic and environmental performance of 25 dairy farms in the Upper Waikato region. There were two components of the study: (1) the development of an environmental scorecard in order to quantify the risk to the receiving environment and (2) identification of relationships between environmental footprint based primarily on nitrogen (N) loss and economic resilience using Return on Capital (ROC) at a range of milk prices. I hypothesised that some farm configurations may result in lower environmental risk concurrently while demonstrating greater economic resilience. The participant group farmed in the Upper Waikato Catchment between Broadlands and Atiamuri on predominantly pumice soils where annual rainfall ranges from 1000 to 1350 mm. Overseer Version 6.0 was used to determine the nitrogen leaching from each of the farms, as a key measure of environmental performance. Nitrogen leached ranged from 15 to 48 kg N ha^{-1}, with an average of 31.8 kg N ha^{-1}. Low-risk farms were selected on the basis of leaching less than 30 kg N ha^{-1} y^{-1}, as well as achieving a “low risk score” on the environmental scorecard. “Nutrient use efficiency” for the study farms ranged widely, from 18 to 60 kg milk solids (MS) kg^{-1} N leached ha^{-1}, with an average of 39 kg MS kg^{-1} N leached ha^{-1}.

A range of agri-environmental indicators (AEIs) were selected to develop the scorecard to provide a comprehensive measure of the environmental risk associated with different farm management approaches. The AEIs were selected

on the basis they were scientifically sound, quantifiable, referred to issues relevant at catchment scale, were acceptable to target groups, easy to interpret, and cost effective.

Return on capital (ROC) was examined for the low-risk farms under a range of milk price scenarios, to test their economic resilience. Over two years (2010/11 and 2011/12) milk prices varied by ± 20%, and total pasture consumption altered by 10-30% due to seasonal effects. Profitability (ROC) for the 25 farms ranged from 2.5 to 9% at a \$6.08 kg^{-1} MS and N losses from 15-48 kg ha^{-1} y^{-1} with an average of 31.8 kg N ha^{-1} $year^{-1}$. Pasture consumed per hectare ranged from 9.3 to 13 t DM $ha.^{-1}$ the study included three irrigated farms. The irrigated farms yielded an average of 20% more feed each year than the non- irrigated farms while the nitrogen lost from the irrigated farms was almost double that of the non- irrigated farms.

To assess how management regimes influenced both nitrogen leaching and profitability, key economic, efficiency and risk parameters were analysed using a regression of ROC on other variables such as stocking rate, milk production and pasture harvested. Twenty-two farms were suitable for this analysis. The only significant factor ($p < 0.05$) underpinning ROC was a low cost of production (R^2 =0.81). For milk prices of \$5.50 to \$6.08 kg^{-1} MS, the more profitable farms also had a higher tonnage of pasture consumed per cow. This correlation was not apparent at a higher milk price (\$7.50 kg^{-1} MS), suggesting that more intensive systems (less pasture and more imported supplement per cow) can be profitable at times of high milk prices as long as feed costs are well managed. Milk prices have averaged \$6.30 kg^{-1} MS over the period of 1995-2014 and in recent years have fluctuated by 25-30% between seasons, suggesting that farming systems will have to adjust their systems quite quickly to adjust to downside risks.

Resilience as it relates to dairy farming includes provision for unexpected events and accounts for volatility of feed, milk price and seasons. This study reinforced that the more intensive dairy systems carry more cow bodyweight per hectare, are dependent on more bought in feed, and can perform comparatively strongly in years of high milk price. These systems can also be more vulnerable, however, with increased environmental risk requiring advanced mitigation strategies such as herd homes, stand- off facilities, supplementary feeding infrastructure and advanced effluent management systems. They also require greater capital investment that can lead to increased debt, compounding business risk.

Agricultural “growth agendas” have been based on the notion that policy approaches will not curb development and will provide more production contributing to a higher national GDP. New farm systems will have to demonstrate high resource use efficiency, minimal environmental risk and robust economic performance to endure in what will be more challenging and volatile conditions.

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Chapter 1 : General Introduction

1.1 International Context

By 2050, global population is projected to be 30% larger than at present and global grain demand is projected to double. This doubling will result from a projected 2.4-fold increase in per capita real income and a shift to more protein consumption, (Tilman, 2002). New incentives and policies for ensuring the sustainability of agriculture and ecosystem services will be crucial to meet food demands improve crop yields and not compromise environmental integrity or public health. (Tilman, 2002).

This study assesses what dairy farms are the most economically resilient and pose the lowest risk to the receiving environment in the Upper Waikato region of New Zealand (NZ). It will be necessary for agricultural systems to adapt to national and regional political regimes to limit diffuse pollution. Across NZ, water quality is particularly poor in lowland stream and river catchments dominated by pasture, (Larned et al, 2004). Many lowland rivers are unsuitable for swimming due to faecal contamination from farm animals, poor water clarity, and nuisance algal growths caused by excessive nutrients (eutrophication), (PCE, 2004 and 2013; Larned et al, 2004; Ballantine 2010, 2013).

The increasing human demands placed on the water supply threaten biodiversity and the supply for food production and other vital human needs. Agriculture accounts for approximately 90% of freshwater withdrawn each year, 70% of this is used, and the unused withdrawal is returned to aquatic ecosystems usually of lower quality, (UNESCO, 2001) (OECD, 2013). Presently around one quarter of the global water footprint is attributable to meat and dairy production, (Hoekstra, 2012). The global human population has now exceeded 7 billion people and estimated 25-30 billion food animals are required to help feed this populations growing demand. This is a global challenge: agricultural development is causing widespread impacts on both the availability of water and water quality in the United States, Europe, Australia, and elsewhere, (Pimentel et al 2004; Brodie, 2005), and more recently in NZ, (P.C.E 2013).

It has been widely recognised that anthropogenic nutrient inputs to aquatic ecosystems must be reduced to protect drinking water, reduce eutrophication and harmful algal blooms, (Huisman et al, 2005), and dead zones in coastal marine ecosystems has been widely recognized, (Conley et al, 2009).

Which particular nutrient is responsible for eutrophication, has been the subject of significant debate. In the early 1970s Schindler and colleagues showed that phosphorus (P) was the primary limiting nutrient in elegant experimental manipulations of whole lakes (Schindler, 1977). This paradigm of P limitation in freshwater systems has been persistent since the early 1970s but more recent work has questioned this. Estuaries and coastal marine ecosystems that have been heavily loaded with nutrients can display P limitation, N limitation, and co-limitation (Conley et al, 1999). The nutrient that is most limiting to primary production can change both seasonally and spatially (Malone et al, 1996). Furthermore, with increasing loading of N relative to P as a result of intensive agricultural practices, phytoplankton in the plume of the Mississippi River entering the Gulf of Mexico has been shown to be periodically limited by P, especially during the spring bloom period (Sylvan et al, 2007). However, implementing only P reductions without reducing N loads could displace the dead zone westward and increase its size (Scavia et al, 2007).

Nitrate nitrogen (NO3–N) typically comprises the majority of the total nitrogen pool in rivers and is a form of dissolved nitrogen that is readily used by primary producers such as periphyton. It has long been recognised that increased nitrate concentrations can cause ecological decline due to eutrophication, at concentrations that are much lower than those at which toxic effects occur (Carmago, 2006; Abell, 2013).

Heathwaite (2000) and Elser (2007) suggest the diversity of habitat-specific climatic, edaphic and ecological influences on N and P availability makes it difficult to obtain a broad picture of the relative importance of N and P limitation in the biosphere. They note that some existing paradigms identify N as the primary limiting nutrient in terrestrial (Vitousek, 1991) and marine (Howarth, 2006) ecosystems and P as the main limiting nutrient in lakes (Schindler, 1977). A meta – analysis by Elser (2007) concluded that enrichment by either N or P can increase autotroph production but that a simultaneous increase in both nutrients leads to dramatically higher levels of production in nearly all situations.

Nitrogen and phosphorus concentrations are influenced by season, flow characteristics, differences in factors such as land management practices between sites, and plant uptake of available nutrients (from substrate or water). Therefore, such variability means that relying on the control of phosphorus alone, while allowing nitrogen to reach levels at which it saturates plant growth or is toxic is fraught with risk because the strategy relies on the assumption that phosphorus concentrations can be continuously maintained at very low concentrations with zero tolerance for occasional elevated concentrations. (Death, 2013, Abell J. , 2013, Joy, 2013: PCE Report 2013).

Changes in land use, creation and operation of large terrestrial and marine food production units and microbial and chemical pollution of land and water sources have created new threats to the health of both animals and humans. Over the past 3 decades, approximately 75% of new human infectious diseases have been identified as zoonotic in origin. (Taylor 2001, Daszak, 2004)

Faecal microbial pollution from agriculture is an emerging issue. Faecal indicator organisms (FIOs) are commonly used as a proxy of pollution of public health significance. Health protection, as indexed by FIO control, is a central aim of new ‘catchment-scale’ water quality management required in the USA by the Clean Water Act and in the European Union (EU) by the Water Framework Directive (WFD). Experience of the former, after a decade of implementation, suggests that the most significant reason for water quality ‘impairment’ is elevated FIO concentrations, mainly in recreational and shellfish harvesting waters. This provides an early warning of possible problems which the EU regulatory authorities are likely to face, (Kay, 2008).

OECD, (2012) highlights the key challenge for policy makers in addressing water quality issues in agriculture is to reduce farm contaminant losses to water systems thereby helping to conserve a range of benefits associated with water systems i.e. recreational use. Water pollutants from agriculture are recognised as nutrients, pesticides, soil sediments, pathogens and now more focus is being given to new and emerging water pollutants arising from agriculture such as veterinary medicines and feed additives. OECD (2012) notes that control diffuse source agricultural pollution is more complicated than addressing point sources of pollution as they are difficult to measure, generally cumulative in their impact, leach form large areas, are highly variable in space and time and also require agreement and co-operation across sub catchments and catchments; (OECD, 2012)

The Water Framework Directive (WFD) was established by European Parliament & Council and came into force on 22 Dec 2000. The EU Nitrates directive (1991) aims to protect water quality across Europe by preventing nitrates from agricultural sources polluting ground and surface waters and by promoting the use of good farming practices. It is proving effective: between 2004 and 2007, nitrate concentrations in surface water remained stable or fell at 70% of monitored sites. Quality at 66% of groundwater monitoring sites was stable or improving. All member states have drawn up action programmes and there are more than 300 of these across the EU. Close to 40% of all territory across member states is subject to the implementation of action programmes.

The WFD implementation is supported by the principles of the river basin management planning approach and eco hydrological principles (interactions between water and ecosystems), (Zalewski, 2010), which are designed to support member states protect and maintain good ecological status for the water bodies within their river basin districts. Identifying ways to remove point source and diffuse pollution are critical parts of these plans. (Dunbar, 2001. Zalewski.M, 2004. Allen, 2012). Early European water legislation began with standards for abstractions, and in 1980 setting targets for drinking water. It also included quality objective legislation on water for fisheries, shellfish waters, bathing waters and ground waters. In 1988 a second phase of legislative improvements was made, and this resulted in a second phase of water legislation implementation 1991 (European Union Directive: European Parliament & Council, 2000). This included an Urban Waste Water Treatment Directive, The Nitrates Directive, a new Drinking Water Directive, and a Directive for Integrated Pollution and Prevention Control (IPCC). Policy responses in the past in Europe have typically used a mix of economic incentives (taxes and subsidies), environmental regulations, and farm advice and education. This has had mixed results however and policies have generally fallen short of requirements to meet water quality policy goals in agriculture, based on the reports recent OECD country experiences. (OECD, 2012). In reviewing the effectiveness of policies, a number of recommendations were forthcoming (OECD, 2012). These included a mix of policy instruments to address water pollution, such as compliance with existing water quality regulations and standards, polluter pays principle to fund enforcement, and removing perverse support in agriculture to lower pressure on water systems.

Water management in the US is managed by the United States Environmental Protection Authority (EPA) underpinned by an overarching science management framework called “WATERS” Watershed Assessment, Tracking and Environmental Results System. The EPA gathers water quality information to address public concerns such as the health of the watershed, provision of potable water, edible fish and swimmable waterways, (US EPA, 2013). Water quality assessments are made at a national level using the TMDL assessment. This programme works on several projects at a time across the state in fresh and salt water. The TMDL refers to the pollutant reductions a water body needs to meet the state’s water quality standards. TMDL’s include a strategy to implement those reductions in order to restore water quality. Identification of a problem pollutant occurs, then water quality goals are established, then a specific load (TMDL) allocation is assigned to each of the sources (this is based on the assimilative capacity of the water body). Monitoring ensures standards are met, (US EPA, 2013). The most critical problems faced by this authority in order of priority are: pathogens – (notably faecal coliform and protozoa), metals, nutrients, organic enrichment and sediment.

1.2 National Context: New Zealand

In NZ the responsibility for environmental monitoring and management lies with the Ministry for the Environment. Reliable national scale information is important for setting national environmental policy. New Zealand’s national environmental reporting programme uses 22 core environmental indicators, comprising 66 national datasets to measure and report on the health of the NZ environment and track changes over time (Ministry for the Environment, 2013). There are also the Environmental Report Cards: these are regular web-based reports to provide updates on environmental data. They cover the domains of air, atmosphere, energy, fresh water, household consumption, land, oceans, road transport and waste. (Ministry for the Environment, 2013) Five national environmental indicators are used to report regularly on the status of freshwater. River, lake, groundwater, recreational water quality, and freshwater demand are the key indicators reported on nationally.

A major challenge to water quality is the pressure being exerted by both the expansion and intensification of farming, especially dairy farming, (P.C.E 2004 and 2013). Dairying has expanded significantly in NZ the past two decades. The national dairy herd increased by approximately 82 per cent between 1980 and 2009, to nearly six million cows. This intensification has contributed to the decline of several essential ecosystem services including the provision of good-quality freshwater, (Abell, 2011). Many rivers draining farmland are unsuitable for swimming because of faecal contamination from farm animals, poor water clarity, and nuisance algal growths caused by excess nutrients. (Ballantine et al, 2010; Larned et al, 2004; P.C.E Report, 2004 and 2013). Furthermore, the groundwater quality in aquifers that exist under pastoral farming areas, particularly dairying areas, tend to have elevated nitrate and pathogen concentrations with an increasing number of sites breaching drinking water standards, (PCE, 2004 and 2013). The expansion and intensification of pastoral farming has largely occurred more marginal landscapes placing pressure not only on water and soil resources but also native biodiversity, (Macleod, 2006; Alibone, 2010; Baskaran, 2010; Carrick, 2013). Intensification of vulnerable landscapes continues despite a lack of research to quantify the actual nutrient losses from intensive dairying on stony soils, (Lillburne, 2010, Carrick, 2013). Young stony sand soils in Canterbury were shown to have a high potential leaching risk of nitrogen, phosphorus, carbon and cadmium in a scoping study (Carrick et al, 2014). Carrick recommended urgent large scale research programme into the effects of irrigation and intensification on vulnerable soils.

Mitigations to prevent nutrient loss from farms will increasingly impact on farm system design. Although mitigations may “hold the line” in terms of declining water quality, it is unlikely to be enough to prevent further deterioration in the face of large scale development of irrigation and intensification (>500,000 ha) proposed for NZ, (P.C.E Report, 2013).

New Zealand loses between 200 and 300 million tonnes of soil to the ocean every year. This rate is about 10 times faster than the rest of the world, and accounts for between 1.1 and 1.7 percent of the world’s total soil loss to the oceans, despite a land area of only 0.1 percent of the world’s total, (PCE, 2004).

1.2.1 River Water Quality Reporting in New Zealand.

River water quality monitoring in NZ includes nutrients (total and dissolved nitrogen and phosphorus concentrations including nitrate, ammoniacal nitrogen and dissolved reactive phosphorus), bacterial, visual clarity, water temperature, dissolved oxygen, and macro invertebrates, (NIWA , 2014).

Overall, river water quality has deteriorated over the past 20 years mainly as a result of diffuse losses from farming, (increased pastoral land cover) despite environmental gains being made in terms of reduced point pollution. (Ballantine, 2010) (Ballantine, 2013) A study conducted by NIWA on water quality state from 1998 -2007 provides and insight into the polluted state of NZ’s rivers. Nutrient concentrations, which contribute to nuisance algal blooms, toxic algae, and decreased ecosystem health, frequently exceeded the ANZECC (2000) trigger values for ecosystem health. Water quality has declined in NZ’s rivers and catchments dominated by pastoral land use, with nutrient enrichment, water clarity and pathogen levels significantly worse than found in hill country and mountain categories (Ballantine et al, 2010). More recently developed regions in NZ exhibited similar trends. For example, Total nitrogen and nitrate in the Waimakariri River has shown a rapid upswing, (Ballantine, 2010).

1.2.2 Lake Water Quality Reporting in New Zealand

Lake water quality is measured using the Trophic Level Index (TLI) which is widely used to measure changes in the total nitrogen, phosphorus, clarity and algal biomass (Burns, 1999). Lakes SPI: Lake Submerged Plant Indicator, this is also used to measure structure and composition corresponding to the native and invasive character of vegetation in a lake.

In a Lake Water (Status and Trends) Quality report by Verburg et al (2010) it was found that 44% were eutrophic (TLI >4) or worse. The TLI score increased with increasing percentage pastoral land cover and decreased with increasing percentage native or alpine land cover. When this data was extrapolated to all NZ lakes (3820 lakes nationwide) the data indicated that 32% would be eutrophic or worse while 43% would be oligotrophic or better.

1.2.3 Freshwater Demand in New Zealand.

Water allocation is another key issue that affects water quality, and regional authorities still allocate water where they believe it will not jeopardise the sustainability of supply. There is no price on water in NZ, yet in almost every region, there are over allocated catchments and the demand for water is increasing. Over the period between 1999 and 2010 NZ’s weekly water allocation increased by one third. Allocation to uses such as irrigation of pasture has doubled since 1999, and there has been a 65% increase in irrigation allocation for pastoral uses in Canterbury alone and forty-six percent of the total NZ water use is allocated for irrigation (Ministry for the Environment, 2013)

1.2.4 Regional Trends: Waikato

The indicators of water quality monitored at the regional level by Waikato regional council are in line with the National Indicators monitored by the Ministry for the Environment. Freshwater monitoring considers groundwater, lakes, rivers streams and wetlands.

Natural resources are seen as an integral part to lifestyle, and are of top concern for New Zealanders. In a recent study by Hughey (2013), it was shown that the public are not in favour of development at the expense of their environment, they want to see rivers and recreational values protected and on the whole, New Zealanders want water that is clean, swimmable, fishable and safe for food gathering. This concern is reflected in the Waikato by the community where 50% of respondents in 2006 identified this as a key issue. (Waikato Regional Council, 2013) Overall, the community "don't want" development to wreck fresh water environments they recreate in, they value the ecology and nature of these resources highly, (Baskaran, 2010; Hughey, 2013).

In a recent study by Vant, (2013) for the Waikato regional council, it was evident that trends were worsening. Clarity, for example has declined by 16% over the period of 1995-2013. This may be partly due to significant areas of pine to pasture conversions in the upper river catchment since 2000. Over 29,000 ha of pine to pasture conversions occurred over the period from 2002 to 2008, (Hill et al, 2011). Since 2008, a further 8-10,000 Ha of conversions have occurred and are continuing (W.Vant *pers comm Reg Council).* A trend analysis of river water quality data over two decades (1992-2013) by Vant (2013) shows that turbidity, clarity and nitrogen levels have continued to worsen while phosphorus and chlorophyll a have remained stable or slightly improved. Groundwater is showing a trend of increasing nitrate levels. Shallow lakes in the Waikato are not in good condition. Most Waikato lakes have moderate to extremely high levels of nutrient enrichment, with 30% being hypertrophic. (Waikato Regional Council 2013)

Research based on data from 73 stream sites across the Waikato region found that median *E. coli* concentrations in 53 sites exceeded the guideline for freshwater recreation (median of 126 cfu/100ml), (Collins, 2002). The pattern of contamination across the Waikato is dominated by the presence of grazing livestock and the highest median *E. coli* concentrations are associated with the most intensive dairy farming in the centre of the region, (PCE, 2004). More than 90% of streams in intensively farmed catchments in the region have moderate to high levels of nitrogen. (PCE, 2004). At present there is little information about microbial contamination of rural groundwater, however a study of 40 wells in

Matangi found that 12.5% were contaminated with faecal coliforms. (PCE, 2004). The Waikato River below Horotiu (just north of Hamilton) due to coliform concentrations breaching the primary contact recreation limits, (Waikato Regional Council, 2013).

1.3 Initiatives to Protect Water Quality in New Zealand

The National Policy Statement for Freshwater Management (NPS-FM) provided guidance for setting limits on water quality for NZ including defined timeframes within which those targets are to be achieved, (NZ Government 2013). Regional Councils will be required to set freshwater objectives and limits through a collaborative process with their communities.

The National Policy Statement for Freshwater Management in NZ, (2011) sets objectives and policies that direct local government to manage water in an integrated and sustainable way, while providing for economic growth within set water quality and quantity limits. It states that "the overall quality of fresh water within a region is maintained or improved while: a) protecting the quality of outstanding freshwater bodies, b) protecting the significant values of wetlands and, c) improving the quality of fresh water in water bodies that have been degraded by human activities to the point of being over-allocated." (NZ Government, 2011).

The policy makes it clear that where water bodies do not meet the freshwater objectives, regional councils must specify targets and methods to assist with improvement within a defined time frame. They must look at water bodies in the context of whole catchments, provide for involvement of iwi and hapu, and all regional councils must implement the changes as promptly as is reasonable, with full implementation of the policies no later than the end of 2030. Regional Plans would be used to manage activities and to ensure that the limits are not breached.

The Land and Water Forum aimed to bring together a range of industry groups, environmental and recreational NGOs, iwi, scientists, and other organisations with a stake in freshwater and land management in NZ. The Forum's objective was to develop a shared vision and a common way forward among all those with an interest in water, through a stakeholder led collaborative process. The first report of the Land and Water Forum, (LAWF) "A Fresh Start for Freshwater", was released in September 2010 and set out for the first time in NZ, a blueprint for change in land and water management in NZ. A second report was released by the LAWF in May 2012, aimed to set out a transparent process for setting objectives and limits. In November 2012, the forum released its third report, on "managing within limits." It recommended integrated decision making in catchments, continuous improvement of management practises to improve water quality and clearer rights to take and use water within set limits, (Land and Water Forum, 2013).

The second LAWF report noted quite clearly that NZ had difficulty setting limits. Without limits it is hard to manage diffuse discharges including nutrients, microbes, sediment and other contaminants. Limits provide certainty, that water can be used for a variety of purposes without unintended and unforeseen consequences. They inform users about the extractive and assimilative capacity of water bodies available for use, protect the key resources and help provide a more certain investment environment. The LAWF acknowledged that there are governance issues, and some regional councils need additional resources and stronger governance skills, (LAWF, 2012). Meeting limits may mean more efficient resource use, tighter regulatory controls, changes in existing land-use practice (including improved management of farming systems) and a limited amount of land-use change in some catchments, (MfE, 2013).

