Getting ahead of the game: maximising profit and environmental protection on 21st century dairy farms

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Summary:

New Zealand dairy farming is under increasing public scrutiny because of the potential adverse environmental impacts on the health of lakes and rivers. Although the industry has implemented several voluntary initiatives to reduce environmental impacts, these alone have failed to halt the decline. To yield effective change farmers will need to more radically reconfigure their approaches and farming systems to reduce the loss of nutrient, sediment and pathogens. Ironically this change can occur while maintaining or improving farm profit. To date most studies of mitigation strategies for farmers has only considered single actions. However, although there is a widespread notion that environmental constraints mean less profit this does not have to be the case. Resilience is the key to any profitable business; as it relates to dairy farming this includes provision for unexpected events, accounting for volatility in feed availability, costs, milk price and climate. Dewes (2014) found 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 are however more vulnerable, with increased environmental risk and the need for more advanced mitigation strategies (e.g. herd home systems, stand-off pads, supplementary feeding and advanced effluent management systems.) As a result they require higher capital investment, potentially increased debt, and consequently compounding business risk.

Agricultural "growth agendas" are currently based on the idea that more production, at any cost, is the best strategy for higher national GDP. Volatile economic and environmental conditions in future will force reconfigured farm systems to demonstrate efficient resource use, minimal environmental effects and risk, and robust economic performance to endure and "stay ahead of the game".

Public opinion - agriculture needs the public on side.

Declining water quality has been linked with worsening public perceptions of agriculture. Increasingly the public need to see legitimate efforts by the agricultural industry to improve water quality. Hughey (2013) found that the public are not in favour of development at the expense of their environment. They want to see rivers and recreational values protected. The public want development, but not if it threatens the environment that is valued for recreation and ecology/nature (Baskaran, 2010; Hughey, 2013).

A recent Horizons Research (Horizons 2014) survey released in March 2014: "indicated that there is a clear risk political parties will lose support this election if they introduce policies promoting economic growth that do not address the affect they have on the environment." (Radio NZ March 2014). Horizons surveyed over 3000 New Zealanders (with ± 1.8% level of accuracy). The survey found 67% will agree to large-scale irrigation schemes to grow agriculture, but only provided scientific evidence shows measures are in place to ensure downstream waterways are not polluted. The board of inquiry into the Ruataniwha dam also grappled with this issue. However, protection of river health by limiting water nitrogen levels was an overriding limit; underpinning that intensification could only occur provided it did not degrade local rivers. This yielded a plan where land use in the Tukituki River catchment will have to meet ecosystem health targets for the river.

The survey respondents were also asked whether they believed regional councils had a fundamental conflict of interest by simultaneously being responsible for protecting water quality and promoting large-scale irrigation for farming intensification. A clear majority of 62% agreed that there was a conflict. Ninety percent agreed that those who pollute waterways should be responsible for ensuring they are still safe for swimming, fishing and food gathering. Currently tax and rate payers fund the clean-up of waterway degradation. Five hundred million dollars has been allocated to clean up waterways throughout New Zealand. Fish & Game argue that it is ironic that taxpayers are paying to clean up farming damage to waterways, while at the same time spending millions on new irrigation projects to increase intensive agriculture. The Parliamentary Commissioner for the Environment reported that 95% of river nutrients are a result of diffuse loss from agriculture but Federated Farmers continue to stress that metropolitan sewerage systems must share the blame for the degradation.

The state of New Zealand rivers and lakes

The national dairy herd has increased by about 82% between 1980 and 2009, to nearly 6 million cows. High intensity dairy farming results in the loss of several important essential ecosystem services including the provision of good-quality water (Abell, 2011). Many rivers draining farmland are unsuitable for swimming because of faecal contamination, poor water clarity, and nuisance algal growths. (Ballantine et al, 2010; Larned et al, 2004; P.C.E Report, 2004 and 2013). Furthermore, groundwater quality in aquifers under pastoral farming areas have elevated nitrate and pathogen levels with an increasing number of monitoring sites breaching drinking water standards, (PCE, 2004 and 2013). The expansion and intensification of pastoral farming has also expanded to more marginal landscapes placing further pressure on water and soil resources and native biodiversity, (Macleod, 2006; Alibone, 2010; Baskaran, 2010; Carrick, 2013).