1.3.1 Setting Freshwater Objectives in New Zealand

"Freshwater objectives are the intended environmental outcomes for a water body that will provide for the values the community considers important." The proposed changes to the NPS-FM, has been the inclusion of National Objectives Framework (NOF) (2013). The primary issue that NOF was to address was to provide a framework which ensured that the life supporting capacity and ecosystem processes of freshwater were safeguarded, while meeting community and iwi aspirations for fresh water.

The National Objectives Framework will be implemented through regulation using the underpinning of the National Freshwater Statement for Freshwater 2011.

Other work has included economic analysis and modelling to test what environmental bottom lines will be tolerable for the various agricultural industries, without significant economic disruption, (Kaye-Blake et al, 2013, Snelder, 2013)

The third and final report released by LAWF deals in detail with the linked issues of water quality and allocation of water, (LAWF, 2012). A challenge highlighted, was the differences in the consenting processes whereby quantity and quality of water were dislocated in the planning and consenting process. Abstraction affects quality and quantity of water. In recommendation 8 (LAWF, 2012), a clear directive was for regional councils to go about setting freshwater objectives and limits including the identification of contaminants of concern and total load of each, in each catchment. A key issue raised by the LAWF, 2012 was that Regional Councils in NZ require more accountability, need to develop consistency of measurement and be open to independent auditing and scrutiny on their performance.

It is clear that degraded freshwater quality has negative consequences for all those who share the resource. Taxpayers and ratepayers bear the cost of poor management decisions that allow degradation to happen. Approximately $500 million of government and community money is committed to the clean-up of just eight lakes and rivers across NZ. The “clean up initiative” also brings together a number of existing one-off clean- ups in Waikato, Rotorua, and Taupo. The external costs of agriculture include a decline in recreational opportunities, reduced landscape and visual values, and the constraints on supply of, or additional treatment requirements for, drinking water, (Abell, 2011). The cost is external because individual farmers usually bear only a small share of the costs (economic, social and environmental) that arise from the depletion of the ecosystem services resulting from diffuse losses from farmland, (Baskaran etal , 2010; Abell, 2011).

1.4 The Challenge of Economy versus the Environment

Dairy made a contribution of $14 billion to the national economy in 2013-14 and is the most significant type of agriculture in the primary sector in terms of earnings. It is expected that dairy exports will continue to increase at 8% per annum to contribute $17.7 billion in 2016-17. (i.e.: >40% of the primary sector income), (Ministry for Primary Industries, 2013). Dairying is now a major land use across NZ. Milk production increased by 47% in 10 years (2003-2013) to reach 1.69 billion kg of milk solids (MS) produced in 2012 and the industry now accounts for 21% of NZ's grassland area and 46% of total stock units, (Dairy NZ, 2013). A typical NZ cow is equivalent to 8 stock units. The sheep and beef industry faces challenges and stock numbers are set to decline due to difficult years, droughts and competition from dairy. Increasingly the sheep and beef industry provides support and grazing for dairying. Both dairy and dairy support, have higher rates of nutrient loss than extensive pastoral agriculture. (NZIER, 2013; P.C.E, 2013). PCE, (2013) notes that a trend towards more dairying and its associated support land will continue, while commodity prices favours industry growth, as a result, water quality is likely to continue to decline.

As yet in New Zealand, comprehensive trials implementing best practice at a sub-catchment scale in intensively farmed areas have failed to show that they can achieve water quality standards. Studies in the "best dairying catchments" of Waiokura and Toenepi over ten years have shown that stock exclusion and effluent management changes have not yet achieved contact recreation standards, (Waikato Regional Council, 2010). Hamilton and Mc Dowell (2013) note that there is a gap in the literature, linking action at the farm gate to an effect in the receiving environment to support land owners to make sound management changes on and to their land. This will require mixing multiple disciplines and research across a range of temporal and spatial sites. (Mc Dowell, 2013)

New Zealand dairy systems have not only expanded into new areas, but have also intensified in the last 10 years as shown in Table 1. Farm working expenses have increased by 190% over the past 13 years. (Greig, 2012; Dairy NZ 2013; Intelact NZ, 2014). Herd sizes have increased, along with milk production, reliance on bought in feeds such as palm kernel expeller, stocking rates, land prices and debt levels.

Table 1.1 - Table Derived from Greig (2012) Changing Dairy Farm Systems in NZ

	1998-99	2008-2009	2012- 13	% change
Dairy Herds	14400	11400	11798	-18%
No. cows milked	3.3m	4.2m	5.01m	+35%
Average herd size	229	364	393	+42%
Average stocking rate In cows per hectare.	2.5	2.8	2.3-3.3	
Total Milksolids per herd	70000	120000	141125	100%
Tonnes of PKE + other feed imports to NZ	0	1,300,000T	1,889,000T	
PKE kg fed per cow on average	0		407 kg	
Milksolids derived from PKE + other	0		170 m	
Value of Milk Derived from PKE/other	0		$1190 M	
National production (million litres)	880m	1393m	1665m	95%
Land Price $/kg MS	18.4	50.8	$40.46	126%
Farm working expenses per kg MS	2.13	3.85	4.08	190%
Liabilities/kg MS	8.03	19.87	19.24	145%
Debt Servicing/Gross Farm Revenue. (%)	14.9	28.3	18.1	30%

The choice of farm system is largely influenced have evolved as farmers attempt to mitigate risk instinctively, (Greig, 2012). Desire by farmers on overstocked farms to avoid seasonal feed deficits from higher stocking rates, (1990's and early 2000) has resulted in the NZ dairy industry having a significant and increasing dependence on Palm Kernel Expeller (PKE) since its importation to NZ in 2003. At $300 per tonne, this supplementary feed is competitively priced in relation to the option of expanding a farming business to procure more pasture (generated from high cost land), (Dias et al, 2008). PKE availability has resulted in farm systems continuing to carry higher levels of stock and intensify (relative to the landscapes productive potential), and as a result, around 10% of NZ milk solids are now generated from PKE.

Economic principles of agricultural production are based around decisions arising from the relative prices of inputs and outputs, (Greig, 2012). Recent proposals for irrigation such as Ruataniwha dam include water price of 22-25c m^3. Farm working expenses for a dairy farm in this scheme are around $5.50 a kg MS, when accounting for irrigation water. (Dewes 2013). Including debt servicing, the full cost is $7.30 -$7.50 per kg MS. Irrigation of dairy in a scheme such as this results in the cost of production being 250% greater than 1988-99 while milk solids prices have only risen approximately 100% since that time.

Farm systems change continues to occur rapidly in NZ, and intensification of farm systems entails higher risk: both economic (due to diminished margins), and environmental (requirement for more complex mitigations). Recently converted farms in Canterbury for example, are more intensive than those at a national level. Sixty three percent of farm systems in Canterbury were reported as importing 20-50% of their feed (via direct supplements or off farm grazing) (Agfirst Waikato, 2009). Intensive systems rely on support land to supply feed requirements for young stock, wintering cows, and supplementation. Canterbury, for example, where there is diffuse nitrogen enrichment of surface and groundwater, (Ford, 2012) support land area is 50-100% of the irrigated dairy milking platform area. This situation results in intensification of extensive pastoral agriculture catchments to support more intensive farm systems. More intensive systems are both vulnerable e.g. from climatic or commodity price fluctuations, but are also coupled with an increased risk of contaminant losses; (Monaghan, 2007; Kaye-Blake et al, 2013; P.C.E, 2013),

As part of adaptive management, all agricultural systems should be regularly assessed on their “farm system risk to the receiving environment”. Several metrics to assess farm system risk are preferred due to their sensitivity to change as a function of land management change, (Sydorovych, 2009). Metrics should be applicable across all sectors of agriculture, and clearly understood by farmers and policy makers. Indicators providing quantifiable results and science based thresholds are preferable, (van der Werf, 2001). Internationally, there have been a range of agri-environmental indicators (AEI’s) developed to validate an agricultural systems risk combining of “management based” and “environmental effects” based metrics, (van der Werf, 2001; Galan, 2007; Pretty, 2008).

It is evident that farm systems reconfiguration will be required in order to meet environmental outcomes. Dairy NZ work has demonstrated that an 18-40% reduction in N loss is possible through farm system change with adversely affecting profitability in some cases. (Beukes et al, 2012; Clark 2012, Dairy NZ

2013). This may involve lower bodyweight (stocking rates) carried per hectare, (Beukes et al 2012) reducing replacement rates combined with high genetic- merit cows, on well balanced diets, enhanced feed conversion efficiency and improved effluent capture with widespread low risk application to pasture (>40% of farm area), reducing the need for soluble fertiliser use.

Debt and vulnerability of the dairy sector may hamper rapid response times to environmental compliance by the industry. New Zealand's dairy sector debt nearly tripled over the past decade, to $30.5 billion in 2012, (Ministry for Primary Industries, 2013). Extended and more frequent periods of dry weather in some regions increases the vulnerability of dairy farmers through lower milk revenues and higher feed costs,(Kalaugher et al, 2013). It was estimated that 40% of North Island dairy farmers could not meet their expenses and debt obligations as a result of the 2012-13 drought, (Ministry for Primary Industries, 2013).

Government initiatives are strongly supportive of further intensification of both marginal landscapes and increased irrigation. (Funding Programmes for Irrigation, 2013) There is a goal to drive an annual growth rate of 7% per annum in the agricultural sector (Riddet Institute, 2010) through a combination of strategies, capture, storage and better use of freshwater, along with improved productivity of Maori Owned Land, (Price Waterhouse Coopers, 2013) as well as increased productivity from current agriculture. The growth seen in agriculture between 1985 and 2011 was 3%. The Agribusiness Agenda (KPMG, 2013) aiming to double agricultural output by 2025, will place considerably more pressure on to a national landscape suffering from decades of poorly regulated intensification. A big challenge is how we manage and balance growth as a nation. Integrated approaches and practices will be required to help farming reduce the negative impacts of production on the environment whilst maintaining economic viability, (Cook, 2009; Mc Dowell & Hamilton 2013).

1.4.1 Agri -environmental Indicators of Risks and Effects from Dairy Farm Practices.

1.4.1.1 Greenhouse Gas and Nutrient Emissions

Agriculture contributes about 60% of New Zealand's total greenhouse gas emissions, with 90% of these agricultural emissions comprising CH4 and N2O in terms of CO2 equivalents. (De Klein, 2002). The principle source of agricultural methane is enteric fermentation in the digestive tract of ruminants, (DeKlein, 2001). Along with gaseous emissions, nitrate (NO 3) leaching and water contamination is a major environmental issue around the globe. In grazed grassland, most of the nitrate leaching occurs in patches of animal urine because of high nitrogen (N) loading rates on a small area, (Di.H, 2007). Thus the predominant source of nitrogen loss from dairy farming is that from urine patches.

OVERSEER is a nutrient management decision support tool based on nutrient budgeting at a farm scale. The model has been applied widely to New Zealand farming systems and is widely used to estimate nitrogen discharges at the individual farm level, (Monaghan, 2007). Nitrogen discharges are estimated based on the main potential sources (cow urine, manure, milking shed effluent and fertilizer), and losses are based on animal type and productivity, soil group, drainage status and rainfall, (Ramilan, 2011). The model estimates losses to the environment at the boundary of the farm system e.g. N loss to water (leaching), P run-off risk and greenhouse gas emissions. Best Management Practises (BMPs) are assumed in all OVERSEER simulations, (Wheeler 2013). The model assumes there is no direct input of excreta to waterways, such as direct animal access to streams/rivers or via stock crossings, tracks or lanes and that the effluent storage ponds are lined with impermeable materials and effluent is only applied under low risk conditions. (Appendix 5) If these best practices are not conducted, the nutrient loss to waterways will be higher than what is reported by OVERSEER, (Wheeler 2013; Horne, *pers comm*, 2013). Nitrogen loss risk (kg N ha^{-1} yr^{-1}) as an output from OVERSEER is widely accepted in NZ as the best indicator of a farms risk to the receiving water body

Indicators such as nutrient use efficiency and nutrient loss are "effects based measures from farming activities." These measures are used quantify the risk of an activity to the receiving environment. Nutrient loss risk should be read in association with nitrogen (N) surplus and N conversion efficiency. The N surplus per hectare is defined as the difference between input and output of N divided by the size of the farm in hectares, (Beukes,2012). Small surpluses mean a reduced pressure on the environment per hectare, (Halberg,1999). Nitrogen conversion efficiency (an OVERSEER output) can be a useful measure to read alongside N loss.

Phosphorus loss is also important. Seventy percent of dairy farms on volcanic soils are operating with high or excessive soil Olsen P levels which is high risk, (Waikato Regional Council 2008; Ledgard, 2011). Serious losses occur when there is soil damage such as pugging and runoff events on exposed or ploughed soils occurs, (Monaghan, 2007; Mc Dowell & Wilcock 2004 &2007 and Mc Dowell 2013; Waikato Regional Council, 2013). “Critical source areas” such as erosion proned areas, lack of waterways fencing, fertiliser form, crop and soil damage, raceway runoff , intensively stocked areas, and high risk effluent application processes, need spatial and temporal identification and mitigation across catchments, (Monaghan, 2007; Ledgard, 2011; Houlbrooke, 2013, Mc Dowell ,2007, 2009 & 2013). The P loss risk measured by OVERSEER however, does not take into account storm events, runoff from 1st and 2nd order streams which are farmed as part of a grazing platform in many cases, and assumes all best practices are always in place. (Mc Dowell 2013).

1.4.1.2 Soil Protection and Effluent Management

Environmental monitoring of Waikato regional rivers and streams indicates that levels of bacteria exceed the Australian and New Zealand guidelines for Fresh and Marine Water Quality 2000 in 75% of sites, and are too excessive for people to swim safely in 70% of monitored sites. (Environment Waikato, 2008). The process-based understanding of Faecal Indicator Organism fate and transport at the catchment-scale is, at best, rudimentary, (Monaghan, 2007; Kay, 2008; Muirhead, 2013). High risk connectivity points such as stock feeding areas, tracks, crossings, sub surface drains, and effluent discharges to high risk soil types all provide opportunities for direct runoff or deposition of pathogens as well as nutrient into receiving waters. (Monaghan, 2005 & 2007; Richie 2010; Wheeler 2013)

1.4.1.3 Waterway, Wetland Protection and Biodiversity Support

Direct waterway protection on farm involving stock exclusion and protective planting is an important part of reducing impacts and supporting native biodiversity. (Beswell et al, 2007;Collins et al, 2007;Wilcock et al, 2009) Waikato has one of the highest rates of biodiversity loss compared to other regions in New Zealand – only 26 per cent of the region remains in native vegetation and this is fragmented into thousands of small patches mostly in hill country. New Zealand has the highest proportion of threatened freshwater fish species (68%). This number has been increasing over time – up from 20% in 1992. (Alibone et al, 2010).

1.4.1.4 Water Use Efficiency

The demonstration of water use efficiencies and water saving technologies in the farm system are increasingly important as agriculture is the major abstractor of water in most countries. Future food systems will need to operate with less water, (Wallace, 2000). Pressures are already arising from urbanisation, industrialisation, degrading water sources and climate change. (OECD, 2012). Where water is used for irrigation of pasture, expected practices will include the use of technologies to monitor abstraction, ensuring precise and efficient use occurs with minimal runoff to groundwater for designated crops. (Evans, 2013) (Hedley, 2012)

1.4.1.5 Energy Use and Waste Management Practices

Energy usage on farm can be linked with increased greenhouse gas emissions and costs Therefore using low cost or low emission energy generation with in production systems is beneficial and of lower impact, (Barber, 2005).

Waste management on farm is also is cause for concern. At present, burning and burying of waste on farms the most common waste disposal method, and was carried out by more than 60% of farmers surveyed by Taranaki Regional Council in 2004. (Taranaki Regional Council, 2005). Recently, Environment Canterbury has reminded farmers that from 2014, they will not be able to burn polyethylene agricultural silage/bale wraps but are to use product stewardship schemes, such as Plasback or Agrorecovery. (Environment Canterbury, 2014).

1.4.1.6 Quantifying the Environmental Risks from Farming Systems.

It is evident there is an urgent need to quantify risk to the receiving environment from different farming systems in NZ. There is growing awareness that it is possible for eco-efficient agriculture to result in increased productivity while concurrently reducing negative environmental impacts, (Keating, 2013; Roberts, 2013). Demand for easy to understand measures of environmental and social sustainability of food systems is growing rapidly, driven by greater producer awareness of public perception and the need to inform catchment groups and policy makers, (van der Werf, 2001; King, 2000; Jay, 2008; Pretty, 2008). Suppliers of agricultural food products are increasingly expected to demonstrate a deep understanding of the environmental and social attributes of their products. This should include the materials and energy used, potential human and ecological health impacts, and product development, (Pretty, 2008; Aneilski, 2010).

1.5 Objectives of the Study

Using economic and environmental data of 25 Upper Waikato farms, this study set out to test what management criteria contribute to a lower environmental footprint and more economically resilient farm systems. These factors are considered important in the context of a volatile commodity market, changing climatic conditions and a national review of water policy. In Chapter 2 the development of an environmental scorecard is described. This scorecard is designed to quantify a farms risk to the receiving environment. It was hypothesised that economic prosperity and resilience of farm systems may not be compromised by careful reductions of diffuse losses and improved environmental performance. In Chapter 3 the economic performance of farms with good environmental performance was examined, based on their return on capital. Economic resilience is described as the farm systems that can demonstrate both strong and the most stable return on capital when milk prices alter by 20% or more. Specific features of farm management were sought that conferred profitability and resilience of these farms.

Chapter 2 : Measuring environmental performance in dairy farm systems in the Upper Waikato River Catchment.

2.1 Introduction

There has been widespread reporting of the environmental impacts of intensive agriculture on water bodies, (Larned et al 2004; Baskaran, 2010; Edgar, 2010; Abell et al, 2011; Ballantine, 2013; Doole, 2013; Vant, 2013). The New Zealand dairy industry in particular has received widespread public comment of its adverse environmental effects resulting from rapid intensification, (P.C.E 2004 and 2013). Freshwater bodies in NZ are highly regarded internationally for their recreational values. However agricultural externalities contribute to declining aquatic ecosystem as well as public health issues. The increase pathogenic micro-organism loads to surface and ground waters from agricultural land uses result in high rates of zoonotic and enteric disease and loss of public amenity, (Larned, 2004; Kay, 2008; Mc Bride, 2011). Coliforms, campylobacter, cryptosporidium, and salmonella are among common pathogens of concern.

In the past decade, nitrate concentrations have increased sharply while in some regions, phosphorus concentrations have decreased, (Vant, 2013). Nevertheless, much of the phosphorus entering fresh water will continue to accumulate as sediment in river and lake beds creating a legacy for the future, (Mc Dowell & Wilcock, 2004, 2007; Mc Dowell, 2013; Abell et al, 2011). While mitigation has become a major focus of changing farm practices (Lou et al, 2007; Monaghan, 2008; Beukes et al, 2012) , it may not on its own be enough to retard declining freshwater trends and continued intensification in some areas, (PCE Report, 2013).

The Waikato region encompasses most of New Zealand's central North Island with a land area of about 2.5×10^{6} ha. About half is pastoral with slightly more than half comprising dairy land use, (Hill, 2011). The Upper catchment between Karapiro and Taupo comprises an area of 0.44×10^{6} ha. Within the Upper catchment, 52% of land cover is exotic forest, indigenous vegetation, scrub, or unmanaged areas, while 45.7% is being for agricultural purposes.

Over the past one hundred years, there have been sweeping changes to the landscape in the catchment. In the early 20th century most of the hill and lower country was cleared for farming. Native timber was logged north and west of Lake Taupo. Plantation forestry began in the 1920s and 1930s and still covers much of the land in the Upper catchment, (Woods et al, 2010; Collier et al, 2010; Hill, 2011). In the early 20th century, most of the hill and lower country was cleared for pastoral agriculture. Bush sickness (cobalt deficiency) resulted in a lot of this land being converted to forestry, (Collier et al, 2010), but since the 1940's bush sickness has been remedied with cobalt - enriched fertiliser, and vitamin B^{12} supplementation (Hawke et al, 1994) . Forestry plantations are now being cleared and converted to intensive, partially irrigated dairy farming. The potential conversion of 567 km^2 of forest (24% of the existing forested land) to pastoral agriculture over the next 15 years represents 12% of the total upper Waikato catchment, (Vant, 2013)

Since 2002 there has been intensification and greater area of pastoral land within the catchment with conversion of commercial forestry land into pastoral farms (over 35,000 Ha by 2013, (pers comm W.N. Vant, Waikato Regional Council). A land area of 29,044 ha of land was converted from pine to pasture between 2002 and 2008 in the upper Waikato catchment, (Hill, 2011). This transition from pine to pasture, for example, will result in a 5-10 fold increase in diffuse nitrogen loss and a 5 to 10 fold increase in phosphorus loss (OVERSEER version 6.1) (PCE 2013). The resulting increase in nutrient loads may be 2012 t nitrogen and 120 t phosphorus per year and in addition there will be increased sediment loads, contributing to reduced water clarity; and increased coliform loads. (Woods 2010, Dewes, 2013). Increasing pressure to assimilate these loads will mean that nutrient losses of sediment and nutrient from land need to be reduced. Therefore, identification and quantification of both risks (management) and effects (output measures that result from farm practices) such as a scorecard or dashboard applicable to pastoral agricultural systems to guide farmers towards lower impact farming systems. (Pretty 2008; Paterson, 2014)

The OVERSEER nutrient budget model has provided the basis for determining compliance by farmers to meet diffuse nutrient limit targets in recently agreed regional plan changes in New Zealand. For example, the Horizons Regional Plan 2012 (the "One Plan") provides farmers with consent to farm on the provision that they demonstrate meeting nitrogen (N) loss target by a set date. In sensitive catchments, consents are issued on the basis that the whole- farm N loss meets the target within a set date, using the current version of OVERSEER at the time. Otherwise the farm must provide a plan indicating how it will meet the target within a certain time frame. (Taylor *pers comm*, 2014). Farms applying for consent must provide a farm plan to quantify the approach and provide assurance to the regional council that their nitrogen reduction plans and effluent management system are compliant with best practice standards. The approach of using farm plans as a policy tool has also been adopted in both the Hurunui and Canterbury Land and Water Plan (2013) and the Tukituki River Catchment Plan (Change 6) 2014.

A range of agri-environmental indicators (AEI's) presented in a scorecard format could provide a more comprehensive measure of the risk associated with a range of farm management approaches. The AEI's should be scientifically sound, quantifiable, refer to issues relevant at catchment scale, be acceptable to target groups, easy to interpret, and cost effective. They therefore become more accessible for use by farmers, resource managers and policy makers. (Parris,1998; Langeveld, 2007; Pretty, 2008; Sydorovych, 2009; Paterson 2014).

Report cards or scorecards, and output measures (such as nutrient loss metrics from OVERSEER) are gaining favour as a method of succinctly informing a wider audience of the environmental impacts from agricultural production. (Lillywhite, 2008; Aneilski,2010). The process of scoring farms and working with farmers can prove to be as valuable as the ability to demonstrate to the public that legitimate processes are in place to avoid environmental effects, (Pretty, 2008). Scorecards need to reflect regional risk factors such as phosphorus, nitrogen and pathogen loss risk to the receiving environment. (van der Werf, 2001; Pretty, 2008; Aneilski, 2010). They have been used on occasion in New Zealand agriculture. There is the visual soil assessment (VSA) that scores biophysical indicators of soil quality, (VSA Book, 2005), also SINDI which is a web based tool developed by Landcare Research, which uses key parameters to score soil health. (Landcare Research, 2014). Saunders et al, (2007) reviewed environmental and financial performance scorecards developed in NZ for sheep and beef and kiwifruit orchards. Paterson et al, (2014) are developing an environmental management system (EMS) dashboard (scorecard) in an effort to describe on farm improvements to meet agreed environmental targets for catchments. Internationally, corporates such as Unilever attempted to develop an agricultural sustainability index, (Pretty, 2008). The indicators included soil fertility and health, sediment loss risk, nutrient and emission loss risk, pest management, biodiversity support, animal welfare measures along with other contextual indicators such as the benefit to the local economy, (Pretty, 2008).

Selection of suitable indicators for environmental impacts of agriculture needs to take account of the following: impacts on the receiving environment as a result of the agriculture, measures that are readily accessible and robust and commonly acceptable, usefulness in assisting farmers to plan to respond to the high risk issues. (van der Werf, 2001; Galan, 2007; Langeveld, 2007; Lillywhite, 2008; Parris, 1998; Sydorovych, 2009; Aneilski, 2010)

The aim of this chapter was to develop a quantitative scorecard to indicate farm impact on the receiving environment. The scorecard is designed to allow farmers to evaluate how their management and mitigation strategies change as they can be adapted to best management practices.

Farm management and OVERSEER data from 25 dairy farms in the Upper Waikato River catchment were used to allow comparative evaluation of farm performance. The approach developed in this chapter is complemented by an economic performance evaluation developed in the second part of this study: Chapter 3.

2.2 Methods

2.2.1 Study Site

The upper Waikato catchment between Karapiro and Taupo comprises an area of 4,400 km^2. The Waikato River below Taupo flows along 336 km of river channel, is fed by over 17,000 km of tributary streams, and drains a catchment area of 11,013 km^2. This sub-catchment is characterised by pumice soils that are erosion sensitive, (Taylor, 2009).

Within this upper catchment, 52% of land cover is exotic forest, indigenous vegetation, scrub, or unmanaged areas, while 45.7% is used for agricultural purposes with potential for further conversion of 567 km^2 of forest (24% of the existing forested land) to pastoral agriculture, (Woods et al, 2010). The upper catchment comprises a mixture of steep to moderately steep land: (42% of land area) with land cover evenly spread between pastoral land and planted forest. There are approximately 200 dairy farms in the study area and around 700 dairy farms in the Upper Catchment, (Collier et al, 2010).

Twenty five farms in the Upper Catchment from Mihi Bridge to Atiamuri Dam, were selected for this study using the following criteria: (1) availability of accurate farm and financial reporting information over at least one year (2) willingness to discuss financial and physical farm performance, participate in the group, and share information and (3) demonstrated motivation to understand and improve environmental and economic performance.

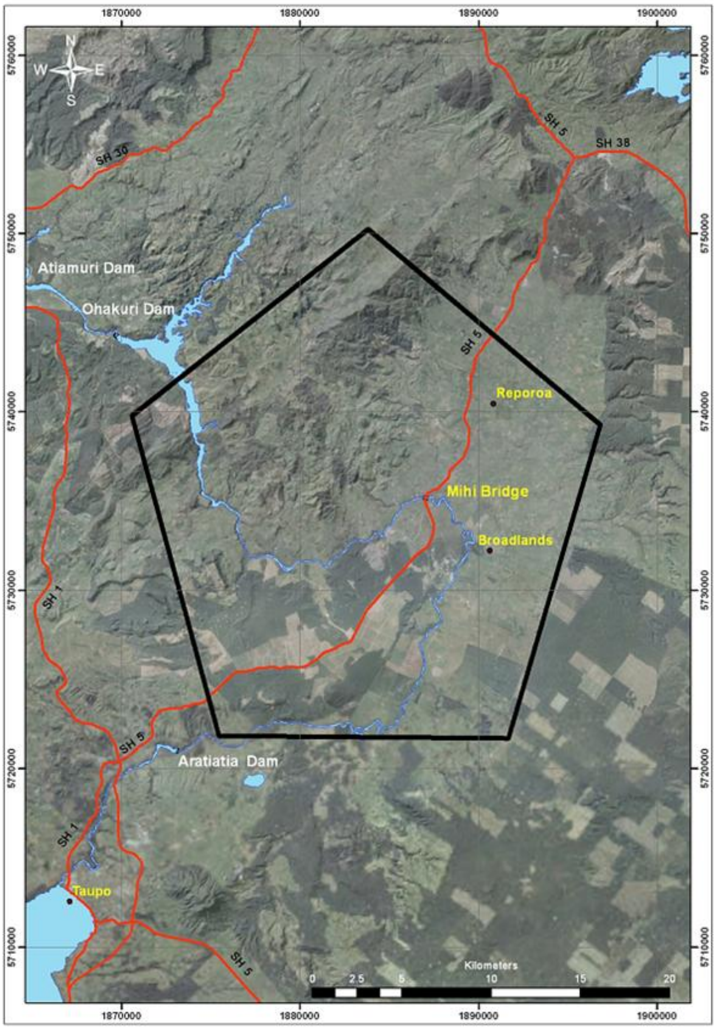

Figure 2.1 - Map of study area - upper Waikato

2.2.2 Information Collection and Scorecard Development

The farm information was collected and analysed for the year of 2010-11 and 2011-12 At a farm visit, data was collected using farm input purchase records, observation of environmental practices (Appendix 1) and an interview with the farmer including consultation about the farm's biophysical characteristics, the collection of financial accounts (see Chapter 3 for more detail), fertiliser and feeding histories, and any details required to update the OVERSEER model. Groups of indicators were compared with the latest available "best management codes of practice" by the dairy industry, and weighted based on whether they were "improved or best practises" as described in Table 2.

Management practices and OVERSEER outputs were scored from best to poor. Higher “total risk points” were given, for higher risk activities undertaken. E.g.: extensive cropping areas, wintering full time on fodder crops, or unlined effluent ponds. The criteria for allocation of risk points are provided in Table 2. These “risk point totals” for each subsection were then averaged for a cluster of indicators, such as nutrient efficiency, nutrient loss risk, or waterway protection as shown in Table 3. A scorecard example is provided in appendix. 4

2.2.3 Agri- Environmental Indicator Selection

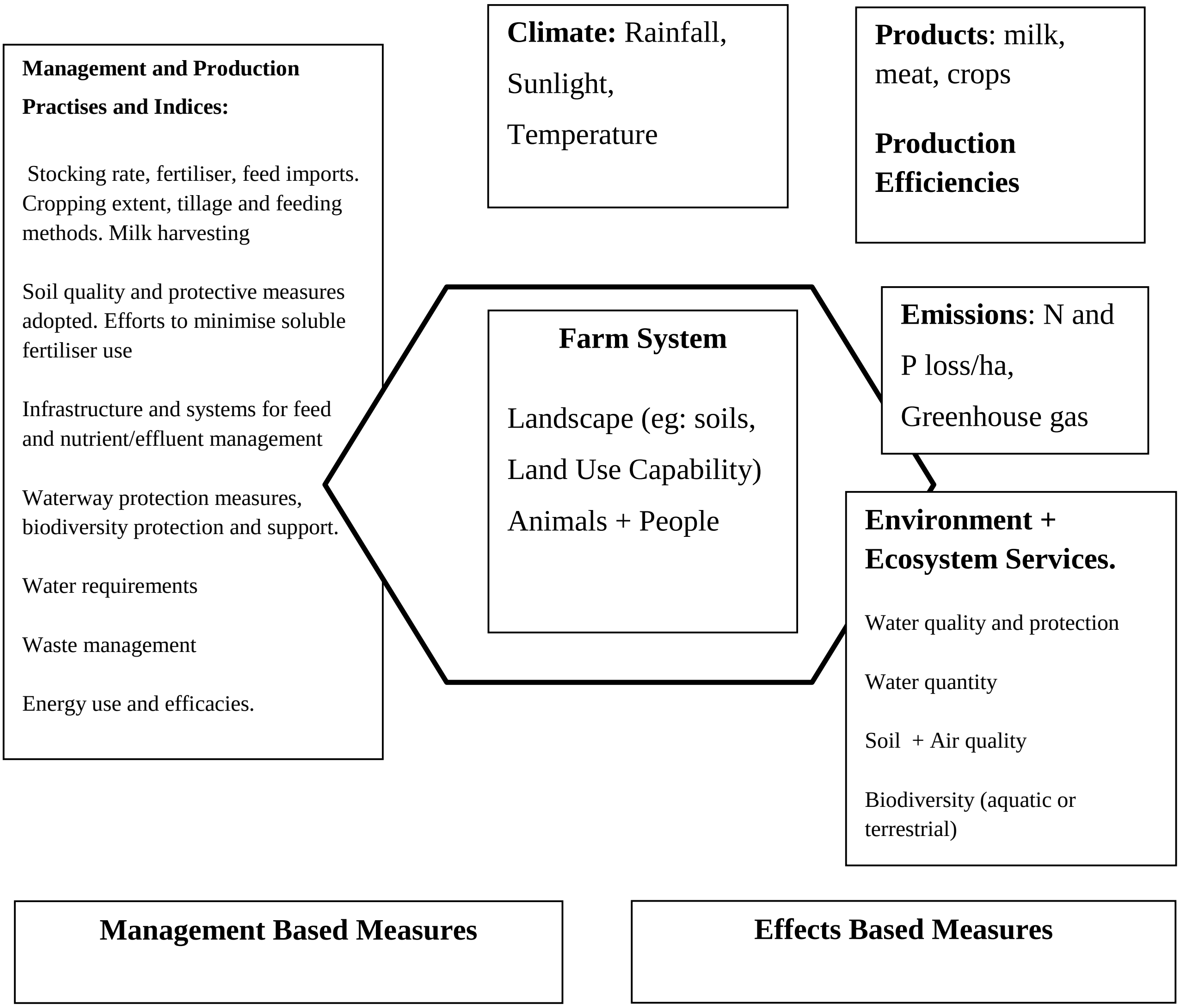

Figure 2.2 - Diagram of the Agri - Environmental indicators (management and effects based) for Waikato dairy Systems

(Figure 2.2 was Developed from concepts in (van der Werf, 2001; Galan, 2007; Pretty, 2008)

2.2.4 Criteria Used to Score Farm Practices and Agri – Environmental Indicators

Table 2.1 - Scoring Criteria of the farming system using OVERSEER outputs and farm management practises

Reporoa Tomorrows Farms Today Group		
Agri Environmental Indicator Section (weighting in brackets)	Units	1 Excellent performance or in line with best management practices 2. Good performance, low risk 3. Average performance, moderate risk 4. Poor performance, needs attention, higher risk to environment 5. Urgent action required: non-compliant (with regional rules) very high risk to receiving environment.
Nutrient Efficiency (OVERSEER outputs)		
GHG g/kg MS (33% of weighting for nutrient efficiency)	CO_2 equiv per kg MS	(1) <8 (2) 8-11. (3) 11-13. (4) >13. (5) >15
Nitrogen Surplus kg N/Ha (33%)	kg	(1) <140 kg. (2) 140-160 (3) 160-180 (4)180-200 (5) >200
Nitrogen Conversion Efficiency % (33%)	%	(1) >40. (2) 35-40 (3) 30-35 (4) 25-30 (5) 20-25
Nutrient Loading (Using OVERSEER model outputs)		
Kg N Leached/Ha (50% weighting of nutrient loading)	Kg N/ha/yr.	(1 <26. (2)26-30 (3) 30-35 (4) 35-45. (5) >45
Kg P Runoff or Loss/Ha (50%)	Kg P/ha/yr	(1) < 0.5. (2) 0.5-1.0 (3) 1.0-2 (4) 2.0-3.0 (5) > 3
Waterway Protection / Biodiversity support (Farm Inspection/ Environment Questionnaire)		
% of waterway fenced stock Exclusion (20% of weighting for biodiversity)	% of waterway fenced	(1) 100 (2) >90 (3) >80 (4) >50 % (5) < 50%

Riparian Planting 1.5 – 10m	% of waterway planted.(a)	(1>70% has Riparian Planting> 5m (2) >50% planted >5m. (3) >30% planted > 5m. (4) 10-30% planted> 5m. (5) No planting or buffer zone on stream banks
Biodiversity Protection - convenants/QE11/etc Biodiversity protection on private land (20%)		(1) Covenants in Place in Perpetuity on Title for 100% of significant sites, (2) > 50% % of Bush is protected with stock proof fences. (3) >50% of Bush is protected but not covenanted. (4) 30 % of bush is protected but not covenanted. (5) Bush or significant sites are on farm, no protection.
Wetlands fenced and protection/enhancement of ephemeral waterways. (20%)	% protection.	(1) 100% Wetlands and ephemeral stream areas are fenced and stock is permanently excluded. (2) Most of the wetland areas are fenced off most of the time. (3) Wetlands are planned to be fenced and protected/planted in next few years (plans with Council for fencing underway). (4) No wetland protection is in place/ nor planned (5) Wetlands are drained and managed for pasture.
Points of Connectivity to Waterways. Bridges over streams, crossings, runoff from tracks to water. (20%)		(1)All points of connectivity are managed or mitigated. Suitable bridges and crossings at all points. Bridges and culverts have nibs or edges to prevent effluent contact with water. (2)All major crossings are managed with infrastructure. Berms or buffers are in place to capture run off from down- hill tracks in order to intercept hot spots. (3) Crossings are suitable but there are some points of connectivity from tracks to waterways, sloping tracks do not always have the runoff intercepted by buffers. (4) Cows are still crossing or contacting streams more than 2 times per week year round. Connectivity from tracks to water is still occurring. (5) Cows are crossing streams and waterways regularly, and entering wetlands that drain to waterways. There are multiple points of connectivity from tracks, underpasses and crops.
Effluent Management		
Meets Requirements for herd & Farm System (compliance with regional rules)	Performance based on latest regional council rules	(1)Farm system has been reviewed, effluent storage and N loading is better than required by permitted activity rules for Waikato Region. (2) Farm system reviewed, storage being increased, extensions planned to effluent area to improve nutrient efficiency. (3)Farm effluent system is adequate for storage, meets present rules. Pond capacity marginal when checked on Pond Storage calculator. (4) Effluent Storage is just keeping up with demand. OVERSEER

	and Code or BMP.(b)	Analysis indicates larger area required to meet N loading requirements. (5) Indications of non compliance and storage or extension required to reduce risk.
Lined Pond and Capacity (25%)		(1)Pond is fully lined with an impermeable liner. Capacity checked using latest pond storage calculator tool (qualified person). (2)Pond is lined or clay sealed, can provide engineer report. Adequate storage for breakdowns and to allow for low risk effluent application to land. (3)Effluent storage is a holding pond that is regularly emptied in a low risk way to receiving land. Pond has not been tested by the PSC. Sealing of the pond may be required, or a new pond constructed. The farmer is investigating this process. (4)Insufficient capacity to hold effluent over high risk or emergency times. Pond is able to overflow in high risk times, or could have contact with groundwater (seepage). (5) Sump or holding capacity is for emergency only. There is not sufficient capacity for deferred irrigation of any type. There is potential for surface and groundwater contamination.
Effluent % area spread over farm % of Farm Area on which Effluent is Re-used (10% is Standard). (25% of weighting in this category)	% of whole farm area irrigated.	(1) > 40% and meets N + K loading requirements. (2) >25% and meets N loading requirements. (3) >15% meets N loading requirements. (4) <10% of farm area. Changes to system means farm system review required for N loading. (5) Effluent area required extension.
Application management (alerts in place) (25%) Effluent Application Risk Management	Has the system adopted latest technology and staff training for risk management?	(1) Automatic shut-off when irrigator enters buffer zones and/or stops moving. Staff fully trained to manage effluent system. (2) Staff trained operations are monitored with an early warning system that is reliable. (3) Irrigation is regularly checked, and ponds are managed to ensure they are never full, or at capacity. (4) Warning systems need to be put in place. (5) Ponds fill quickly, irrigator needs service or upgrade.

Soil Quality and Protection		
Olsen P range (pumice) Olsen P for Pumice/Ash Soils ideally is 35-45. (30% of soil quality weighting)	Olsen P compared with optimum range.	(1) All soils fall within the optimum range, and regular monitoring is being done to reduce P use where possible. (2) Olsen P levels are above optimum, but management and monitoring is in place in order to reduce P use, and fall back to optimum range. (3) Olsen P is close to optimum, but monitoring & budgeting not done. (4) Soil Olsen P levels are high. Not using nutrient budget. (5) Soil P levels are high, and continuing to use P. Irregular soil monitoring.
Winter Cropping % of farm/ Cultivation Techniques Winter cropping can be high risk for sediment, effluent and nutrient loss. (30% of soil quality rating)	% of whole farm area winter cropped.	(1) Minimal Winter Cropping Practised. Not part of regular system. (2). < 2% of area. 10 M buffers used. Minimum tillage. On Off grazing used. (3) < 3 % of area, cows wintered on 24 hours. (4) > 3+ % of area using conventional cultivation, 24 hour wintering, no buffer zones. (5) >5% of area cropped, sloping land, cows wintered on, conventional cultivation used, no buffer zones.
Standing off (pugging avoidance) Winter Management Pugging of soils damages soils structure, reduces pasture productivity and compacts soils resulting in poor nutrient use. (30% of soil quality rating)	Use of latest technologies to prevent soil damage from pugging.	(1) Cows stood off, in sheltered environment in wet conditions (wintering areas). Effluent is captured and re-used at optimum times (i.e. Herd Home). (2) Cows on feed pad or loafing area, in wet conditions. Loafing area, effluent is captured from stand-off area. (3) Cows removed from paddock to yard area, where effluent is captured in bad weather. Most pugging is avoided. (4) Cows only sometimes removed from paddocks, pugging and soil damage is an issue. (5) Only option is to leave cows on paddock in weather and no ability to capture effluent/runoff from sacrifice paddock.
Water Use Efficiency		
Dairy Water Saving Systems in Place (Stormwater diversion and storage).Water Use Efficiency - Capture and Re	(c) Use of latest technologies to preserve and minimise water use for industrial use.	(1) Roof water captured storage. Cooling water is recirculated and re used for yard wash-down. Yard wash-down uses recirculated water. (2) Water is captured and stored. Water saving technology is used. (3) No water capture is done, but water efficiencies are used when washing down/in dairy. (4) No water capture/ saving. No

use is a priority on Dairy Farms. (50% of water efficiency rating)		cooling water recirculated. Farmer is aware of need to make changes. (5) No water saving practises, no storage. Not aware of requirements.
Alert or Early Warning System in place for water loss. Awareness of early warning systems for water leaks. (50% of water efficiency rating)	Is latest technology used to minimise water use and staff trained in water saving techniques.	(1) The farm pump has an early warning system (light) or indicator that is well placed to alert of problems. Isolators to parts of the farm, that can be shut off in order to readily manage water leaks. There is map visible to all staff. (2) Early warning system for leaks in place, all staff is aware of it, but cannot isolate parts of farm. Map is held by manager. (3) Early warning system for leaks in place, but not visible to all involved in farming operation (i.e. a pressure gauge is the main indicator on the waterline). Parts of the farm are not able to be isolated. Not all people know where the lines are. (4) No early signal for leaks in place, no isolation taps to parts of farm. No map of lines done. (5) No early signal for leaks. Water leaks are common and difficult to find and solve. No map of lines present.
Irrigation & Soil Moisture Monitoring (adds to weighting only if an irrigator) (this component was not used)	(d) Latest precision tools used to minimise water use and maximise efficiency for irrigation	(1) Soil moisture monitoring (tensiometers used) precision application technology used when irrigating. Water efficient crops used.(not pasture) (2) Low rate application used, pivot or spray irrigation. Rotational cropping with minimum tillage to enhance water use efficiency. (3) No Soil moisture monitoring, good quality pasture only is watered. (4) High rate applications, no monitoring, low fertility low yield pastures irrigated. (5) Flood irrigation, no monitoring, low soil fertility, and old pasture species.
Energy Use and Waste Management		
Renewable Sources used on farm Energy usage on farm can be linked with increased GHG, but also is a cost, while we have renewable sources and ways to	Use of technology to reduce energy use.	(1) Renewable sources are used on farm e.g. solar, energy saving technology, such as pre milk cooling, glycol, insulation for hot water, minimal hot water use. Energy audit planned to see what other savings can be gained. (2) Pre cooling of milk is undertaken to reduce cooling times, and insulation is used on hot water pipes, minimal hot water used for washing, plans to improve energy efficiency and implement these efficiencies.

reduce our use available. (50% of weighting)		(3) Farm system has insulation on hot water pipes, minimises hot water use, no pre milk cooling system. No efficiencies being considered. (4)Power costs and use is higher than average. No hot water insulation or efficiencies, no pre cooling. (5) No renewable or conserving technologies implemented or planned.
Waste Management		
Silage wraps & disposal of hazardous waste and chemicals collected -Disposal off farm. Farm offal holes are not for these wastes. (50% of rating)	Compliance with regional rules for plastics and effort to use plastics recovery services.	(1) Plans to completely reduce the use of plastics in the farm system. Silage covers are re-used where possible, and then sent to Agrecovery once used. Hazardous chemicals and plastic containers are also triple rinsed and collected by Agrecovery. No Plastics are disposed of on farm. (2) Farm system still uses reasonable amount of plastics, but does recovery/collections. Other hazardous wastes collected, or dealt with by qualified contractor. (3) Plastics still part of system. Planning to reduce use of them. Some hazardous waste and containers are removed by collection. (4) Plastics part of system; containers and plastics not collected, but disposed of locally. (5) Plastics part of farm system, no collection, and disposal (bury or burn) is done on farm.
(a) Appropriate Setbacks for Riparian Planting (Wildlands consultants appendix 5) The Proposed National Environmental Standard for Plantation Forestry Discussion Document(MfE 2010) (b) This relies on assessing the farm against the Dairy NZ Code of Practice for Effluent (version 2, 2013) The pond storage calculator (PSC) must be the must up to date version and storage capacity checked against PSC output. (c)Smart Water Use on Dairy Farms – Assessment Workbook and Technical Manual. (d) The “irrigation guide”, “NZ irrigation manual” & “Guide to good irrigation”: Dairy NZ.		

2.2.5 Weightings of Selected Parameters Chosen for the Scorecard:

The weightings contributing to each topic are listed in Table 2.2 (e.g.: the contribution of a high risk Olsen P to soil quality, or risk points from an unlined pond in effluent management.)