This increasing intensification of vulnerable landscapes continues, despite limited research to quantify nutrient losses (Lillburne, 2010, Carrick, 2013). Carrick et al (2014) recommended a large scale research programme into the effects of irrigation and intensification on vulnerable soils. They found young, stony, sandy soils in Canterbury have a high potential to leach nitrogen, phosphorus, and cadmium (Carrick et al, 2014). To prevent these losses, mitigations will increasingly impact farm system design. Current strategies may maintain the status quo of declining water quality, but it is unlikely to be enough to prevent further deterioration in the face of the large scale irrigation and intensification (>500,000 ha) proposed for New Zealand (P.C.E Report, 2013). New Zealand loses between 20 and 300 million tonnes of soil to the ocean every year. This is 10 times faster than the rest of the world, and accounts for 1.1 - 1.7 % of the world's total soil loss to oceans, despite a land area of only 0.1% of the world total, (PCE, 2004).

Across New Zealand water quality in rivers has deteriorated over the last 20 years principally as a result of diffuse losses of nutrients, bacteria and sediment from farming, despite significant improvement from reduced point source pollution. (Ballantine: 2010, 2013). Nutrient concentrations, algae blooms, and decreased ecosystem health, often exceeded ANZECC (2000) thresholds between 1998-2007. Water quality has declined in many of New Zealand's rivers where pastoral land use dominates, with nutrient enrichment, water clarity and pathogen levels significantly worse than in hill country and/or mountain rivers (Ballantine et al, 2010). For example, total nitrogen and nitrate in the Waimakariri River has increased rapidly between 1998 and 2007, (Ballantine, 2010).

The quality of water in New Zealand lakes is also less than perfect. Verburg et al (2010) found 44% (49/112) of the lakes examined were eutrophic (high in nutrients) or worse (i.e. TLI>4). The Trophic Level Index (TLI) score (a measure of nutrient enrichment) increased with more pastoral land in the catchment but was low in catchments with a large amount of native or alpine land cover. Extrapolating these findings to the 3820 lakes in New Zealand the data implies 32% are eutrophic (enriched) and 43% oligotrophic (low in nutrients).

Abstraction of water also places pressure on the ecological health of waterbodies. There is no price on water in New Zealand, yet in almost every region, there are over allocated catchments. Furthermore, demand for water continues to increase. Between 1999 and 2010 water allocation from New Zealand's waterways increased by one third. Allocation of water for irrigation has doubled since 1999, with 46% of total water use now allocated for irrigation (Ministry for the Environment, 2013).

The Economy versus Environment Dilemma

The dairy industry contributed $14 billion to the national economy in 2013-14 and is the most significant earner in the primary sector. Dairy exports are expected to continue to increase at 8% per annum to contribute $17.7 billion in 2016-17 (Ministry for Primary Industries, 2013). Dairying is now a major land use across New Zealand and the industry accounts for 21% of New Zealand's grassland area and 46% of total stock units, (Dairy NZ, 2013). In the past two decades, significant production increases have occurred in the New Zealand dairy industry. Between 1990 and 2012 the dairy cow population increased by 87%. Milk production increases were double this (195%) over the same period, while the land area used for dairy production increased by 46% between 1993 and 2012. This production growth has largely relied on externally sourced inputs, particularly fertilisers, feed supplements, and irrigation (Foote 2014) The speed and scale of the growth of dairy (debt) has been staggering: in a little over a decade it has more than tripled (from about $10B in 2002 to $32B in 2014) whilst dairy output has grown by about 64% (Fraser, Ridler & Anderson 2014).

Put differently, the marginal milk production has an effective debt loading of over $31 per kg MS (compared to an average debt loading of less than $18 per kg MS), and at an interest rate of about 6% debt servicing alone would present over a third of the forecast total dairy payout for the 2014/15 season. (Fraser, Ridler & Anderson 2014)

Increasingly the sheep and beef industry are experiencing ‘difficult’ years, droughts and competition from dairy. Many now supplement their income with support and grazing for dairying. In general both dairy and dairy support, have much higher rates of nutrient loss than most other forms of pastoral agriculture. (NZIER, 2013; P.C.E, 2013). The PCE (2013) notes that a trend towards more dairying and associated support land will continue while commodity prices favour industry growth, but as a result, water quality is likely to continue to decline.