2.2.6 The Scorecard – Reported to Farmers

A scorecard example is shown in Appendix 5. The design colour codes the highest risk areas. The scorecard design, criteria and risk ratings could be modified for different catchments. This approach encourages farmers to focus key measures that correlate with increased risk to receiving water bodies rather than just focussing solely on diffuse N loss as an output from OVERSEER. Nutrient loss risk scoring for example across all farms was based score given (from criteria) for nitrogen leached per hectare, and phosphate loss per hectare. The score for both was averaged, giving the overall nutrient loss risk score.

2.2.7 Overall Environmental Score and Lower Risk Farms

The total environmental score was represented by the sum of all the sections as noted in table 2.3. The total number of points from each of the criteria were totalled then correlated to give an overall risk score of 1-5 for the farm. The points were graded against the risk score (1-5) .The total points on the farms ranged from 37 to 74 and were graduated against points from 0 to 5. For example, if the total points were ≤38 then they scored as 1.7 , ≤ 40, then scored as 1.8, ≤ 42 scored as 1.9 etc. with the absolute range was potentially from 22 as the lowest risk score equating to 0.6 the best possible to 110 which would be the worst possible scoring an overall metric of 5.

The lowest risk farms based on the scorecard metrics, were chosen on the basis that they scored consistently lower than 2.3

2.3 Results

2.3.1 Farm System Characteristics.

The group represented in Table 2.2 are a typical representation of dairy farms in the sub catchment area from Mihi bridge to Atiamiuri, soil type was mainly pumice and where good rainfall records existed, they were used in OVERSEER.(e.g.: 30 year average Stathmore Road, Reporoa as 1000mm). This was around 200mm less than what is typical for the concentration of Waikato Farms that lie in the Northern part of the “upper catchment” (Tokoroa, Tirau and Karapiro). The average rainfall in the Southern Waikato according to NIWA records is in the range of 1000-1500 mm per annum. This lower rainfall contributes to a pasture growth pattern and total annual dry matter harvest that is approximately 15-20% lower than the higher class soils of Cambridge or Te Awamutu. (10.4 tonnes dry matter harvested per year vs 12.5 tonnes dry matter per year). “Pasture harvested” or “consumed” is a back calculation of what “must have been consumed by livestock” in this case, on the milking platform after adjustments have been made for factors such as cow energy requirements, supplements from imported feeds or grazing off. This measure can vary by 30% per year (due to climate) but tends to show less variation on better class soils and land. The lower pasture harvest on the study farms underpins a marginally lower stocking density than that of central Waikato. This is typical of the pumacious soils, which feature low water holding capacity and are prone to summer droughts. Milk production per hectare (output) is relatively high despite the lower pasture productivity.

While dairy farming has been practised in the Reporoa area for more than 30 years, since the late 1980s, there has been a move toward irrigated pasture production to reduce the risk of dry years. (Rout, 2003). Two of the 25 farms had surface water takes and irrigation of pasture on more than 40% of the farm area. Some farms received Fonterra waste water. The irrigation resulted in higher pasture productivity on one farm by 20% (3 t/DM per ha per year for 400 mm applied), while others showed no improved productivity than the non irrigated farms. The low response rate of pasture to irrigation is not unusual in higher rainfall bands (900-1100mm) and reflects an eight kilogram dry matter response for each mm of water applied per hectare on average rainfall years. (950-1100mm). Nutrient use efficiency (kg MS per kg N lost) was poorest on the irrigated or Fonterra waste water farms.

The study group's farm systems reflected the wider industry trend towards intensification evident in NZ. Imported feed (on average) amounted to 434 Tonnes of dry matter per farm. Excluding the tonnage that is contributed from "wintering off" the milking platform, the imported feed total equates to 3.4 tonnes of dry matter imported per hectare. (30% of all feed on the farm). The imported feed component contributes to imported nutrient loading for the whole farm system. This can be seen in the relative nutrient value of imported products across the total effective hectares as reported by OVERSEER across the study farms in Table 2.2 below.

Table 2.2 - Characteristics of the Study Group Farm Systems Compared with Average Central Plateau and Waikato Dairy Farms

	Study Group 25 Farms Average	Range in Study Group	Average Dairy Central Plateau	Ave Central Waikato Dairy
Rainfall (mm)	1100	1000-1300	1200	1200-1500
Soil Types	Pumice	Pumice (some ash)	Pumice	Ash, Clay, Peat.
Effective Ha (designated milking)	124.7	74 - 646	174	105
Total Hectares (ha)	129.7	75-652	174	114
Herd Size (cows)	350.6	187-1621	403	360
Stocking Rate (cows/eff ha)	2.85	2.4-3.3	2.75	3.3
Bodyweight/ hectare (bwt ha^{-1})	1385	1104 - 1650	1350	1584
Milksolids per hectare (MS $ha^{-1)}$	1208	816-1585	1125	1200
Total MS per farm.(MS)	151229.3			133266
Winter Graze Off				
% herd off (%)	43	0-100	0-100	0-100
% year off (%)	12.	0- 16	0-20	0-20
Supplements Imported(T DM)				
T maize silage/year	94	0-660	0-100T	30-100T
T pasture silage/year	98	0-167	0-200T	0-300T
T Hay/Year	50	0-213		
T PKE/Year	306.8	30-1473		50-300T
T Concentrates	192	0-660		
Winter cow grazing (T)	59	0-264		
Total Tonnes Imported (T)	493.5	30-2859		

	Study Group 25 Farms Average	Range in Study Group	Average Dairy Central Plateau	Ave Central Waikato Dairy
Total Imported excl winter grazing (T)	434.4	30-2659		
Home grown feed eaten per Ha per year(tDM ha^{-1})	10.4	9.30- 13.8	10.5	12.5
T DM Suppl imp/(T DM pasture+ supp eaten ha^{-1}) %	30	5 – 41	20-30	20-30
Farm System 1-5 Dairy Systems	3-4	1-5	3	3
Fertiliser and Lime				
kg N ha^{-1} yr^{-1}	99			128
P	20.7			66
K	36.6			73
S	56.3			78
Nutrients imported via Imported Feeds (kg ha^{-1} yr^{-1})				
N	93			
P	21			
K	52			
S	13			
Change in P pool.	-15			
N loss: (kg N $ha^{-1}yr^{-1}$) (Ov.v.6.0)	31.4	15-48	39	36
Nutrient use efficiency (kg MS kg N $ha^{-1}yr^{-1)}$	39	18-60	29	33
N conversion efficiency (%)	32	21-41		28
N surplus (kg $year^{-1}$)	193			150-200
Total N Loss kg/farm/year	4155	1903-9925		4095
Farm P loss. (kg ha^{-1}year)	3.8	0.7 – 6.7		1.5-3
Total P loss. (kg $farm^{-1}$ year	230	70-5353		
Area of effluent: (% of farm)	25	9-44		10-20
Total loading N on effluent block(fert/feed/effluent)	254	86-342		
kg CO2 equiv MS^{-1}	7.5	7.2-19		

Table 2.3 - Study Group Environmental and Scorecard Results 2012

Farm number	GHG/kg MS	N Surplus/Ha	N Conversion Eff	**Nutrient Efficiency score**	kg N leached V 6.1	kg P runoff/loss	**Nutrient Loss Risk Score**	% fenced+ stock exclusion	Riparian Planting 1.5-10M	Biodiversity Protection	Major Hotspots + points of connectivity	Wetlands Fenced and Protected	**WATER WAY SCORE**	Meets requirement for herd and farm system	Lined Pond and adequate storage based on pond calc(irr to SWD)	Effluent % spread over farm
1	8.1	169	31	**2.7**	25	1	**2.5**	90	>5	Y	crossing	Y	**1.8**	78	N	85
2	10.2	198	28	**3.3**	20	1.5	**1.5**	90	1	2		2	**1.5**	119	Y	38
3	7.5	167	31	**2.3**	40	2.8	**4**	100%	10	Y	0		**2**	248	N	9
4	7.2	181	30	**2.3**	19	2.5	**2**	100	1	2	0	1	**2**	136	N	0.25
5	7	189	36	**2.3**	24	1.8	**2**	100%	10	Y	0		**2**	139	Y	0.25
6	6.4	221	26	**3.3**	48	1.2	**4**	100%	0	gullies	0	NA	**1.2**	110	no storage	0.31
7	7.5	229	28	**3**	31	0.9	**2.5**	100%	10	gullies	N	NA	**2**	210	N	0.14
8	8.3	148	27	**2.3**	25	3.7	**2.5**	100%	10	Y	Y	na	**2**	160	Y	0.2
9	7.4	282	20	**3.3**	44	1.2	**3.5**	100%	10-20 m	Y	N	1	**1.2**	218	N	0.25
10	11.6	176	30	**3**	35	1.3	**3**	100%	10	Y	N	Y	**1.3**	240	N	0.1
11	6.7	217	33	**3.3**	31	0.8	**3**	100%	na	na	N	na	**1.8**	124	Y	40
12	7.5	252	25	**3.3**	35	2.7	**3.5**	100%	10	Y	N	N	**1.5**	201	N	0.39
13	8.6	273	23	**3.7**	51	2.6	**4.5**	100%	30	Y	N	NA	**2**	255	N	0.15
14	19	212	20	**5**	43	6.7	**4.5**	90%	3-5 M	N		N	**3**	175	Y	0.24
15	7	163	34	**2.3**	15	0.9	**1.5**	100%	10	N	N	NA	**1**	205	N	0.19
16	6.4	203	33	**3**	47	1.8	**4**	95%	10-15M	Unfenced	None	N/A	**1.8**	288	No/unlined/	10
17	6.9	126	53	**1**	21	1.7	**1.5**	100%	5-100m		N/a	1.5 Ha fenc	**1.8**	217	Unlined, no	0.13
18	8.9	189	29	**3.3**	40	1.6	**3.5**	NA	NA	NA	NA	NA	**0**	321	N	0.25
19	9.4	226	29	**2.3**	30	1.3	**2**	100%	10	Y	NA	NA	**1**	279	N	0.12
20	7.5	234	30	**1.7**	41	1.8	**3.5**	95%	5	N	3bridges	NA	**2**	93	limited/smal	38
21	7.3	233	34	**3**	24	0.9	**1.5**	100%	30	na	na	na	**1.8**	140	N/adequate	0.45
22	7.5	180	30	**1.7**	18	0.9	**1.5**	100%	20-30	Y	N	Y	**1.3**	<150	Herdhome	0.37
23	7.4	211	30	**3**	20	1.2	**1.8**	100%	5	y	N	na	**1.7**	247	N	0.24
24	9.3	188	33	**3**	21	1.3	2	100%	10 m	Y	N	Y	1.5	121	N	0.3
25	7.8	198	31	**2.7**	51	1.6	4	100%	10m	N	no nibs/brid	Y	1.3	279	N	0.21

Farm number	Application Manageme nt Alerts in Place	**EFFLUEN T SCORE**	Olsen P range(pumice)	Winter Cropping % of Farm.	Winter Soil Manageme nt	**SOIL PROTEC TION SCORE**	Dairy Water Savings Systems in Place	Alert or Early Warning system in Place for loss	Irrigation - Water Use Efficiency + practises.	**WATER USE SCORE**	Renewable Sources used on Farm	Waste managemen t + Disposal of Hazardous Waste	**ENERGY SCORE**	**TOTAL POINTS**	**SCOREC ARD (2-14 u[dated)**
1		1.5	91-112 (-31	2	Stand off	**1.5**	N	Y		**2.5**	N	Y	Y	46	2.1
2	N	2.5	38-76	0	winter off	**1.7**	3	2		**2**	3	2	2.5	**44**	**2**
3	N	3.8	42-90	2.50%	Sacrifice pd	**3**	N	N		**3**	N	recycle plastic		**55**	**2.6**
4	N	2.8	60-66	summer		**2**	2	2		**3**	3	1	1	**44**	**2**
5		2.3	34-36 Inc	0		**2.3**	Y	Y		**2**	Heat exch	recycle		**42**	**1.9**
6	no	3.3	40	Y	stand in pdk	**3.3**	Y	N		**3**	Glycol/prec	bury/burn	3.5	**60**	**2.8**
7	contractor	3.5	40 increasin	8%	stand on	**3.2**	yardwash	Y		**2**	N	Bury	3	**55.5**	**2.6**
8	N	2.3	58-67	4%	Some	**3**	Y	Y		**2**	Solar	Y	2	**46**	**2.1**
9	N	3.3	52/41/56 de	2%	Some	**3**	N	Y	N	**3**	N	N		**61**	**2.9**
10	contractor	3	74/61/86dec	>6%mintill	N	**2.3**	N	Y		**2.5**	N	Y	2.5	**49**	**2.3**
11	Y	2.5	70/39/90	0	Y	**2**	Y	Y		**1.5**	N	Y	2.5	**47**	**2.2**
12	N	3	78/79 dec	8	N	**2**	N	Y		**2.5**	N	Y	2.5	**56**	**2.6**
13	N	3	49-70slight	5.2	N	**3**	Y	Y		**2**	Heat exch	recycle	2	**55**	**2.6**
14	N	3	24-46	8%	stand on cro	**3.3**	N	N		**2.5**	N	N	3	**71**	**3.4**
15	N	2.8	66-97declin	N	cows off	**1.7**	N	Y		**2.5**	N	recycle	2	**37**	**1.7**
16	Installing	3.8	43-119	3.60%	Stand on cro	**3.3**	Yes	Yes	No control factory wastewater	**as above**	None	Burns Plastics		**70**	**3.3**
17	none	3.8	55declining	none	cows off	**1.7**	only cooler	none		**3.5**	none	burn	4	**50**	**2.3**
18	N	3.5	48-79 increa	None	cows off	**1.8**	cooler recirc	Y		**2**	Mahana Blu	Bury/Burn	3.5	**47.5**	**2.2**
19	N	3.5	48-110 incre	N cows off	cows off	**1.8**	basic saving	N		**3**	mahana Blu	Bury/burn	3	**46**	**2.1**
20	N	2.3	50/static	0	Y	**2**	recirc cooler			**2**	N	Wraps burnt	3	**47**	**2.2**
21	Y	2	61-73declin	0	cows off	**2.6**	Y	Y	No SWD or	**3**	N	N	3	**46**	**2.1**
22	Visible	1.8	75-80declin	0	cows stand off and off farm winter	**1.3**	recirc cool	visible	NA	**2.6**	N	N	3	**37**	**1.7**
23	N	3	40-60	N	Y	**1.7**	Y	y		**1.5**	n	Recycle	2.5	**42**	**1.9**
24	N	3.3	56-75	N	N	**1.7**	N	y	NA	**2.5**	N	Recycle	2.5	**47**	**2.2**
25	N	4.3	37-96	N	off farm	**2**	Y	N	N	**2**	N	unknown		**48**	**2.2**

2.3.2 Results of Eco Efficiencies

The range of GHG loss per kg of milk solids produced ranges from 6.3 to 19 kg CO_2 equivalents per kg MS. The excessively high output on one farm reflects significant losses that are likely to be a result of a large winter cropping area. 10% of the farm is cropped conventionally. On average, there was low risk performance (high eco efficiency) on the majority of farms for GHG losses. Nitrogen Conversion Efficiency ranged from 20% to 53%. The highest nitrogen conversion efficiency did not necessarily correlate with the lowest leaching as illustrated in figure 4. Although it is a useful measure of how much nitrogen is being converted to product, it does not appear to relate well with a lower risk of nitrogen loss to the receiving environment.

2.3.3 Relationship between Eco Efficiency and Nutrient Loss Risk

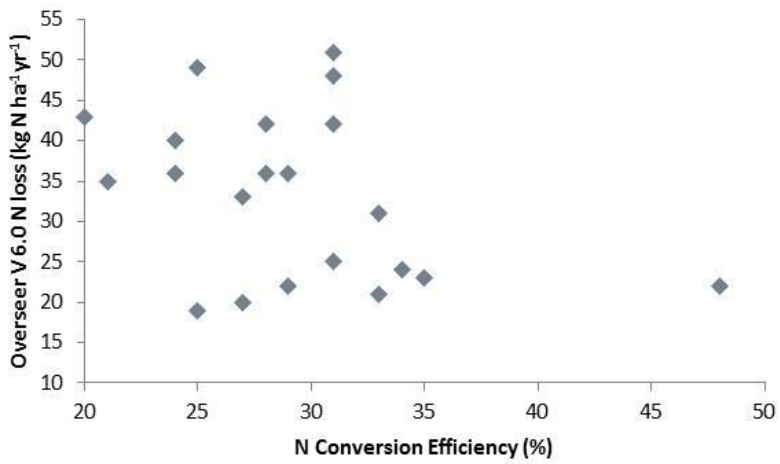

Figure 2.3 - The correlation between nitrogen leached and nitrogen conversion efficiency

There was no significant correlation between kg N ha^{-1} yr^{-1} and N efficiency % ($R^2 = 0.15$, $p > 0.05$) in this study. The dairy industry has been using a measure of "nutrient use efficiency" to describe how many kilograms of milk solids per hectare can be generated for each kilogram of nitrogen leached. Essentially this compares production relative to pollution, (Anastasiadis & Kerr, 2013). The study farms appear to be more efficient producers than the average with 39 kg of milk solids produced per kg of N leached, and a range of 19-66 kg MS per kg of N leached across the participants, compared with the Upper Waikato average of 29 kg of milk solids per kg of N leached. Anastasiadis & Kerr (2013) refer to a mean in their studies of being 34 kg MS/kg N leached and a range of 10-105 kg MS kg N^{-1} ha^{-1}. Anastasiadis & Kerr note that they can explain only 48% percent of the OVERSEER-modelled variation in New Zealand dairy farms' nitrogen use efficiency on geophysical factors, specific mitigation technologies and practices that move emissions across farms such as wintering off animals. This suggests a potentially large role for management factors such as movement of stock or specific mitigation technologies indicating that a large role for management factors and farmer skill, particularly for N efficiency and losses.

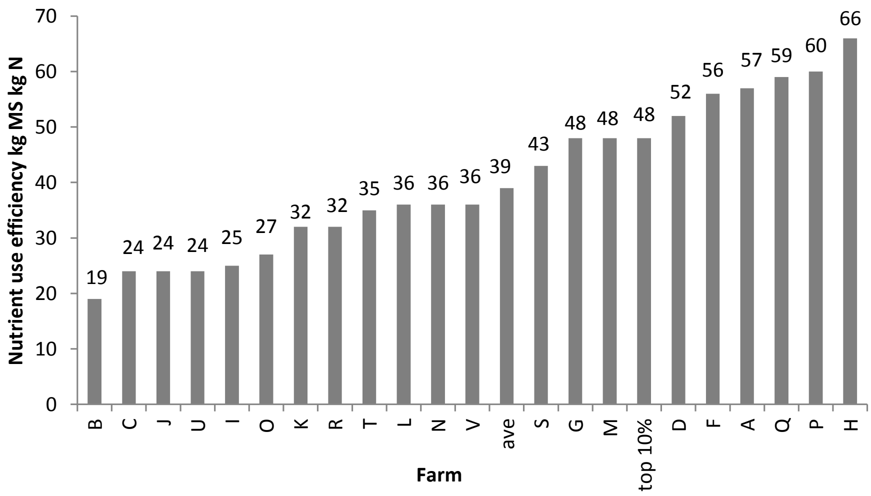

Figure 2.4 Nitrogen use efficiency (kg MS per kg N loss) ranked for 25 farms. (Overseer Version 6.0)

This efficiency measure was one of the efficiency criteria tested against farm profitability on the 25 farms (ROC) in Chapter 3.

Each study farm was ranked on Nitrogen Loss risk (kg N $ha^{-1}yr^{-1}$). There was no significant relationship between lower nitrogen surplus and lower nitrogen loss risk.

2.3.4 Nutrient Loss Risk across the Study Farms

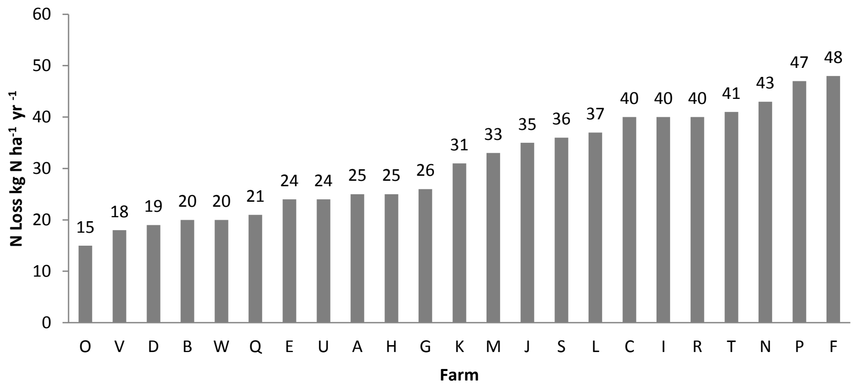

Figure 2.5 - Nitrogen Loss Risk for Study Farms
(Overseer Version 6.0 Sept 2013 using DairyNZ Protocol)

The range across the study group was extremely wide. This reflected a variation in the farm systems and their respective management systems in the study.

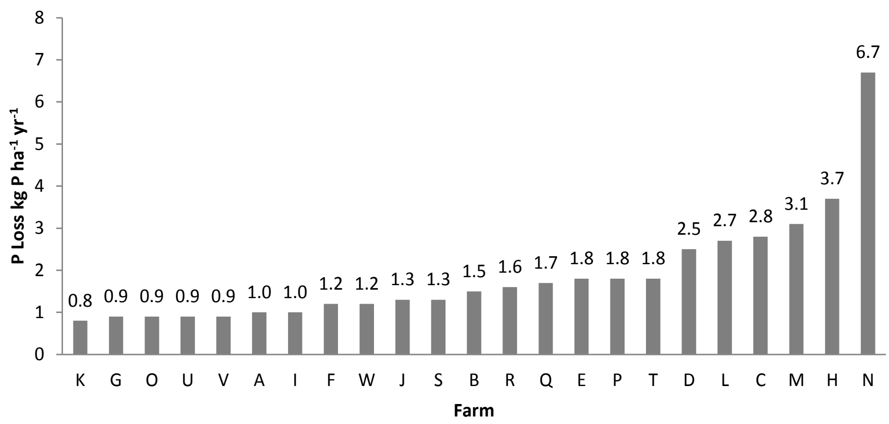

Figure 2.6 - Phosphate loss risk from case study farms
(Overseer Version 6.1 using DairyNZ protocol)

It was noticeable with the version 6.01 (Oct 2013) OVERSEER that was released that the phosphate loss risk was higher (by 30%) than the 2011 years P outputs from previous versions.

2.4 Discussion

2.4.1 Challenges

The OVERSEER version underwent five modifications during the course of study resulting in outputs data for the scorecard requiring alteration several times. There were upgrades to the code of practise for effluent management also occurred affecting the scores. Although it should be clear that the Waikato Regional Council Rule 3.5.5 permitted activity for the discharge of effluent to land, would mean that all storage ponds for effluent are lined to prevent connectivity with ground water however, this particular rule has not been enforced in the upper catchment, sending a confusing message to both the industry and farmers.