As yet in New Zealand, comprehensive trials implementing best practice at the sub-catchment scale in intensively farmed areas have failed to demonstrate significant improvement in water quality. Studies of 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) stressed that there is a large gap in our understanding of actions at the farm gate and the benefit for the environment. This knowledge is critical if we expect land owners to continue investing and changing management practices. We need studies utilising a cross section of disciplines - social, economic, ecological, agricultural, veterinary and soil science at multiple temporal and spatial scales (Mc Dowell, 2013).

Even on farm activity has intensified over the last 10 years. Expenses have increased by 190% (Greig, 2012; Dairy NZ 2013; Intelact NZ, 2014). Herd size and stocking rates, reliance on external feed source such as palm kernel expeller, land prices and debt levels have all increased pushing farmers into an increasing spiral of trying to match these increases with higher production.

The choice of farming system has been largely influenced by farmer’s instinctive attempts to mitigate risk (Greig, 2012). Overstocked farmers try to avoid seasonal feed deficits with increasing dependence on Palm Kernel Expeller (PKE) imported into New Zealand. At $300 per tonne, this supplementary feed is priced to provide a more competitive option to procurement of more land (Dias et al, 2008). PKE availability has resulted in farm systems continuing to carry higher levels of stock and further intensify, relative to the farms productive potential. As a result, around 10% of New Zealand milk solids are now generated from PKE.

Economic principles of agricultural production are based on decisions of the relative cost of inputs and outputs, (Greig, 2012). Developments such as the Ruataniwha irrigation scheme will provide water at 22-25c /m^3. General farm expenses for a farm in the scheme are thus around $5.50 per kg MS, including the water cost (Dewes 2013). With debt servicing, the full cost is $7.30 -$7.50 per kg MS. The cost of production in such a scheme is thus 250% greater than 1988-99, while the price of milk solids has only risen by around 100%.

The continued focus on expansion and intensification entails higher risk: both economic (due to diminished margins), and environmental (due to more complex mitigation). For example converted dairy farms in Canterbury, are more intensive than those nationally. Two thirds of these farms import 20-50% of their feed directly or with off-farm grazing (Agfirst Waikato, 2009). Intensive systems such as these rely on support land for young stock, wintering cows, and supplementation. In Canterbury, around 50-100% of equivalent milking platform land area is required in addition for support purposes (Ford, 2012). This intensification extends beyond the fence of the dairy farm. More intensive systems are less resilient (e.g. to climate and commodity price fluctuations) and also have increased risk of contaminant loss (Monaghan, 2007; NZIER: Kaye-Blake et al, 2013; P.C.E, 2013),

DairyNZ research has demonstrated that an 18-40% reduction in nitrogen loss is possible without adversely affecting profit in some cases (Beukes et al, 2012; Clark 2012, Dairy NZ 2013). This may involve lower bodyweight (stocking rates) per hectare (Beukes et al 2012), reducing replacement rates, retention of high genetic-merit cows, better balanced diets, enhanced feed conversion efficiency, improved effluent capture and consequent reduced need for soluble fertiliser.

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 policy is strongly supportive of further intensification of both marginal landscapes and increased irrigation (Funding Programmes for Irrigation, 2013). The goal is to drive annual growth of agriculture by 7% per annum (Riddet Institute, 2010) (Price Waterhouse Coopers, 2013). The growth seen in agriculture between 1985 and 2011 was only 3%. The Agribusiness Agenda (KPMG, 2013) to double agricultural output by 2025 will place considerably more pressure on a national landscape suffering from decades of poorly regulated intensification. The challenge is how to manage and balance growth as a nation while retaining environmental integrity. New and integrated approaches will be required to reduce the negative impacts of increasing production on the environment but maintain economic viability, (Cook, 2009; Mc Dowell & Hamilton 2013).

Government Initiatives to balance economy and environment

The National Policy Statement for Freshwater Management (NPS-FM) was released in 2014 to provide guidance for maintaining or improving water quality by setting environmental bottom lines for a range of parameters to safeguard human and ecosystem health (NZ Government 2013). Regional Councils will be required to set freshwater objectives and limits through a collaborative process with their local communities to manage water in an integrated and sustainable way, while providing for economic growth within set limits. It states that "the overall quality of fresh water within a region is to be 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. They must look at water bodies in the context of whole catchments, provide for involvement of iwi and hapu, and implement 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 limits are not breached.