80% of the ponds in the study group were unable to demonstrate proof of lining when data was collected in 2012. This would not be unusual for the southern Waikato region.

2.4.2 Variations and Upgrades to Overseer and protocols during the course of the study.

Due to versions and protocol changes during the course of the study, N loss results produced for the irrigated farms varied significantly. Overseer assumes (using DNZ designated protocol default settings) that all effluent irrigation systems are entered into Overseer as being actively managed (that is: application of effluent is only occurring under low risk conditions and there is no connectivity with ground or surface waters). In this study, 75% of the ponds were unlined, and therefore the Overseer outputs could be underestimating the N loss figure by 10% or more (*pers. comm* Horne 2013). Refer to Appendix 3 for further detail.

The Overseer Version has changed from 5.4 to version 6.1 during the course of this study and is part of long term continual change. Some of the modifications have (particularly on irrigated farms) resulted in significant changes to the models and farms N loss outputs. The input protocol used for the model was consistent between versions.

Practitioners in the agri – environmental field will need to continually adapt as science work on climate, soils and irrigation will continue to result in upgrades to the model as field information becomes available to allow validation, (Wheeler, 2013). It is likely that input protocol for the model will keep changing over time.

In addition to the fact that the model is continuing to be updated, is that field estimates of N leaching are difficult, and have significant measurement errors associated with them, Wheeler, (2013) suggests these are in the range of 20-50%. An implication is that when comparing measured and modelled data, the differences may just as likely be due to measurement as modelled errors.

There has been no uncertainty analysis undertaken for Overseer, (Wheeler, 2013). Differences in outputs from the model between versions (when there was no change to the farm system) in this study yielded changes of 100% in some cases.

The model is based on calibration or validation of sub models against experimental data, and extrapolation to cover the range of NZ farm management and site conditions. Earlier versions of OVERSEER were validated on the pumice soils (Ledgard et al.2007; Wheeler, 2013). The estimate of the uncertainty for phosphate loss in the model is likely to have a margin of error of plus or minus thirty percent. (Mc Dowell, 2013). This margin of error does not include the runoff that occurs from storm events, which could contribute potentially a further anomaly of 30-50% (*pers comm* Clarke 2013). Furthermore, the estimates for P loss are further complicated by the fact that OVERSEER fails to account for the fact that farm systems operate without the protection of first and second order streams. These streams when farmed, unfenced, as part of a grazing platform, also provide an additional source of phosphate from overland flow.

The phosphate loss reported in OVERSEER 6.1 (kg P ha^{-1} yr^{-1}) increased by 49% across the sample group since 2012. With one outlier removed, the difference between version 6.0 and 6.1 for this group of 25 farms is 30%. As a result of these anomalies and continual changes, it is important therefore to rely on “relative changes in nutrient loss outputs” from OVERSEER rather than absolute nutrient loss figures as they are reported.

Initial changes occurred first in 2012(5.4 to 6.0) and included a significant alteration to the hydrology component of the model, (Wheeler 2013). The irrigation component of the model is still undergoing validation and is subject to change. The drainage effects under irrigation as modelled, are still likely to be underestimating what is actually happening. (D. Horne – *pers comm*. 2013).

The irrigation component of the scorecard was designed to measure both water use efficiency and the application of precision irrigation practises (soil moisture deficit irrigation, variable rate application etc.). Although there were three irrigated dairy farms in the study group, only one had accurate application rates and none were using precision technology for irrigation practices. This component of the scorecard was then not populated as the data was difficult to obtain and water metering was not practiced by the irrigation farms in 2010-12.

2.4.3 Factors influencing Nutrient Loss Risk

Higher nitrogen loss risk was characterised by some key similarities. The three farms that were above 40 kg N loss per ha per year (OVERSEER version 6.0 and 6.1) were characterised by the presence of irrigation (irrigation of pasture fresh and waste -water), and were not necessarily making use of precision technologies. Two farms leaching over 40 kg N ha^{-1} yr^{-1} (OVERSEER Version 6.0 and 6.1) was irrigating with Fonterra waste water with no ability to govern the nitrogen loading from the waste water. In a subsequent version of OVERSEER (6.11, December 2013) the losses from the irrigated dairy farms have increased to 60-80 kg N ha^{-1} yr^{-1}. A common feature of the farms that had N losses above 31.4 kg N ha^{-1} yr^{-1} was wintering their cows on the farm, using cropping, irrigation, or keeping cows on crops over the autumn and winter period without stand- off facilities, or capture and storage of effluent (urine).

This practice also led to a higher phosphate loss risk on most farms reported by OVERSEER 6.1. The higher loss rates (above 2 kg P ha^{-1} yr^{-1}) on the three highest risk farms (3.1-6.7 kg P ha^{-1} yr^{-1}) all had common features of rolling to steeper contour, conventional tillage methods for winter cropping of 4%, 5.5% and 10% of the total farm area, with no opportunity to stand cows off. (Cows grazed on crops twenty four hours.) All the study group farms demonstrated Olsen P levels at or well above optimum levels. Most participants in the group were reducing their soluble phosphate inputs equating to an Olsen P decline of 3-6 units per annum.

2.4.4 Characteristics of Better Performing Farms that had Lower Risk to the Environment

Farms that scored very well (low total risk points) on the scorecard, demonstrated that vulnerable areas of their farms well fenced off and provided adequate buffer zones to waterways. Four of the better farms had fully compliant effluent systems in accordance with the code of practice guidelines resulting in a lower risk effluent score. Nutrient loss and efficiency measures all were "low risk" for the better (less than 30 kg N loss ha^{-1}) farms, and this category had a strong correlation to differentiating the farms in the group.

Wintering cows off for around 12% of the year, was a practice undertaken by 43% of the study group. This component of risk was not studied, but presents a challenge as part of integrated catchment management because of diffuse loss risk transfer. This practice became more prevalent in the course of the study with several farmers purchasing nearby land for support and wintering. At the end of the study, 15 of the 25 farms had secure dairy support blocks under their management for wintering cows, rearing young stock and provision of supplement for the milking platform. (i.e.; owned or long term lease arrangements)

Lower risk farms also demonstrated efficient nutrient use and fully compliant effluent systems with a large area (>30%) of the farm irrigated. Nearly three quarters (73%) of the study participants were undertaking upgrades to their effluent systems at the conclusion of the study period. Soluble nitrogen use ranged across the group from 60 to 180 kg N ha^{-1} yr^{-1} on the milking area. The average was 99 kg N ha^{-1} yr^{-1}. Farmers were aiming to reduce N use further using pasture growth enhancers such as Giberillic Acid; a compound that promotes cell elongation in plants.

"Lower risk farms" did not undertake winter cropping or only had small areas with minimum tillage and cows "on – off" grazing. There was very little net difference between farms in the water efficiency section. Waste management components of the scorecard between farms except where farmers (40%) chose to bury and burn their plastics rather than recycling. These farms received a "high risk score" and lowered the overall environmental performance slightly. Water management was difficult to quantify due to absence of water meters on farms in 2012 making data difficult to collect. The irrigation component of the scorecard was not able to be used as it failed one of the key criteria that were set out in the methods and design: the data on actual water use was not readily available from the farms.

2.5 Conclusion

The scorecard was a concept developed to use in conjunction with N loss from OVERSEER in order to test if it was possible to quantify risk from pastoral systems more comprehensively. It was applied to the 25 Upper Waikato Farms and was well received by the participants as a useful method to compare farm system risk through inclusion of nutrient and emission loss and efficiency metrics, effluent management, fertiliser, water use efficiencies, and waste management for the milking platform alone.

The practice of wintering cows off, and shifting diffuse loss risk from one part of the catchment to another was not dealt with in this study, but is an area that deserves considerably more research. To quantify the true influence of dairy in a catchment, wintering practices and support land should also be considered as part of the overall system.

Rather than just considering N loss, (which is the focus of many plans), this scorecard provides a far more comprehensive metric of diffuse loss risk and eco efficiency from a farm system. The scorecard concept may be used by policy makers to provide relative environmental risk metrics to allow comparison of risk between different agricultural sectors, across catchments, in some cases using different risk weightings, for what may be more important environmental challenges.(e.g.: sediment in Waipa vs Waikato river for example).

Chapter 3 : Factors contributing to economic resilience and environmental performance for dairy farms in the Upper Waikato region

3.1 Introduction

New Zealand presently faces an “economy versus environment” dilemma (PCE 2013). In catchments where there has been large-scale land use change to dairying, the gains made by increased on-farm mitigations have been negated by the scale of land use conversion and intensification (PCE 2013). Voluntary mechanisms to achieve environmental goals have been insufficient in NZ and the Horizons One Plan reflects the first regime to be implemented in NZ to allocate nutrient emission rights from land for the purpose of ecosystem health, using land use capability as a proxy for nutrient allocation. This approach has been followed in the Tukituki River Catchment Plan (Change 6) (EPA 2014).

Various policy regimes to regulate nutrient emissions have been analysed by Doole (2013), who considered farm costs incurred from single changes in response to a range of policy instruments in the Waikato and nationally. He used individual mitigations rather than full farm systems changes, and costed singular management changes such as reduced stocking rate, shortened duration of nitrogen applications, no nitrogen application, nutrient trading under a cap, uniform nitrogen cap and land-use change from dairy to sheep and beef. The most recent work by Doole (2012) has revised costs to be considerably lower than earlier studies (Doole, 2010) but does not appear to have looked as system reconfiguration and the efficiencies gained.

Eco-efficiencies refer to measures used by industry that increase the ratio of production relative to non-profitable outputs. For example it may be used to refer to the mass of product (milk solids) produced per unit of nitrogen mass leached from the system. Such a measure can be used to compare production vs pollution between farms.

“Eco-efficiencies” are being sought by the dairy industry to incentivise on-farm changes. Ecosystem health limits have now been included in regional council plans (e.g.: Horizons, Hawkes Bay, Otago) which potentially place tighter constraints on emissions from agriculture and may place greater emphasis on eco-efficiency metrics.

Anastasiadis and Kerr (2013) noted that some farm systems leached 30% less than others, suggesting that in the absence of other natural influences, management choices had a major impact on levels of eco-efficiency between farms.

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The wider public is cognisant of the requirement that farm mitigation measures allow farm profitability to be maintained in order to support the national economy (Monaghan, 2008). Strategic use of fertilisers and optimum soil fertility levels can result in win-win outcomes while other "good management practices" generally reduce nutrient and faecal bacteria losses at relatively small cost to the farm business (Monaghan, 2008; Agfirst Waikato, 2009; Beukes, 2012, 2013).

The financial impact to a dairy business of reducing diffuse nitrogen losses is best assessed by considering whole farm system reconfiguration rather than "costs of single mitigations". Dairy NZ and Horizons Regional Council used this approach in a study in 2013 study of the impacts of the Horizons One Plan on farm profit. They showed that farm system reconfiguration could reduce N loss by 18-23% without adversely affecting profitability as long as there was sufficient time to adapt.

Farming innovators are aware of this concept and are adapting their practices accordingly but they continue to be a minority (Monaghan, 2008). De Klein (2005) noted that whole dairy system evaluation (i.e. dairy farm and associated land used for feed production) was needed to fully assess the cost-effectiveness of a range of mitigation options. Reducing diffuse losses may require a range of strategies to be implemented at once (Vogeler et al., 2013) which is counter to the single-management economic assessment approach used by Doole (2012). Research by (Beukes et al, 2012) suggests that gains can be made by reconfiguring farm systems to achieve 1200 kg milk solids (MS ha^{-1}) whilst long-term average nitrate leaching losses are approximately 25-30 kg/ha/yr. Eco-efficiency studies previously conducted by Ledgard (2003) and Basset- Mens et al. (2009) have indicated that increasing intensification does not always couple to increased efficiencies and could potentially erode NZ’s competitive advantage of being a low cost producer. Moynihan (2013) questions whether increased efficiency on NZ farms can outpace rising costs. Globally, milk production costs have converged while traditional low cow cost producers (e.g. NZ) have incurred rises in production costs due to increasing dependence on imported feeds, high debt levels and greater environmental regulations resulting in reduced competitiveness. (Moynihan, 2013). Intensively-farmed systems can incur increased risk and can have more difficulty in ensuring consistent margins (Clark 2011). Risks include factors such as increased variability in milk prices, changes in trade policies, increased cost of inputs, increasing consumer awareness about sustainable food systems, and greater regulation of animal welfare and the environment, (Gray et al., 2009, Shadbolt 2013b) .

Shadbolt (2013a) reviewed economic data for 40 dairy farms across NZ from 2006-07 to 2010. However her study did not include the economic impacts of possible environmental constraints on farm resilience. Resilience his defined here as the ability of a farm to demonstrate a sound return on capital at a range of milk prices and seasons. In more general terms resilience can be described as the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks (Walker, 2004). Shadbolt (2013a) concluded that dairy farms that were more economically resilient able to ‘bounce without breaking’ and included features such as technical efficiency (more milk per cow, per hectare and per labour unit), financial efficiency (more profit per unit of revenue, linking costs with prices), higher return on assets, cash liquidity, more discretionary cash for investment/drawings and debt servicing capacity. Of significance in the study by

Shadbolt et al, (2013a) was that none of the farmers in the top quartile who best captured opportunities arising from higher milk prices was in the top quartile of those who were able to be best prepared for the risk of years with lower milk prices. Farm gate prices paid by Fonterra in NZ over the period 2009-2014 have averaged $6.40, but with fluctuations of ±20% or more between years, illustrating a high degree of volatility (Appendix 6).

The most recent report by PCE (2014) makes it clear that by 2020 the water quality in most places in NZ will worsen. Agricultural "growth agendas" have been based on the notion that policy approaches will not curb development. However most recent decisions such as the Plan Change 6 Tukituki River (EPA 2014) support ecological health rather than toxicity as a bottom line, and clearly underpin the intent of the National Policy Statement in Freshwater Management (MfE 2013) to enhance the Resource Management Act (1991) where it has failed to protect the environment from diffuse-source pollution. It is increasingly clear that dissolved inorganic nitrogen (DIN) limits in receiving water bodies are being set at levels to sustain life support capacity and future generations (e.g., 0.8 mg N/l for rivers in the Tukituki PC6, 0.44 mg N/l in the Otago Regional Council Plan and 0.44 mg N/l for preservation of river health in Horizons One Plan). The levels that have been adopted will link aquatic ecosystem health directly to land-derived nutrient loads and, as a matter of course, nutrient allocation rights to land units.

The shift towards protection of ecosystem health through identified water quality metrics has significant implications for agricultural activity in NZ. Historically a lack of quantifiable measures to describe water and ecosystem health has resulted in lax policy frameworks that enabled unbridled agricultural intensification. Land use has been production orientated; assuming externalities be limitlessly absorbed. An assumption of limitless growth also generally underpins the historical input/output "decision support tools and models" used to forecast economic returns from management changes on farms where each input provides similar output with no concept of diminishing returns. A reconfiguration of agricultural systems to optimal profit, high resilience, and low impact systems will be required as setting limits based on "ecological health" will test the currently prevailing economic philosophy based on singular production goals. Pretty et al. (1999, 2000) notes that most economic activities affect the environment either through use of natural resources as inputs, or by using the clean environment as a sink for pollution. The need to transition to more resilient systems extends beyond NZ. Compared with 1950, grain crops in the UK have tripled, and milk yields per cow have more than doubled, but at a high cost to the environment, public and social health (Conway & Pretty 1991; Pretty 1995). The present system of economic calculation grossly underestimates the current and future value of natural capital (Abramovitz, 1997; Costanza et al., 1997).

Farming within limits will mean that in the future, externalities from agriculture will need to be costed into economic models. This is complex as externalities tend to have five distinguishing features: costs are neglected, distinct lags, damage to unrelated groups of people, difficulty to identify the producer of the externality, and potential for sub optimal economic and policy solutions (Pretty et al 2000). Conservative estimates by (Pretty et al, 2000) indicate externalities may account for up to 89% of the net farm income in the UK.

Innovative farm management systems will be needed to derive high value products while risk is managed and environmental outcomes are enhanced. Business seeks to maximise certainty and from an agricultural viewpoint this will include fair and equitable allocation of ecosystem services and diffuse loss rights to farmers. Under such a regime, farmers can design their farm systems being sure of their limitations, rather than being surprised by a policy change at a later date when ecosystem services become over allocated, resulting in ‘clawback’ policies. Resource claw back (such as water buy back) (Haisman 2004) can result in social and financial stress for farmers as they are faced with unexpected change.

Growth needs to be economically, environmentally and socially sustainable. Using “land use capability” as a proxy for nutrient loss allocation (as adopted in the Horizons One Plan and Tukituki River Catchment Plan) can provide improved certainty for businesses (both new and established) to plan within, reducing the risk of stranded capital and ensuring that nutrient headroom (if there is any) in the receiving catchment will be allocated in a way that links to the inherent productivity and vulnerabilities associated with the land (Dewes 2013; EPA, 2014).

Resilience allows for unexpected events to occur, which in the dairy industry might include variations in feed and milk prices, climate, and resource constraints. The notion of resilience recognises limits, and the imprecise nature of the future. Holling (1973) notes that management approaches based on resilience emphasise the need to keep options open. The resilience framework requires systems that can absorb and accommodate further events in whatever unexpected form they may take (Holling 1973; Peterson et al 1998; Gunderson et al 2009).

Some studies have assumed that farmers instinctively change their systems based on their risk preferences (Greig, 2012, Shadbolt et al, 2013b.). However Smeaton et al. (2009) notes that agricultural decisions tend to involve multiple criteria. Business performance, environment and lifestyle factors all influence on farm decision making (Smeaton, 2009). At a higher level is the notion that there is are fundamental modes of behavioural responses (Catton 1982) Philosophically it appears that many forms of human organisation are based on the paradigm of limitlessness, and the notion that humans will be able to overcome ecological limits with technological advances. Catton (1982) suggests that there is wide variation in how people view ecological limits, from "realists" who understand that environmental limits exist to "ostriches" who deny the existence of ecological limits altogether.

This study sets out to ascertain if there are common management factors on dairy farms that result in lower environmental risk simultaneously with increased economic resilience using return on total capital across years when milk prices and total pasture growth vary. Twenty-five dairy farms with similar geophysical characteristics are used to examine how management actions may affect environmental risk and economic resilience.

3.1.1 Objective of the Study

The overarching objective of this study was to examine how economic and environmental stressors influence farm management and system configurations. I test the commonly held notion of farmers and others involved in the dairy industry, that if there are constraints on farming activities due to limits on nutrient losses, then the business will be less profitable. I hypothesised, however , that high return on capital may still be able to occur at the same time as low nitrogen leaching. For these cases I sought to examine the farm configurations, environmental risk and economic resilience.

I used a process of a) identifying the farms which had the lowest environmental risk using an environmental scorecard approach and theoretical nitrogen leaching cap of 30 kg N ha^{-1} yr and b) identifying the lowest risk farms with consistently high returns on total capital even with a hypothetical 20% decrease in milk price.

The management characteristics of selected farms were analysed further in order to identify what management characteristics led to resilient, low impact farming systems.

This study of low-footprint, profitable and resilient dairy farms is pertinent to regions of Waikato, Bay of Plenty, Canterbury, Hawkes Bay and Northland where regional councils who are reviewing and updating land and water policies. These policy changes are occurring against a backdrop of increasingly variable climatic and commodity price cycles, (Moynihan, 2013). Although farm system modelling has been undertaken previously (Beukes et al, 2012; Agfirst Waikato, 2009; Doole, 2013; Anastasiadis & Kerr, 2013), including exploring which farm systems may have lower risk to the environment, no study has identified the characteristics of actual farms performing well economically and environmentally within a subcatchment with similar geophysical characteristics.

3.2 Methods

3.2.1 Economic Data Collection and Analysis

The participant farmers for the economic analysis were the same as those used for scorecard assessment (Chapter 2). At the preliminary visit, economic and physical data were collected for the farm system. The data included farm geophysical details, stock numbers and movement, average cow bodyweight, and infrastructure relating to dairy, feed and effluent systems. To enable efficient data collection, the farmers were first sent a checklist in order to prepare for each visit.

Farm physical data (e.g.: milk production, stock reconciliation) were collected, and aligned with the annual taxation accounts provided from the farm's accountant. The data were then analysed using farm performance analysis software: Red Sky Farm Performance Analysis, which is a farm performance analysis tool that develops annual accounts into relevant and useable management information for farmers, (Beca, 2013). The software acts as a decision support tool also develops annual budgets and business plans; provides benchmarking measures for continuing business improvement; allows individuals to form and join groups over the internet to share data e.g. a 'discussion group' of likeminded farmers could decide to share their individual data to look intensively at their comparative performance; and efficiently processes complex financial information and reduces it to readily understandable performance measures that make business decisions easier for farmers. Red Sky Farm Performance Analysis generates reports of the farm performance providing a suite of profit (P) measures, risk (R) and efficiency (E) measures that are all important metrics to describe business health while also allowing standardised comparisons between farms for benchmarking purposes. These are described in Table 3.1.

Farm performance indicators describing important physical characteristics were selected, such as animal performance, feed growth and efficiency (Beca, 2013). Any discrepancies found between the data provided and those of the accounts and OVERSEER were reconciled in order to ensure the financial accounts lined up with the environmental data for each financial year. The choice of economic Key

Performance Indicators KPIs (Table 3.1) was based on relevant industry-accepted measures that were robust and meaningful (Dairy NZ:Dairy Base, 2014).

Farms were selected that leached less than 30 kg N ha^{-1} yr^{-1}. These farms were assessed for return on capital (ROC) in 2010-11 and 2011-12. They were tested for the net change in ROC when milk price was adjusted by ±20% within a year, and across years.

Different components of the ROC function were tested for significant relationships with the major component that changed between farms (cost of production per hectare). ROC was also tested against a wide range of farm management factors such as stocking rate, milk production, fertiliser use, labour efficiency and pasture harvested per hectare.

Resilience in this study was defined as the farms that could operate within a notional nutrient cap (<30 kg N ha^{-1} yr^{-1}) and that demonstrated a strong ROC at different milk prices within and between years. The farms that had the lowest net change in ROC at different milk prices and < 30 kg N lost ha^{-1} $year^{-1}$ as well as having a low environmental risk score were deemed to be "resilient" economically and environmentally.

Workshops were undertaken with participants to benchmark business and environmental performance across farms. Share milkers and lease farms were then omitted from the dataset to ensure fair comparisons of the KPIs across farms. This resulted in only twenty-two of the twenty five sets of data being used for economic comparison purposes.

3.2.2 Selection of Key Performance Indicators (KPIs) for "business health"

3.2.2.1 Economic parameters

Economic parameters were chosen to allow comparison between farms and to provide standardised benchmarking. Equity percentage or return on equity, although important measures, was not used because of sensitivities amongst participants. The most important measures that underpinned the study were as follows:

Economic Resilience: where a farm demonstrates a return on capital above the cost of borrowed capital, and the net change in the milk price between seasons results in a minimal impact to the return on capital.

In this study resilience was tested by measuring the net difference in ROC between years, at the received milk prices and also “within a year” by testing the farm’s ROC at two different milk prices while all other variables remained constant. ($6.50 and $5.50 per kg MS)

Total ROC was the strongest measure used to define profitability and used to compare between farms. It was therefore selected as the key indicator for profit in this study.

Return on Capital = [Operating profit excluding capital gains/total Assets (including leased assets) at start of year] x 100.

The equation can be expanded: Return on Capital = [“farm income” – “cost of production kg MS^{-1}” x kg MS including “imputed labour and adjustments”] / Total capital employed.

Regression analysis of return on capital against all the standardised components of its components was undertaken.

Return on Capital can be influenced by gross revenue for product per hectare, cost of milk production and total capital employed. Total capital employed in this study did not include capital gain, but rather “ used four year average market values.” These values were used to determine the value of the farm land.

Equations or explanations for other variables were as follows:

Operating profit per hectare = [gross revenue – gross expenses* including adjustments] / total milking area in hectares.

Cost of production = gross operating expenses (less non milk revenue)/ kg milk solids.

*Gross operating expenses = total operating expenses including adjustments (feed/supplement on hand, imputed labour and management, depreciation and other expense adjustments)

Pasture dry matter harvested (t dry matter (DM)/ha) = equivalent tonnage of 11.0 mega joules of metabolisable energy per kg DM pasture consumed per hectare. Any hay and silage conserved on the farm and fed back to cows within the financial year was included in the total pasture yield. This measure needs to be interpreted for land quality and farming system (e.g. good versus poor soils, irrigation versus dryland).

Dry matter harvested per cow (t DM/cow) = proportion of intake that is based on low-risk, low-cost feeds to support milk production.

3.2.2.2 Environmental parameters

A regression analysis was undertaken between ROC and a range of environmental measures. In order to ascertain the most profitable farms with low footprint, farms were weighted using an environmental scorecard which included nitrogen leaching. Risk from phosphorus (P) losses was not used as a separate metric as the output from the OVERSEER model still has to be validated at the time of study and can vary by up to 30% (Mc Dowell, 2013). Phosphorus loss per hectare per year only provides a “guide to risk” and therefore was included in the scorecard (overall score of risk).

Table 3.1 Measures used to denote business and environmental performance using profit, risk and environmental measures. (P; Profit, R: Risk, E; Efficiency)

	P/R/E	Farm c	Central Plateau Ave.	Criteria for inclusion
Physical parameters				
Cows per milking hectare (cows ha^{-1})	R	2.47	2.79	Stocking rate underpins farm system intensity, size of feed deficits, financial risk and environmental risk profile.
Bodyweight per milking hectare (kg ha^{-1})	R	1,185	1,324	Due to variation in cow size: bodyweight best descriptor (cows range from 360 kg to 600 kg).
Milk solids per cow (kg MS cow^{-1})	E	462	403	Indicator linked to performance and efficiency. Intrinsically related to bodyweight, farm system, genotype, and landscape and management capability and selection pressure.
Milk solids per milking hectare (kg MS ha^{-1})	E	1,140	1,125	Production metric which needs to be read alongside home grown vs imported feed metrics to assess productivity and economic risk of the system
kg Home grown feed eaten per cow (kg $bodyweight^{-1}$)	R/E	9.40	6.8	Productivity and risk measure. Can be used to denote resilience of system.
Pasture dry matter harvested (t DM ha^{-1})	P/E/R	11.7	11.0	Important measure, best used as 3-year rolling average to even out climatic variance. Linked to productivity of landscape.
Home grown feed eaten per cow (t cow^{-1})	P/E/R	4.7	3.9	Measure that links the lowest cost feed to total cow intake.
Economic Parameters (profit, risk, efficiency of system)				
Operating profit for farm area ($ ha^{-1})	P	3,087	1,885	Operating profit / effective milking area. Metric of profit against the largest capital asset and correlated with return on assets, although it needs to be interpreted in light of the wide variation in land values.
Return on Capital (ROC) at 4-yr avg values @$6.08 kg^{-1} MS. This measure (%) excludes capital gain.	P	7.7	4.6	Operating profit / total assets under management at start of year x 100. Should be assessed with capital gains/losses both included and excluded. This profit measure records the return on total assets employed in the business. Most important measure of business performance. Resilience (net change in ROC) measured at range of milk prices (± 20%)
Return on Capital at $5.50 kg MS (ROC) at 4-yr avg values	P	6.2	3.6	

Cost of production per kg milk solids ($ kg^{-1} MS)	R	3.69	4.57	Linked to risk. (or gross operating expenses less non-milk revenue per kg milk) = (manufacturing milk sales – operating profit) / total milk sold. This is the effective net cost of producing each kg of milk and can be used for break-even analysis.
Core per-cow cost ($)	E	738	593	(Animal health + breeding + dairy shed expenses + electricity +grazing/agistment + freight + other expenses + 50% repairs and maintenance + 30% standing charges + 70% vehicle expenses + 50% depreciation) / Peak milking cow numbers. This metric determines the underlying livestock cost structure of the business after removing the major cost centres influenced by different farming systems.
Core per-hectare cost per t DM pasture harvest ($ t DM^{-1})	E	104	112	(Administration + cropping (green feed) + phosphorus & all other fertilisers + pasture maintenance and renovation + 50% repairs and maintenance + 70% standing charges + 30% vehicle expenses + weed and pest + 50% depreciation) / Effective milking area / tDM pasture harvest. This measure of efficiency determines the underlying land cost structure of the business after removing the major cost centres influenced by different farming systems.
Cows per full-time staff equivalent (cows $unit^{-1}$)	E	161	165	Efficiency metric: peak milking cow numbers / total 50-Hour week equivalent full time staff. This measure of efficiency records the number of cows that are being milked per 50-hour full time staff equivalent.
Management and staff costs per cow. ($)	E	331	535	Efficiency measure calculated from (paid + imputed management + staff costs) / peak milking cow numbers.
Pasture as % of total consumed (%)	R	90.1	79.8	Risk metric: [Energy consumed from pasture on farm / total energy consumed by livestock on farm] x 100. Records the proportion of the overall diet that is composed of pasture grown on the farm.
Operating profit margin (%)	R	40.3	25	[Operating profit / gross revenue] x 100. This identifies the gross revenue that is retained as profit. Takes account of changes to the amount of livestock and feed on hand, depreciation, imputed labour and management, and other adjustments to revenue and expenses, this is A more complete measure than operating expenses as % of gross revenue.

Environmental Parameters				
N Leaching (kg N ha $^{-1}$ yr) OverseerV6	R	18	36	Risk metric for N loss, generated from Overseer v 6.0.
Nitrogen conversion efficiency (%)	E	25	30	Efficiency metric, generated from Overseer 6.0. Not correlated with risk.
kg MS per kg N leached (kg MS kg N^{-1} ha $^{-1}$ yr^{-1})	E	63	31	Efficiency of production relating to N lost per hectare. Higher MS per kg N lost is desired.
Environmental Scorecard	R	1.9	N/A	Risk metric – encompasses risk of nutrient, pathogen, sediment loss from farm management techniques.
Fertiliser nitrogen applied kg/N/ha/yr (kg N ha $^{-1}$ yr^{-1})	R/E	130	126.4	Risk, efficiency and productivity metric: needs to be read in light of pasture harvest/ha, N loss risk.

3.2.3 Analysis of the Farm Data for Comparisons

To assess how management influenced both nitrogen leaching and profitability, economic, efficiency and risk parameters were analysed using a regression of ROC on other variables. The final sample size tested (i.e. farms) was 22 (farms) and any correlations where $R^2 > 0.4$ were therefore significant (i.e. $P < 0.05$).

The data for all farms was available from the 2010 and 2011 seasons, (i.e.; two years) Due to the range in performance of farms (by up to 50%) when assessed between versions of OVERSEER, only the 2012 data set was used in combination with OVERSEER version 6.0. Nitrogen loss risk, nitrogen efficiency and scorecard risk factors were also tested against management factors using a regression analysis.

Economic resilience in this study was determined by the ability of a business to retain a strong return on capital (ROC) in the face of a 20% milk price fluctuation between years. Milk price from 1999 -2007 fluctuated by an average of 15% between years as compared with 2008-2015 fluctuation is 27% between years. (see Appendix 6) for milk price fluctuations in the past decade. Farm environmental risk was determined by the scorecard, and ability of a farm to have N loss of less than 30 kg N ha^{-1} $year^{-1}$. The first step was to identify the lowest risk farms (environmentally) and then assess economic resilience, with the final step being to analyse the characteristics of the best farms. The top performing farms (top 20% of 25 farms) were selected based on lower environmental risk coupled with an ability to demonstrate economic resilience (i.e., consistently strong ROC at different milk prices). This method was chosen as it identifies what characteristics farm systems will need to operate "within limits defined by catchment ecological health", i.e.; according to the goals of the National Policy Statement for Freshwater Management. (MfE 2013)

3.3 Results

3.3.1 Low impact farms and their profitability

Return on capital was not significantly related to the nitrogen leached for the farms examined (P ≥ 0.05). Some farms had a high ROC and low leaching (see circled farms in Fig 3.1). These farms were selected to examine relevant management factors that could impact on profitability.

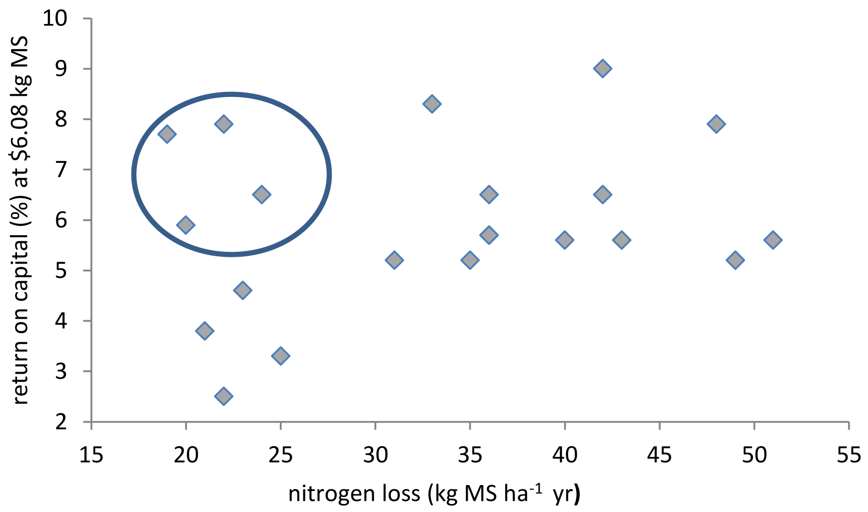

Figure 3.1 - Return on capital (%) vs nitrogen loss at $6.08 per kg milksolids.

The farms in the circle were identified as strong performers economically and environmentally. There was no relationship between ROC and stocking rate, pasture harvested, milksolids production, gross revenue per hectare, or nitrogen use. The highest percentage of variation in ROC explained by simply linear regression was cost of production in relation to milk solids produced ($R^2 = 0.82$, $P < 0.05$) in Fig 3.2

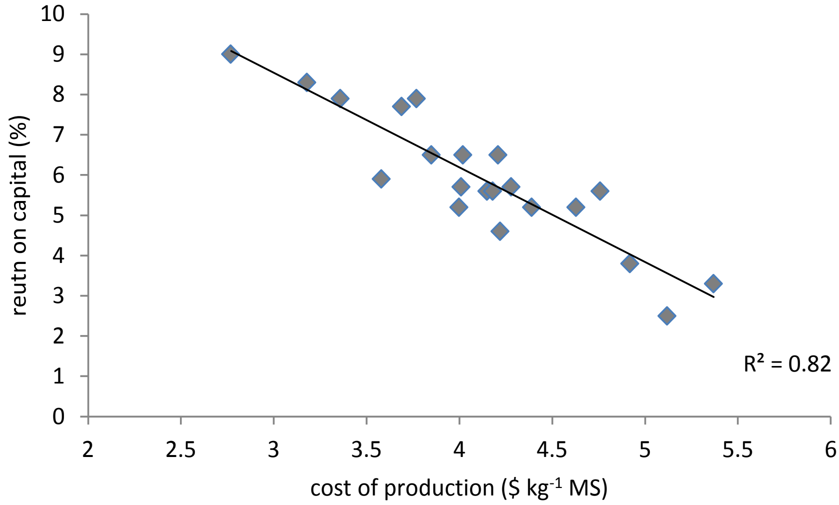

Figure 3.2 - Return on capital (%) vs cost of production per kilogram milk solids ($ kg^{-1} MS) ($R^2 = 0.82$, $p < 0.05$).

Return on Capital = ["farm income" – "cost of production kg MS^{-1}" x kg MS including "imputed labour and adjustments"] / Total capital employed. There is a significant correlation when a regression of ROC is tested against cost of production.

Cost of production kg MS^{-1} is not related to milk production ha^{-1} in Fig 3.3, there is no significant relationship. ($P > 0.05$)

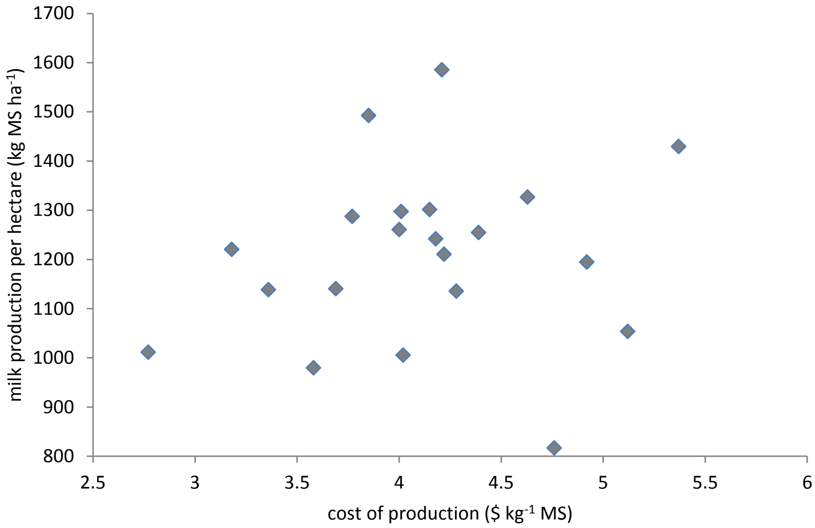

Figure 3.3 - Milk production ha^{-1} (output) vs cost of production per kg MS

There was not the same degree of difference between farms for milk production per hectare and gross revenue per hectare. Neither of these two components (Fig 3.3 and 3.4) of the return on capital function, showed any relationship to the cost of production suggesting that altering the cost of production will not necessarily have any influence on more revenue or more milk.

The cost of production per kg MS (standardised input) ranged from $2.77 per kg MS to $5.37 kg MS. (i.e.: a 100% variation.) The range of Gross Revenue per hectare of land area (standardised gross returns) was $6754 to $10,712 with one outlier removed (a 37% difference between the lowest and highest). The outlier in the data was removed as it had just undergone significant management changes at the outset of the year and was not considered representative of the normal farm system operation. Milk solids production per hectare ranged from 979 to 1585 kg MS per hectare (standardised output) a 38% difference between lowest and highest values.

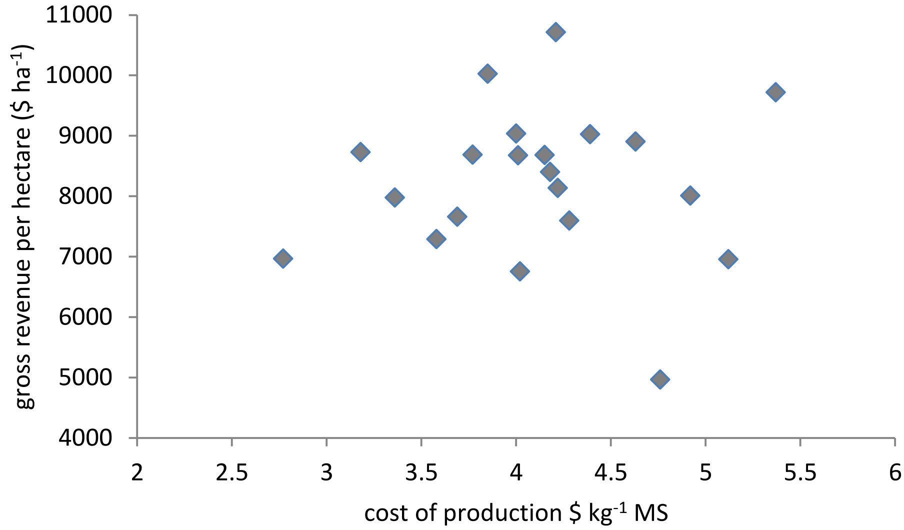

Figure 3.4 - Gross revenue ha^{-1} (gross returns) vs cost of production per kg MS (increased spending)

A component of the (operating profit component) of return on capital is the gross revenue. Gross revenue per hectare did not relate to increased spending for milk solids. ($p>0.05$). This was at a $6.08 kg milk solids price. (2011-12).

ROC was tested against a range of farm management factors such as stocking rate, milk production, fertiliser use and pasture harvested per hectare. Although there is a perception that increases in stocking rate relate to more production, leading to more profit, this study did not show this. (Fig 3.5). Stocking rate and bodyweight per hectare in this study was closely correlated as to be expected, as the cow size across the group was largely homogenous. Cows averaged from 440 kg to 550 kg cows and an average of 480 kg with no Jersey herds. The range in stocking rate across the farms ranged from 2.4 to 3.3 cows ha^{-1}, and bodyweight range from 1104 kg ha^{-1} to 1650 kg ha^{-1}

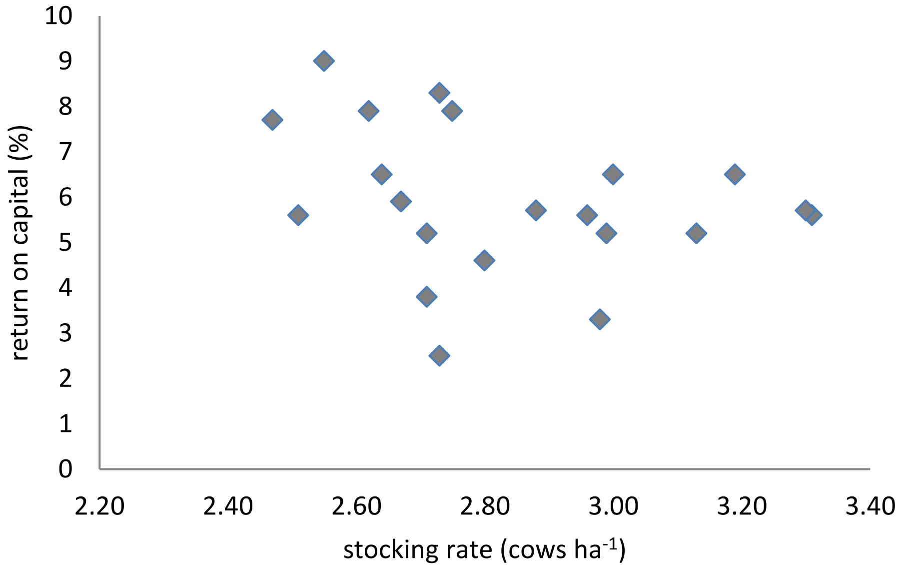

Figure 3.5 - Return on capital (%) vs stocking rate (cow per hectare)

There was no significant relationship between return on capital and stocking rate. ($p > 0.05$). One of the few management factors that was significant was the amount spent on management and labour for each cow farmed. The metric used to measure this was management and staff costs per cow, used to quantify labour and economic efficiency within the system.

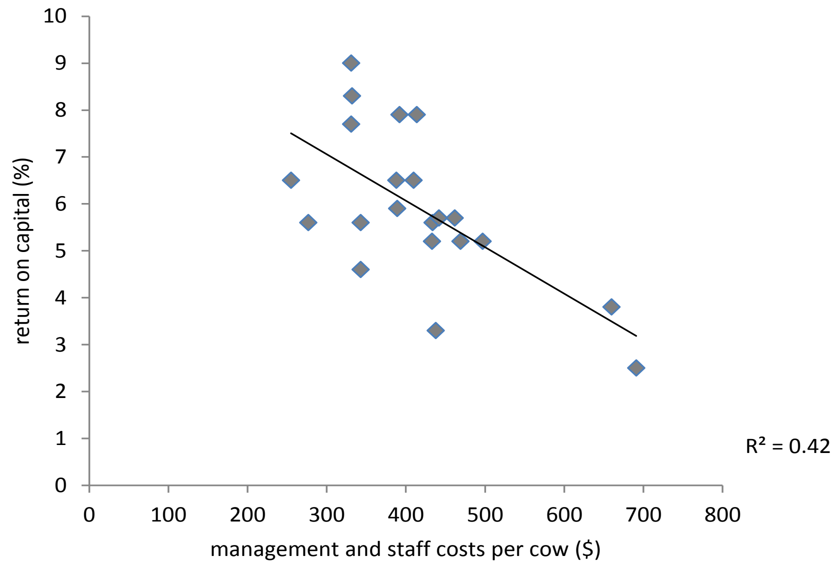

Figure 3.6 - Return on capital (%) vs management and staff costs per cow ($)

A regression of ROC was undertaken against the efficiency measure of "management and staff costs per cow." $R^2 = 0.42$, $p < 0.05$, suggesting the more profitable farms tended to have higher labour efficiencies (and more productivity per labour unit).

When a regression of ROC on both cost of production ($ kg MS^{-1}) and "management and staff costs per cow." R2 = 0.86, $p < 0.05$. This suggested that when both a low cost of production and a high efficiency of labour (lower staff costs per cow) was achieved, there is more chance of improving return on capital.

Although there was no significant relationship between ROC and stocking rate, there was a relationship between total pasture eaten per cow, and the ROC in a moderate milk price year ($6.08 kg MS^{-1}).

The milk price differed across two years, and therefore a single year comparison across a range of farms needs to be considered in context. In modest (more difficult) milk price year, there is a stronger relationship (Fig 3.7) between ROC and tonnes of feed consumed per cow.

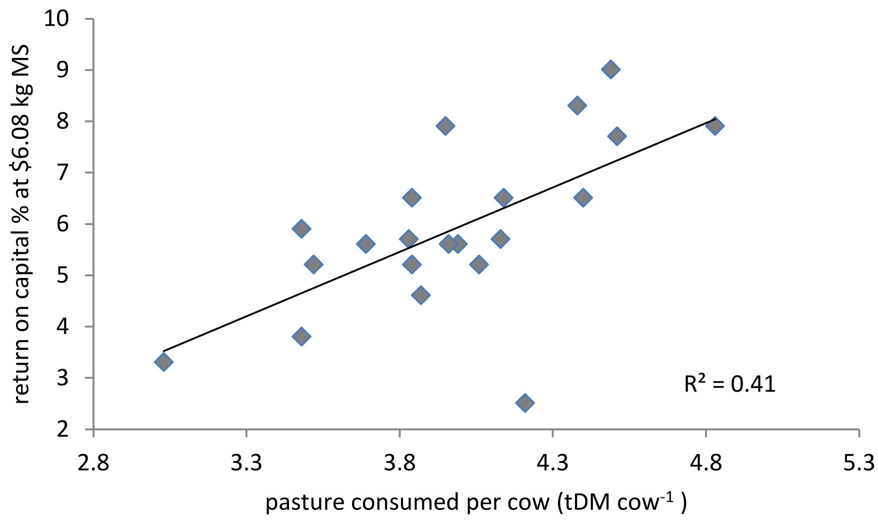

Figure 3.7 - Return on capital vs tonnes of home grown feed eaten per cow

At the milk price of $6.08/kg MS, in the 2011-12 season: $R^2 = 0.41$, $p < 0.05$. However in a higher milk price year ($7.50 kg MS) in Figure 3.8, the relationship is not significant as a higher milk price has a more significant influence on the profitability of the business.