"Freshwater objectives are the intended environmental outcomes for a water body that will provide for the values the community considers important." The NPS-FM now includes the National Objectives Framework (NOF) (2013). The NOF provides a framework to ensure life supporting capacity and ecosystem function in freshwater is safeguarded, while meeting community and iwi aspirations. This has been supported by economic analysis to evaluate what environmental bottom lines will not cause significant economic disruption to agriculture (NZIER:Kaye-Blake et al, 2013, Snelder, 2013).

The intention of the NPS-FM and NOF to balance environmental and economic interests above a bottom line of environmental degradation based on the current priorities of local citizens is certainly laudable. However, the authors do not believe the bottom lines for environmental degradation or even the attributes for assessment of environmental condition have been set appropriately to achieve the desired result. Attributes for river ecosytem health such as phosphourus, invertebrate life (i.e. MCI), nitrogen for ecosystem health (rather than toxicity) and deposited sediment are all missing despite the widespread scientific evidence of their importance. Furthermore there are no “bottom line attributes” for groundwater or estuarine environments. It clearly remains to be seen just how effective this approach will be in halting the decline in water quality.

Agri-environmental Risk

Quantifying Environmental Risk

There is an urgent need to quantify environmental risk and impact from farming systems in New Zealand. There is growing awareness that it is necessary to balance agricultural productivity and 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 concerns and the need to inform catchment groups and policy makers (van der Werf, 2001; King, 2000; Jay, 2008; Pretty, 2008). Suppliers of food products are increasingly expected to demonstrate an 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).

Nutrient leaching

Nitrate leaching is a major environmental issue globally. In grazed grassland, most of the nitrate leaching occurs in patches of animal urine because of the high nitrogen loading in such a small area (Di.H, 2007). Thus the main source of nitrogen loss from dairy farming is urine patches. OVERSEER™ is the widespread nutrient management tool for New Zealand farmers and is based on nutrient budgeting at the farm scale (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). OVERSEER™ estimates losses to the environment at the boundary of the farm system e.g. nitrogen and phosphorus loss to water (leaching) 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 through direct animal access or via stock crossings, tracks or lanes and that the effluent storage ponds are lined with impermeable materials and that effluent is only applied under low risk conditions. If best practices are not conducted, the nutrient loss to waterways will be higher than that reported by OVERSEER™ (Wheeler 2013; Horne, *pers comm*, 2013). Despite this nitrogen loss risk (kg N ha^{-1} yr^{-1}) as an output from OVERSEER™ is widely accepted in New Zealand as the best indicator of a farms enrichment risk to receiving water bodies.

Phosphorus (P) loss can also have detrimental effects on waterbodies. Seventy percent of dairy farms on volcanic soils are operating with high or excessive soil Olsen P levels (Waikato Regional Council 2008; Ledgard, 2011). Serious P losses occur when there is soil damage such as pugging or rain on exposed or ploughed soils (Monaghan, 2007; Mc Dowell & Wilcock 2004 &2007 and Mc Dowell 2013; Waikato Regional Council, 2013). Critical source areas of P such as erosion prone areas, waterways without fencing, fertiliser type, 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). P loss assessed by OVERSEER™ does not take account of P from storms or small streams and assumes best practices are always in place (Mc Dowell 2013).

Effluent Management

Bacteria levels in Waikato rivers and streams often exceed the ANZEC guidelines; 70% of monitored sites are too contaminated for people to swim safely (Environment Waikato, 2008). Although the transport of faecal bacteria into waterways is poorly understood (Monaghan, 2007; Kay, 2008; Muirhead, 2013) high risk sources are likley to be stock feeding areas, tracks, stock crossings, sub-surface drains, and effluent discharge to high risk soils These istes all provide opportunities for direct runoff or deposition of pathogens into receiving waters (Monaghan, 2005 & 2007; Richie 2010; Wheeler 2013).

Waterway, Wetland Protection and Biodiversity Support

Direct waterway protection on farm involving stock exclusion and protective planting is an important part of reducing environmental 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.