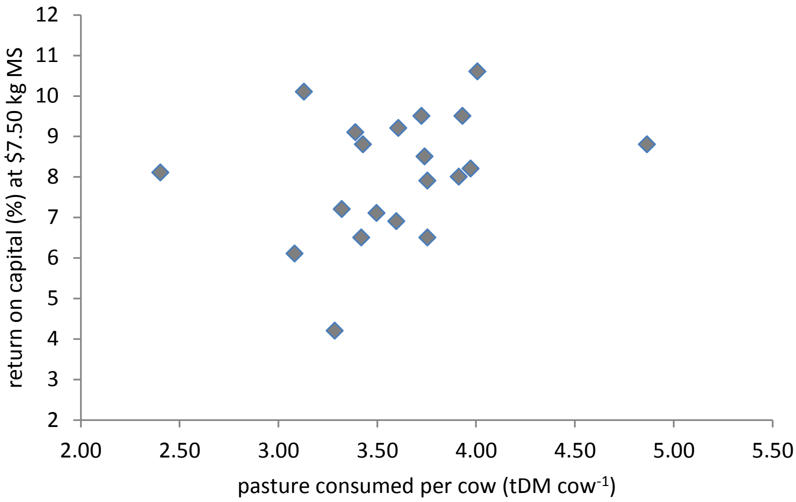

Figure 3.8 - Return on capital vs tonnes of home grown feed eaten per cow

In the higher milk price of $7.50/kg MS 2010-11 season, there is no significant relationship. ($p > 0.05$)

Table 3.2 - Relationship of ROC (%) vs pasture consumed per cow (tDM) at two milk prices

	Milk price	Correlation	R^2	P
2010-11	$7.50	0.28	0.079	0.23
2011-12	$6.08	0.64	0.40	0.002

3.3.2 Return on Capital and Relationship to Environmental Risk

A regression of return on capital at a $6.08 MS price and environmental risk score (higher total score indicates riskier environmental management practices) was undertaken to see if there was any relationship.

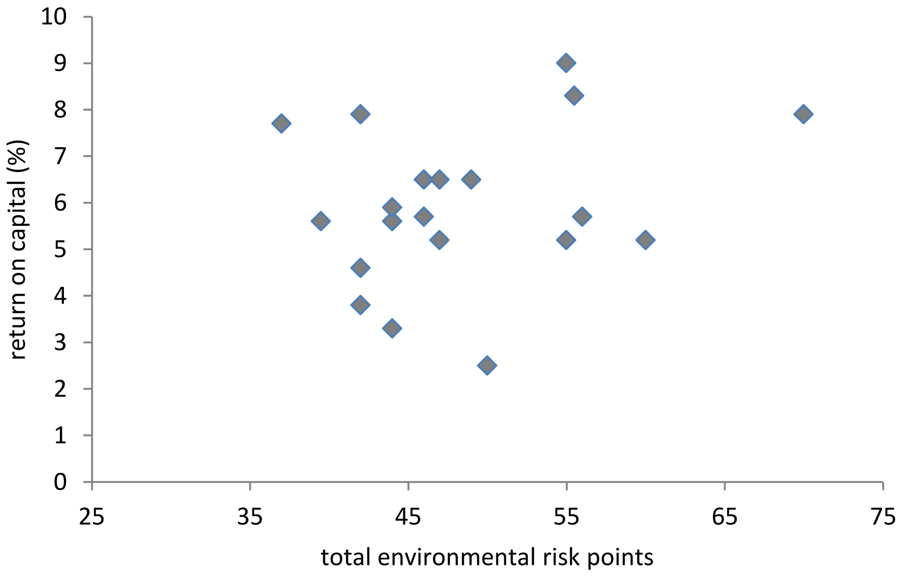

Figure 3.9 - Return on capital vs total environmental risk score

When a regression is done between ROC and environmental risk score using the total risk points from the scorecard, there is was no relationship, $p > 0.05$.

3.3.3 Profitability vs Nitrogen Use Efficiency

Nutrient use efficiency is a measure used by industry to describe the relationship of production to emissions. Milksolids produced per kilogram of nitrogen leached. A regression of ROC on nutrient use efficiency was undertaken in Fig 3.

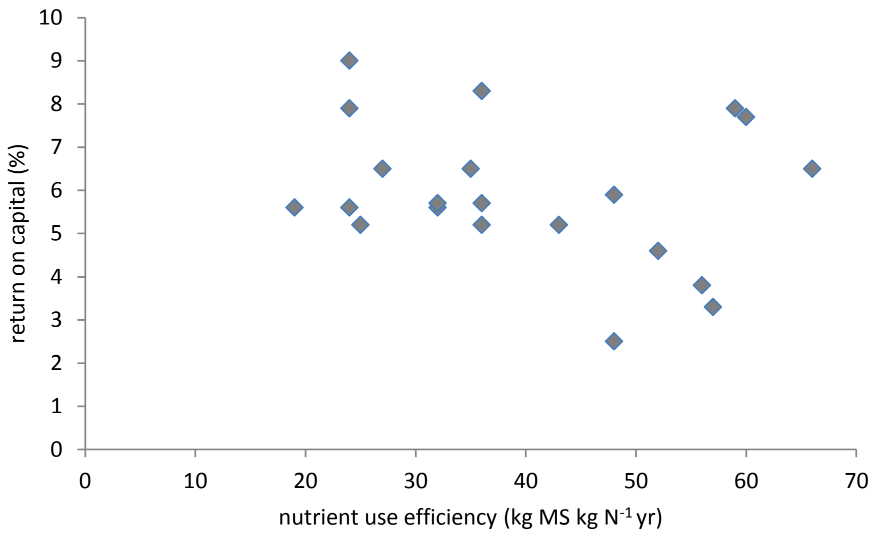

Figure 3.10 - Return on capital vs nutrient use efficiency.
(kg MS per kg N leached ha^{-1} yr). Nutrient use efficiency is not significantly related to ROC, ($p > 0.05$)

Some researchers have suggested that improvements in nutrient use efficiency (kg MS kg N^{-1} yr) may be associated with greater profitability. No significant relationship was apparent in this group of farms between improvement in N use efficiency, and return on capital (profitability) suggesting that improving milk solid production while reducing nitrogen lost from the system to the receiving environment is not related to financial performance.

3.3.4 The lowest environmental risk and most profitable farms

In Table 3.3, Farm "a" was a share milker farm that was analysed using the owners accounts to reflect an owner - operator farm (to allow fair comparison), this farm showed very high performance in all areas of the business so has been included to inform the discussion. Given that there was no significant difference between nitrogen loss and profitability (ROC). The lowest risk farms (environmental scorecard) were then tested for their economic resilience at both a lower milk price ($5.50 kg MS) and the 2011-12 milk price ($6.08). The farms that had the strongest ROC on this basis were chosen from the study group and are tabulated above. Further investigation of the farm management characteristics of high profit, low environmental risk farms are explored in Table 3.3.

Table 3.3 The most resilient and lowest footprint farms in the TFT study 2011-2012

Farm Code	a	b	c	d	e	Central Plateau Ave*
% feed imported/total feed + pasture (incl.winter grazing off)	20	25	30	32	28	20-25
Cows per milking hectare (cows ha^{-1})	2.59	2.67	2.47	2.75	2.80	2.82
Bodyweight(bwt) per milking hectare (kg ha^{-1})	1,165	1,199	1,185	1,291	1,345	1325
Milksolids per cow (MS cow^{-1})	388	368	462	469	432	357
Milksolids per milking hectare (MS ha^{-1})	1,005	979	1,140	1,287	1,210	1,009
Milksolids as % of bwt	86	81	96	99	90	76
Tonnes home grown feed eaten per cow (t DM cow^{-1})	4.5	3.7	4.7	4.03	3.97	3.9
Feed conversion efficiency. (kg DM kg MS^{-1})	12.7	11.4	10.7	10.9	11.5	12.0
Pasture dry matter harvested per hectare (tDM/ha)	11.7	9.9	11.7	11.1	11.1	11.0
Economic performance						
Operating profit per hectare ($ ha^{-1})	3,210	2,753	3,087	3,312	2,645	1,885
Operating profit per cow ($ cow^{-1})	1,239	1,033	1,251	1,206	944	676
Return on Capital (ROC) at 4-Yr Av Values @$6.08 kg MS (%)	6.3	5.9	7.7	7.9	4.6	4.6
Return on Capital at $5.50kg MS (ROC) at 4-	5.1	4.8	6.2	6.3	3.6	3.6

Yr Av Values						
Cost of production per kg milksolids \$ kg MS^{-1}	3.10	3.58	3.69	3.77	4.22	4.57
Operating profit margin (%)	45.9	37.8	40.3	38.1	32.5	25.1
Core per cow cost (\$)	452	588	738	571	657	593
Core per hectare cost (\$ ha^{-1})	964	999	1,217	1,430	1,527	1,230
Core per hectare cost per tDM pasture harvest	82	101	104	128	138	112
Cows per full time staff equivalent (cows $unit^{-1}$)	145	167	161	134	154	165
Management and staff costs per cow (\$)	372	389	331	392	343	535
Pasture as % of total consumed (%)	88.7	81.9	90.1	75.5	80.5	79.8
Environmental Performance						
N Leaching kg/N/ha/yr Overseer V 6.0 (Sept 2012) (kg N ha^{-1} yr)	25	20	19	22	23	36
N Conversion Efficiency (%)	26	27	25	29	35	30
Kg milksolids per kg N lost.(kg MS kg N^{-1} ha^{-1} yr)	41	49	60	59	53	28
Environmental Scorecard	2.3	2.2	1.9	2.1	2.2	N/A
Soluble Nitrogen Use(pasture) kg N ha^{-1} yr applied	55	91	130	57	140	126.4

*Central Plateau Average economic performance from the Red Sky and Intelact financial database, and may represent above average farm performance than what is seen typically.

3.4 Discussion

The study identified key factors that increased dairy farms in terms of creating a "resilient business". Resilience was highest when adequately managing fluctuations in milk price concurrently with minimal decrease of return on capital as well as lowest risk to the environment based on both the scorecard measure and N leaching rate (< 30 kg N ha^{-1} $year^{-1}$). A ± 20% change in milk prices between years (see Appendix 6) was used to describe variability of prices for the purpose of examining resilience.

A simple regression of ROC with nitrogen loss demonstrated no relationship, suggesting that some farms can be profitable with low nitrogen losses and low environmental risk based on the scorecard. A subset of farms with high profit and low N loss was investigated further to test for common management approaches. The greatest influence on ROC amongst the variables tested was from the cost of production per kilogram milk solids rather than measures such as total milk solids production per hectare, gross revenue per hectare or stocking rate. More stock and more milk did not reflect a greater likelihood of profitability. However at a modest milk price, an "optimal stocking rate" is more likely to be of significance in ensuring consistent returns, as shown by the stronger performers; Table 3.3 and Figure 3.7 where more home grown feed eaten per cow can reduce the cost of production down, leading to a more reliable business model. When systems are run so that there is a high labour efficiency gained, and a low staff cost per cow achieved (Figure 3.6), the likelihood of improving profitability increased.

To ensure that more tonnes of home grown feed are eaten per cow, it is essential that the number of cows per hectare or average bodyweight carried per hectare is linked to the long term average pasture harvest for the farm. In NZ most dairy farms are not routinely measuring or monitoring their historical average pasture harvest. As a consequence farming methods are based mostly around rule of thumb approaches with regard to stocking rate. There is also a historical perception that increasing stocking rate correlates with increasing production. Related to this, is a perception that more gross income per hectare, from more milk, is associated with more profit. This study failed to show any such relationships.

For the higher milk price tested ($7.50 kg^{-1} MS), the regression of ROC against home-grown feed consumed per cow is weaker. Milk price may drive decisions on farm and there is a tendency to intensify quickly to capture a high milk price when feed prices (e.g. PKE) are relatively low. Therefore decisions on farm will be largely governed by milk price and season rather than farmers electing to develop the most resilient business (i.e.; those that can endure fluctuations in milk price (± 20%) with minimal decrease in ROC.

Results from this study indicate that for lower milk prices ($6.08 kg MS) the higher pasture eaten per cow (> 4.0 t DM cow^{-1} year^{-1}) is associated with better performing businesses due to containment of the cost of production, generating high levels of milk per cow through fewer, better-fed cows and a well-managed feed supply, while operating under environmental constraints.

The stocking rate on a farm can underpin the whole farm system resilience across different milk prices and seasons, and can significantly influence the degree and cost of environmental mitigation requirements. An "optimum stocking rate" requires knowledge of a farm's long-term capability to generate energy. This is best evaluated with historical farm performance analysis. Many farms consume less home grown feed (i.e.; energy per hectare) than is desirable, hence stocking rates above "optimum" are driving a need for annualised cropping, reactive nitrogen use, a high reliance on bought in feeds (> 20% is now typical), and subsequently soil damage and reduced margins from systems. In contrast to suggestions by some authors (Anastasiadis & Kerr, 2013) that an increase in nitrogen conversion efficiency may be a factor associated with increased profitability, my study failed to show any such correlation.

Factors that influence farm environmental and economic performance include the nature of the farm system, geophysical risks and variations, and the values and capabilities of individual farmers. There will be different solutions for each farm to achieve true resilience, and the most appropriate solution will largely be governed by the risk preferences of the business operator. The farm system should be assessed using historical farm performance analysis, use of OVERSEER and the scorecard approach, to identify all business risks.

The most efficient farmers in my study achieved around twice the profitability of the average dairy business for the central plateau region. Their farms had lower environmental risk and nitrogen loss than the average across the study. These farmers appeared to be systems thinkers; they considered cause and effect in relation to their actions, while being cognisant of external variations that impacted their systems. Their responses tended to be timely in relation to impacts on their businesses.

Notional responses to higher inputs and costs, as noted by Ridler et al (2010) do not always eventuate. Increasing both milk solids and gross income per hectare did not show any relationship with both cost of production nor improved returns in this study. For each standardised unit of input, there is not always a corresponding linear response in units of output and therefore not necessarily higher profits (i.e. the notion of diminishing marginal returns).

There was a 100% variation in the cost of production across the study farms. Although the return on capital calculation includes gross income, milk solids and price were less variable between farms. Farms were tested at actual milk prices for the year ($7.50 in 2010-11, and $6.08 in 2011-12), and also a lower milk price of $5.50. The most resilient farms featured showed the least change to their returns at lower milk prices, as well as having low N leaching and environmental risk measured by the scorecard.

A common feature of the more resilient farms was that the operators were able to demonstrate excellent cost control while still achieving higher than average levels of production per cow and per hectare. Low cost of management and staff per cow was also a feature, reflective of the simple, efficient systems in place.

The farms were not overstocked relative to their historical pasture harvest, with high quality cows fed at low cost on home grown feed and efficient conversion to milk. This feature was confirmed by the measure of 3.8 -4.4 t DM of home grown feed being consumed by each cow, with the best performer (farm c) getting 4.44 t DM of home grown feed eaten by each cow, and milk solids performance of 96% of cow bodyweight compared with the district average of 77%.

The better performers may be assessed as having near optimal stocking rate for the farm, whereby cows were “well fed” and productivity was high from low cost feeds (home grown) and high pasture harvest despite a “lower than district average” stocking rate and bodyweight per hectare. The higher productivity per cow (>90% body weight as MS) and per hectare that was common to these farms possibly reflected good genetic merit and strong selection pressure resulting in more high performance cows on the whole. However, when these farmers were asked about this feature (higher genetic merit) in particular, their view was that their herds breeding and production indices were not of significance when compared against industry databases. A view was expressed that their consistent approach to feeding their cows well, and having attention to detail on cow welfare aspects were the main factors in their strong performance.

The strongest performing farms also had an ability to store and spread effluent at optimum times over much of the farm (>40%) and minimise imported soluble fertiliser. Soluble nitrogen use per hectare on two of the top performing farms was only one-third of the average for the region, with no loss of productivity when compared with the average.

The better operators demonstrated practices that reflected that they understood the effects of external forces on their systems and adapted accordingly and in a timely manner. There was a very strict approach that was adhered to in their business: such as the philosophy of the “KISS (Keep it Simple Stupid) principle” that underpinned daily decisions, making them scrutinise all spending, ensuring optimal animal performance (e.g.; cow health and welfare focus), adhering to simple, repeatable systems and processes that achieve high labour efficiency and a wise use of infrastructure. They were excellent risk managers bearing in mind that “It’s not the good years that make you but the tough years that break you.” (Guyton *pers comm*, 2013)

Emerging rules and policies related to ecological health limits will drive a period of rapid adaptation by the agricultural sector. In many cases this will require further investment at farm level, leading to increased economic risk (lower equity on balance sheets). Farms will become increasingly polarised in terms of their operational systems, either adopting a low input, low stocked, efficient farm system with simple mitigations such as the “resilient” farms shown in this study, or high stocked, high input - output, with investment in advanced mitigations.

In my study some farms imported 40-50% of the annual supplement to support high production and to fill feed gaps. Three farms in the study ran profitable intensive systems in the high milk price year (2010-11 at $7.50 kg MS^{-1}) but did not demonstrate consistent profitability (strong ROC) for $5.50 and $6.08 $kgMS^{-1}$.

Higher input systems may be riskier, less resilient businesses, when milk price is variable and in the presence of climatic fluctuations. Indebtedness compounds this risk. In economics, diminishing returns (also called diminishing marginal returns) represent the decrease in the marginal (per-unit) output of a production process as a single input factor is increased,(while others remain constant), (Samuelson, 2001). In dairy systems for example, strategic nitrogen (N) use improves pasture production, but at a point increasing N improves the yield less per unit N applied, while excessive quantities can even reduce the yield, and increase leakage from the system.

There is evidence to show that as farm system intensity increases so do the risks, (Ledgard *et al,* 2003; Journeaux 2013). Higher input farms are then less able to mitigate downside risks (Shadbolt 2013a). This study showed that at a lower milk price ($6.08) the more modestly stocked systems with better - fed cows, and high production per cow (Table 3.3) were more profitable, and had a lower corresponding environmental risk profile.

There was a perception amongst some farm operators in the study group that lower stocking rate and higher performance (more milk from fewer cows in a pasture based system) added risk as the requirement to be an excellent pasture manager became paramount. Previous modelling has shown that this perception may be overstated (Anderson & Ridler, 2010) as in such circumstances, economic loss occurs at an increasing rate with high input systems due to feed deficits occurring more rapidly and requiring increasing quantities of supplements per cow, with an increasing marginal cost per cow.

Consequently, for every farm, there will be an optimum zone that ensues the most suitable system is chosen for the soils, climate and landscape. System optimisation will account for factors such as operator and herd capability, cost of supplements and support land for the system. This is likened to a “sweet zone” at which a farm system is operating with maximum efficiency (operating profit margin), minimum risk and optimum profit.

The Sweet Zone for a farm system is clearly illustrated in the conceptual graphs of Figs 3.11 and 3.12. They demonstrate that increasing milk production and intensity (growth orientated goal setting) (blue line) through greater inputs is not linear.

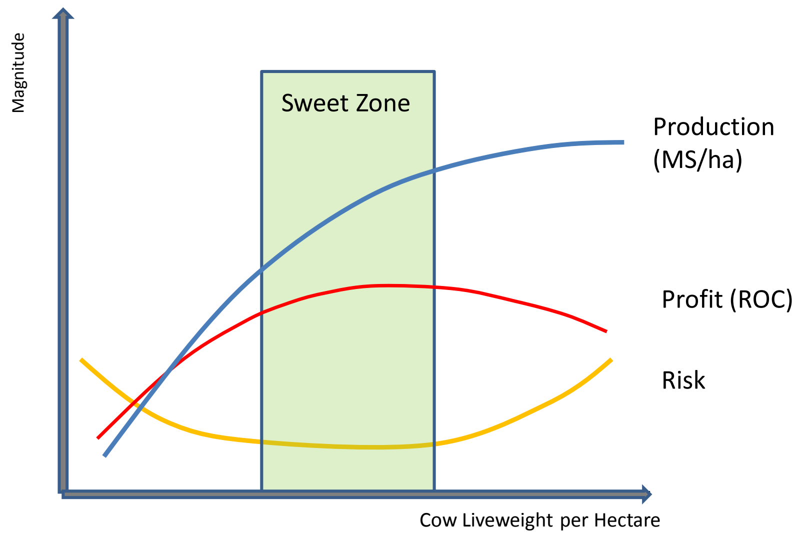

Figure 3.11 - Conceptual Diagram of the magnitude of production, risk, profit, in a farming system relative to cow live weight per unit area, illustrating a hypothetical “sweet zone” of cow live weight per unit area that best balances production, profit and risk.

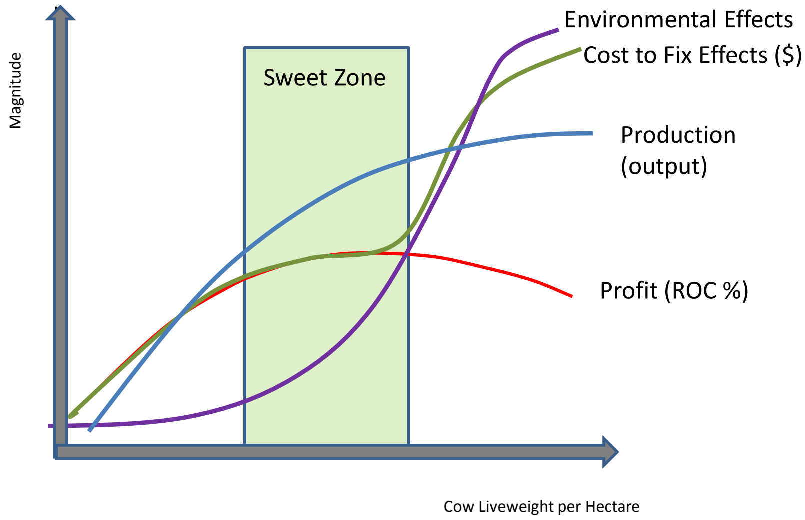

Figure 3.12 - Conceptual diagram of profit vs environmental effects vs cost to fix effects

According to the conceptual diagram of fig 3.11, there is a diminishing return on capital with increased intensity and risk (yellow line). The increased risk at high levels of production becomes evident with continued spending (increasing of inputs and cost of production), without a concurrent and linear response in income per hectare. (e.g.: milk solids or gross income per hectare). Increased business risk associated with increased farming intensity (attempting to get higher production) means that any sort of volatility (i.e.; climatic, irrigation constraints, commodity prices) can result in escalated vulnerability and increased risk of failure to the business. The "Sweet Zone" for each farm is established by doing a thorough farm performance and environmental risk analysis over 1-3 years, as undertaken in this study. If farmers have this information at their disposal, then the most optimal operational zone for their mix of landscape, cows, social capability and risk preferences can be ascertained.

Studies conducted on Waikato farms have been based on earlier versions of OVERSEER and have included dicyandiamide (DCD) as a mitigation option whereby nutrient loss risk is reduced by around 10%. (Agfirst Waikato, 2009; Beukes, 2012; Di, 2002; Doole, 2010; Monaghan, 2007). DCD has been removed from use on NZ farms since January 2013 as traces of it were found in milk products (MPI, 2013). The case of DCD proves an example where the approach of costing single mitigations in studies is flawed. By placing high reliance on single mitigations in these studies, they have risked complete failure when these mitigations become unavailable such as the case of removal of DCD. Historically studies have had a focus on single mitigations and subsequent cost effectiveness to reduce leaching rather than considering whole farm system configurations to achieve resilience.

As NZ seeks to grow agricultural output by converting extensive pastoral land to more intensive dairy systems in vulnerable landscapes (PCE, 2013) there will be increasing pressure to transition to 'hybrid type' farming systems, where stock housing occurs during high environmental risk times of the year. Farm c, had a herd home. This farm ran a comparatively low- cost, low- input system with infrastructure that contributed to efficiencies. Bought in feed (10% of total) was fed in the herd home. The herd home benefits were for cow welfare, and to provide effluent storage. In this particular case, benefits were efficient nutrient use, cow welfare, and better feed conversion efficiency (FCE). Feed conversion efficiency was 10.7 kg DM per kg MS produced. (20% better than the Waikato average) This farm had flat topography which would have contributed to higher efficiencies and had leaching of only 19 kg N loss ha^{-1} yr^{-1} based on OVERSEER 6.0, with the lowest risk score of all farms in the study on the environmental scorecard.

Hybrid systems (e.g.; herd homes) can assist nutrient efficiency by providing containment of effluent and storage of the nutrient for use at times of greatest seasonal growth, protection of soils and stock from adverse climatic conditions, and enhanced welfare and feeding infrastructure that optimise feed conversion efficiencies. New Zealand has scant data on the economic performance of hybrid farming systems. A report by Journeaux (2013) that modelled their profitability indicated that these systems were problematic for the average farmer to adopt. His study showed that wintering facilities can provide a significant gain in terms of reduced nitrogen leaching, to as little as 18 kg N ha^{-1} yr^{-1} provided intensification of the farming system did not occur, (Journeaux 2013). Intensified systems are then more vulnerable to feed and milk price fluctuations, which can lead to less certain profits and higher risk. Therefore, these systems should only be adopted when the farmer has a high level of skill to manage costs, achieve high productivity from both cows and resources and has sufficient equity on balance sheets. Farmers should seek strategic guidance (farm system modelling and business strategy) to help them make these choices.

This study re enforces modelling work done by (Ridler et al 2010) showing that dairy system profitability is optimised where technical and biological efficiency combine to provide the best economic and co incidentally, environmental outcomes. The stronger (most resilient) farms in this study tended to be lower input systems with fewer, well fed cows, that were simple to run, with a lower environmental risk. The lower environmental risk did not require expensive mitigations, nor did it mean additional costs for the business. Although they were more profitable at a range of milk prices, these lower input systems may not always capture all the upside benefits of a high milk price (>$7.50 kg MS^{-1}) that a high input – output system could. These business models will be best suited to operators that are able to manage the pasture growth changes competently, as lower bodyweight carried per hectare may well result in smaller feed gaps, requiring less bought in feed, but greater surpluses in spring and early autumn periods requiring careful management.

Chapter 4 : Conclusions and Recommendations

4.1 Conclusions

This study has shown that some dairy farm systems in the Upper Waikato are already demonstrating economic resilience while operating within prospective ecological limits. The farm systems highlighted in this study demonstrate that risk minimisation, optimal profitability and reduced resource use is possible. However, for change to happen on farm, it will require a shift towards “systems” thinking, and away from singular production orientated goals toward consideration of a range of external forces that impact on dairy farm systems in their entirety. This will require taking more of an ecological approach to designing systems. Table 4.1 describes this concept.

This study provides farm system examples that demonstrate profitability can be optimised while operating within ecological limitations. This study considered two farming seasons on 25 farms. The two years were considered “relatively normal” by the participants. Following this study, however, was a drought year. Longer periods of dry weather appear to becoming more frequent in the study area, reinforcing the requirement for farmers to configure their systems to cope with fluctuating feed availability, milk price and resource constraints. This study showed that in the upper Waikato on pumice soils, with 1000 -1200 mm of rainfall per year, that a good proportion of the participants can operate their businesses profitably at a range of milk prices and seasons while having a low risk to the environment.

More broadly, the decisions to protect ecosystem health may result some areas of New Zealand having land prices transitioning to more accurately reflect inherent values such as the natural capital, the soils attenuation capability, and inherent vulnerabilities rather than what has been the historical driver for land price; that of total output (milk solids) from a farm. Some soils, topography and climates will be less viable for intensive pastoral agriculture due to the inherent risks they present to the receiving environment. This will mean there will be a requirement for more advanced mitigations and investment, and more risk from more debt in some cases.

Increasingly the public will require primary industries to internalise its effects and risks through the use of legitimate measures of diffuse losses from farms. This will place increased pressure on farmers to know their landscapes, understand their farms' strengths and weaknesses better, and adapt their farm systems more appropriately to work within their landscape strengths and limitations.

Irrigated and more intensive farms may require more mitigations to meet limits, while simpler less intensive systems with optimal stocking rates, high levels of efficiency coupled with low cost of production appeared to be better off in this study (when analysed using OVERSEER version 6.0, and the environmental scorecard).

To enable a transition in agriculture, New Zealand will require new thinkers and leaders in the sector. Strategies and plans will need to be supported by a suite of measures that that allow comparison between pastoral and industry sectors such as the measures used in this study so there is "assessment on a level playing ground."

New Zealand farming as a whole is struggling to reform into a sustainable management system after year of production - orientated goal setting. During the course of this study, the understanding by the farmers improved with respect to what were the most appropriate measures for profit and performance were e.g.: ROC for profit, rather than production or stocking rate, as a metric for economic performance. Metrics that represent total farm environmental risk, consider the law of diminishing returns, and optimise resource use efficiency are now of integral importance as there will be a compulsion for farmers to seek the most profitable, low risk land uses in the face of environmental limits.

There is a requirement to use metrics that describe economic and environmental performance across agricultural sectors such as dairy, dairy support, sheep and beef and deer. (e.g.; ROC and resilience test, scorecard metric). At present, a common suite of metrics is not being used and the extensive pastoral sector is being enticed to switch to more intensive systems due to the perception of more gross income rather than true profitability (i.e.; ROC, excluding capital gains). The absence of a common suite of metrics (KPIs) is resulting in unnecessarily complex processes when comparing performance and risk across different pastoral sectors. (e.g.; optimised sheep and beef system versus dairy systems)

As this study has shown, it is not single actions or mitigations in a farm system that improves economic resilience when environmental limits are in place, but rather it is a management approach, that makes the best of the farmers, cows and landscapes capabilities.

Increasingly farmers and leaders in agriculture will need to conceptualise systems, and how land uses perform both economically and environmentally. This will require the constructive articulation of the top-down cross disciplinary approaches to development aligned with bottom-up or grassroots initiatives. Broader thinking of the spatial and temporal horizons must occur, taking into account both intra-generational and inter-generational equity.

From a practical perspective in NZ, an improved approach will arise from a mix of disciplines to work to assist farmers with more strategic planning and technical assistance for farmers in a similar manner to how this study was undertaken. This may involve sharing key farm data between trusted professionals who operate at the farmer - land interface and support bureaus providing technical support for front line professionals. “Farm- facing professionals” could gather essential data and link the farm operation to business support networks to provide systems, economic, environmental analysis and modelling data to farmers, while also taking into account actual or prospective ecological limits being imposed from regional resource managers.

A centralised database with institutional support, of regional farm management risks that emerge from the farm plans, scorecards and OVERSEER files required by Horizons, Canterbury, Otago and Hawkes Bay in their recent plan changes for example would be a positive step to allow farmers to share some components of relevant farm system information with their regional authorities via a third party authorised to hold independently validated data.

An independent data management system populated by annual data of land use and system risks (such as the scorecard approach) would also inform regional resource managers of current practices and emerging trends. Such a database is absent in New Zealand at present, and as a result, has meant that land use trends and changes have eluded and surprised regional resource managers and led to over allocation of resources.

A system such as this would also means the costs of compliance are met by the industry rather than the ratepayer. Although there may be resistance to this by the farming sector, farm plans (to manage N, P, sediment and pathogens) are already required by regional rules as agriculture transitions from a permitted activity status, to a controlled status in well over half of New Zealand's regions.

Table 4.1 – Ecological approach in Dairy Systems

Effects	Ecological Science Approach to Dairy Systems		Economic "Business as Usual Approach" to Dairy Systems		Effect
↑Resilience	Homeostasis↔ Buffers + Latent Energy Stores↔ System Designed to operate within Carrying Capacity		Resource Use→ Growth (resource + energy drawdown)→Technology to overcome limits→ Diminishing returns→ Challenged competitiveness→ Overshoot↔ ←Regulation + Resource Claw-back		↑Vulnerability
↑Ability to move laterally ↑Flexibility Moderate reliance on "Environmental Services".	Cows stocked at optimum rate for land, human and animal capability Self- sufficient energy system. If buffer land is used – vertically integrated and assessed as one system. Carefully configured to landscape risk, repeatable processes. Low – moderate environmental effects + pollution Simple mitigations manage effects		↑Inputs(feed, fertiliser, cows) drive growth ↑Reliance on support landscapes to provide energy into production system ↑Skills required ↑Increasing pollution risk with intensity ↑Disease risks – intensive systems. ↑ Expenditure for advanced mitigations ↑Debt		↑market dominance/ monocultures ↓diversity + resilience ↑Reliance on "environmental services" ↑environmental clean up
↓↓↓ Profit via cost control, higher operating profit margin gives resilience	↓↓↓ Resilience from Buffers + minimising stress in system	↓↓↓ Reduced Environmental Impact	↓↓↓ Growth + production + higher costs	↓↓↓ More marginal returns lower operating profit margin, less certain profits.	↓↓↓ Increased Environmental Impact and cost to fix effects

4.2 Recommendations for Further Research

To ensure New Zealand's continued competitiveness on the global stage, there is a pressing requirement for both top down strategic thinking as well as grassroots technology improvement, namely the validation and verification of OVERSEER for a wider range of soils, climates and modern farm systems. The validation of OVERSEER under intensive irrigated dairying on porous soils is especially important. Along with that we need further understanding of the most appropriate technical extension processes that have proven successful in improving both farmer understanding of business resilience and environmental performance operating within resource limits.

Clear metrics that adequately define the interrelationships between production (growth, intensification) profit, ecological and public health and welfare implications are required. This can, to assist both agriculturalists and professionals in the sector to operate using systems orientated approaches to problem solving.

NZ has some of the highest global rates of campylobacter, cryptosporidium, and giardia (Lal 2014) along with declining lowland freshwater amenity, in many cases due to pathogen enrichment (94% of lowland streams: Larned et al 2004): Nonetheless national knowledge on the aetiology and processes regarding pathogens is poor. The origins of zoonotic pathogens resulting from intensive agricultural systems, their transport and fate in the environment, and the corresponding public health significance of pathogens originating from agriculture are still poorly scoped and understood. Moreover, one of our greatest global challenges may be the emergence of new antibiotic resistant pathogens that may have their origins in more intensified agricultural systems and links to public health via environmental pathways. (W.H.O, 2014) There is an urgent need to gather more data on this in NZ where probably more than half of antibiotic use is in food production systems. (Sarmarh et al 2006)

The pathogen challenge, along with the national development challenge (economy vs environment) will require strong national trans-disciplinary partnerships to be forged to solve the immediate challenges faced that consider sustainable "development" concepts, spanning ecological, public health and food production systems rather than just “economics” with a degree of creative thinking and comprehensiveness required by the nature of the problems that New Zealand in particular faces. These trans-disciplinary partnerships will be required to assess future development for NZ with a broader scope than just economics (as has been the NZ approach previously).

For New Zealand to retain a robust and prosperous farming sector, it is essential that there are a common suite of metrics developed whereby profitability, resilience and environmental risk are all able to be compared between the different primary industry sectors in a manner that is easily understood. The profitability(ROC) and resilience measures used in this study can be adapted for all farming systems, however the concept of the environmental scorecard (metric) would need further development for different catchments should it be used more widely.

With the availability of suitable metrics to demonstrate optimum performance, business resilience and environmental risk between sectors, more comprehensive approaches to analysing both current and future agricultural growth projects (e.g.;Ruataniwha Dam) would occur. More robust assessment of the socio political effects supported by a transparent and robust methodology is essential to ascertain their true feasibility.

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APPENDICES

1. Questionnaire for collection of environmental data at visit.
2. What is measured and not measured by Overseer. (Referring to Waikato Catchment risks)
3. Limitations of OVERSEER for reflecting some management activities.
4. Scorecard Example
5. Appropriate Setbacks for Riparian Planting
6. Fonterra Prices paid to Farms

APPENDIX 1: Questionnaire for collection of environmental data at visit.

Farm Name: Date: Waterway Protection Length of waterway through the farm Google earth map % Fenced? Riparian margins – planting, width, description. Wetlands within the farm area? Fenced? Tree or bush stands – fenced or protected? Points of connectivity to waterways If stock are crossing streams more than 2x week – are there crossings in place? Tracks and runoff direct connectivity points to waterways Any risk sites?	Notes
Effluent system description & storage Storage capacity approx.(m^3) Has this been validated with pond calculator? Is the pond lined + placement right – proof of no leakage? Application rate known? Soil risk known? Effluent testing done? Mitigations Alerts in place to auto stop % of farm irrigated + ability to expand this area Solids emptied from ponds how often Emergency storage period capacity	
Soil protection Winter cropping process Cultivation of soils for crops Buffer strips Managing winter pugging/soil + stand off areas Feed Pads? Loafing Pads? Stand off areas and practises? Points of connectivity (intensive feeding) to waterways?	
Water use efficiency Water saving initiatives - capture and storage at dairy Is water diversion or recirculation in place? Washing of yard- water saving technology in place. Water leaks and management on farm Are Alerts in Place for Water System Farm Staff aware of water line – map Isolation of parts of the farm able to be done.	
Energy use and efficiency -renewables on farm? Insulation of hot water pipes insulated Pre cooling of milk? Vat insulation? Milk harvesting efficiencies	
Waste management Silage wrap /plastics/hazardous waste Silage conservation wrap? Collections by Agrecovery Hazardous waste containers/veterinary chemicals.	

APPENDIX 2: Risks to Receiving Upper Waikato Environment: What is measured and is not measured by Overseer

Issue	Measure	Source	Measured by Overseer?
Erosion and sedimentation in headwaters of catchment	Main areas of concern are Upper Waipa - into which the Puniu and Owairaka and Mangetutu Streams	Diffuse/Agriculture	No: Assumes sediment loss rare
Lack of protection of steams and water bodies in upper catchment from direct entry by stock (faecal contamination being main concern)	35 % of steam length in the Upper Waikato is protected with permanent fencing – ensuring stock exclusion from these sites on a permanent basis.((Journeaux, 2011). This is greatly improving with Industry Accord (2013)	Point + Diffuse/Agriculture	No: Assumes all stock is excluded 100% of time. 1st and 2nd order streams are not accounted for.
Nutrient Loss through soils in upper Waikato (70% of N to Waikato is from diffuse land losses)	Nutrient enrichment of Upper River can predispose river to increased chlorophyll a growth, loss of clarity.	Diffuse/Agriculture	Yes, measures diffuse N loss.
Nutrient Enrichment of upper Waikato streams and tributaries of the Waikato	N enrichment P enrichment Coliform (pathogen) and fine particle sediment.	Diffuse/Agriculture	Measures Diffuse N loss. Average for P loss. Not pathogen or silt runoff.
Loss of versatility of use of lowland waterways	70% unsuitable for stock drinking (coliforms) 75% unsuitable for swimming(coliforms) (Ballantine, 2010)	Diffuse/Agriculture	No pathogen loss measure. Assumes BMP in place.
Soil quality issues over whole of Waikato	Only 34 % meet soil quality guidelines 2009 report. (Waikato Regional Council, 2008) Including toxic land contaminants	Agriculture	Overseer and protocol assumes BMP for soils and fertiliser.
Access to Waikato river and wetlands	Only 26% of original wetlands remain, many of which cannot be accessed as they are on private land.	Agriculture/ Municipal etc.	Assumes nil animal – water connectivity 100% of time.
Continued Intensification	Approximately 20% intensification (as measured by lifts in stock units over two land use classes) – i.e. forestry to moderate intensity dairying over period of 2002-2008 (Singleton, 2010) No limit/constraint on further conversions	Agriculture/ Governance	Partially: Overseer assumes Best Management Practise 100% of time. N loss difference between land uses.

Microbial contamination of water	Surface and aquifer. Point and diffuse sources. Regional Council is still issuing consents for two pond point source discharge(these discharges are not monitored for coliform loads as they would breach the limit) (Whiteman, 2011)	Agricultural and Municipal	No: cannot validate pathogen loss risk.
Water use and allocation/over allocation	Waihou 300% over allocated Waikato fully allocated.	Agricultural, Municipal, Industry	No: Overseer does not account for water use on farm.
Continued discharge of point source waste (including partially treated effluent)	Point source discharge from human waste treatment plants still occurring direct to waterway. (land based application would be preferable)	Point source. Municipal, Industry	No: Overseer only measures N loss for pastoral agriculture.

APPENDIX 3: Limitations of OVERSEER 6.1 for quantifying risk from these sources.

Farm Management Attribute	Model Limitations	Protocol Changes + Effects
Winter cropping + cows on crop areas 24 hours.	Assumes all BMP is in place and no runoff or connectivity occurs. Cannot have cows on crops 24 hours, therefore understates risk	
Pugging and Soil Damage	Rare, Often	Must Default to Rare
Herd Homes + hybrid systems, and housing cows in HH for lengthy periods	Cannot have cows in more than 20 hours at a time. Cannot feed cows more than 8 kg DM as winter feed as ration.	The model tends to understate the environmental benefits of a herd home or infrastructure.
Fully Housed Systems	Cannot replicate these systems, have to cut, carry and have cows off 100% of time.	Must quantify effluent NPKS in hybrid system effluent produced then import back to cut carry block.

APPENDIX 4: Scorecard as reported to farmers

Headlands

ENVIRONMENTAL IMPACT ASSESSMENT : B Farms

SECTIONS	DEFINITION	1. EXCELLENT PERFORMANCE or VERY LOW RISK	2: LOWER RISK or GOOD PERFORMANCE	3: AVERAGE RISK or IMPROVEMENTS POSSIBLE	4: ABOVE AVERAGE RISK or ATTENTION ENCOURAGED	5: POOR/HIGH RISK or NEEDS ATTENTION	YOUR FARM RESULTS	THE GROUP AVERAGE	YOUR SCORE	AVERAGE FOR SECTIONS
NUTRIENT EFFICIENCY	GHG's/kg MS		■				9.1	9	2	
	Nitrogen Surplus kg N/Ha		■				151	198	2	
	Nitrogen Conversion Efficiency %			■			31	28	3	2.3
NUTRIENT LOADING	kg N leached/Ha		■				28	31	2	
	kg P runoff/Ha		■				1	2	2	2.0
WATERWAY PROTECTION/ BIODIVERSITY SUPPORT	% of waterway fenced	■					100%	100%	2	
	Riparian Planting 1-5- 10 M	■					5	10-15m	1	
	Biodiversity Protection		■				Y		2	
	Major Hot Spots(connectivity)				■		Y		4	
	Wetlands fenced and protected	■					Y		1	2.0
EFFLUENT & WASTE MANAGEMENT	Meets Requirements for Herd & Farm System (kg N Load)	■					77	83	1	
	Lined Pond + adequate storage based on Pond Calculator - No Irrigation unless SWD present			■			No		3	
	Effluent % area spread over farm	■					42%	11	1	
	Application management (alerts in place?)	■					Y		1	1.5
SOIL QUALITY & PROTECTION	Olsen P range			■			70-100	65	3	
	Winter Cropping % of farm/ Cultivation Techniques?			■			9%		3	
	Standing off(pugging avoidance) Winter Management		■				Y		2	2.7
WATER USE EFFICIENCY	Dairy Water Saving Systems in Place			■			N		3	
	Alert or Early Warning System in place for water loss		■				N		2	
	Irrigation (If applicatble)						N/A			
	Soil Moisture Monitoring				■		N		4	3.0
ENERGY USE	Renewable Sources used on farm			■			N		3	
	Waste Management		■				No wraps		2	2.5
							OVERALL SCORE		49	2.8

APPENDIX 5: Appropriate Setbacks for Riparian Planting

The Proposed National Environmental Standard for Plantation Forestry Discussion Document (MfE 2010) suggests the following planting setbacks along streams:

"The following minimum planting setback distances being applied:

- 5 m minimum from perennial rivers and streams with a channel width less than 3 m.
- 5 m minimum from the 'landward extent of wetland vegetation' for wetlands.
- 10 m minimum from perennial rivers and streams with a channel width greater than 3 m.
- 10 m from lakes larger than 0.25 hectares.
- 20 m minimum from regionally significant wetlands, lakes or rivers.
- 30 m minimum from the Coastal Marine Area."

APPENDIX 6: (Adapted from Interest.co.nz, 2014)

		Fonterra			
$/kgMS		Milk	Dividend	Total	% change between years.
		$	$	$	
1998-99	A			3.58	
1999-00	A			3.78	5.291005
2000-01	A			5.01	24.55
2001-02	A			5.35	6.35
2002-03	A	3.34	0.29	3.63	-47.38
2003-04	A	3.97	0.28	4.25	14.58
2004-05	A	4.37	0.22	4.59	7.40
2005-06	A	3.85	0.25	4.10	-11.95
2006-07	A	3.87	0.59	4.46	8.07
2007-08	A	7.59	0.07	7.66	41.77
2008-09	A	4.75	0.45	5.20	-47.30
2009-10	A	6.10	0.27	6.37	18.36
2010-11	A	7.60	0.30	7.90	19.36
2011-12	A	6.08	0.32	6.40	-23.43
2012-13	A	5.84	0.32	6.16	-3.89
2013-14	F	**8.65**	**0.10**	**8.75**	29.6
				6.50 predicted*	-39
The % net variance in milk price between years, from 1999 - 2008 was **15.6%** while the net variance from 2008 and 2015 is **27 %**					