Water Use Efficiency

Demonstration of efficient water use on farm are increasingly important to agriculture. Pressure from other urban and industrial users is increasing, water sources are degrading and climate change is altering availaibility (OECD, 2012). Thus the quanitity of available water is declining and the cost of supply increasing. Future food systems will need to operate more efficently and with less water (Wallace, 2000). Increasingly food systems will have to demonstrate the most profitable use per unit of water used (i.e:as $profit per megalitre of irrigation/ha).

Waste Management

On farm waste management is also of concern. At present, the most common waste disposal method is burning and burying of waste. This is used by more than 60% of farmers surveyed by the Taranaki Regional Council in 2004 (Taranaki Regional Council, 2005). From 2014 Environment Canterbury farmers will not be able to burn polyethylene agricultural silage/bale wraps but must use product stewardship schemes, such as Plasback or Agrorecovery (Environment Canterbury, 2014).

Getting Ahead of the Game: Resilient, Profitable and Eco-efficient Agricultural Systems.

New Zealand presently faces a perceived "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 not been sufficient. The Horizons One Plan is the first plan to allocate nutrient loss rights from land to preserve ecosystem health, using land use capability as a proxy for nutrient allocation. The approach has subsequently been applied to the Tukituki River Catchment Plan (Change 6) (EPA 2014).

Policies to regulate nutrient loss have been analysed by Doole (2013), who considered farm costs incurred from single changes in response to a range of policy instruments. He used individual mitigations rather than full farm system change, 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 more recent work by Doole (2012) has revised costs to be considerably lower than earlier studies (Doole, 2010) but does not appear to have evaluated system reconfiguration and the efficiencies that can be gained from that.

Eco-efficiency is an approach to increase the ratio of production relative to non-profitable inputs and outputs. For example mass of product (milk solids) produced can be expressed per unit of nitrogen leached from the system. Such a measure can be used to compare production and pollution between farms. "Eco-efficiencies" are being sought by the dairy industry to incentivise on-farm changes. The regional plan changes (e.g. Horizons, Hawkes Bay, Otago) place tighter constraints on nutrient loss from agriculture and thus 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 how eco-efficient farms are.

The wider public is also cognisant of the requirement that farm mitigation measures maintain farm profitability for the national economy but not at the expense of the environment (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 the "costs of single mitigations". Dairy NZ and Horizons Regional Council used this approach to evaluate the potential 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 (Dairy NZ

& Horizons Regional Council, 2013)

Farming innovators are aware of this 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 simultaneously (Vogeler et al., 2013). 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 nitrate leaching losses are only 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 New Zealand's competitive advantage as a low cost producer. Moynihan (2013) questions whether increased efficiency on New Zealand farms can outpace rising costs. Globally, milk production costs have converged while the traditional low cost producers (e.g. NZ) have incurred rises in production costs as a result of increasing dependence on imported feeds, high debt levels and greater environmental regulation 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) .

The most recent report by the PCE (2014) makes it clear that by 2020 the water quality in most places in New Zealand is likely to worsen if we maintain the current farming practices. Agricultural "growth agendas" are based on policy that does not curb development. However most recent decisions on regional plan changes support maintenance of ecological health rather than forging ahead with land development without protecting ecological health of waterbodies.

It is increasingly clear that dissolved inorganic nitrogen (DIN) limits in receiving water bodies are being set at levels to sustain life supporting capacity e.g: 0.8 mg N/l for rivers in the Tukituki, 0.44 mg N/l in Otago and 0.44 mg N/l for rivers in the Manawatu/Wanganui region. The levels adopted link aquatic ecosystem health more directly with land-derived nutrient loads and, as a consequence, 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 New Zealand. Historically a lack of quantifiable measures to describe water and ecosystem health has resulted in limited policy frameworks to manage agricultural intensification. Land use has been production orientated and has assumed externalities are 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 return. A reconfiguration of agricultural systems to optimal profit, high resilience, and low impact systems will be required as setting limits based on "ecological health" test the current economic philosophy entirely based on production goals. Pretty et al.(1999) notes that most economic activities affect the environment either through use of natural resources as inputs, or by using the environment as a sink for pollution. The need to transition to more resilient systems extends beyond New Zealand. Compared with 1950, grain yields 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 be costed into economic models. This is complex as externalities tend to have costs that are neglected, distinct lags, damage to unrelated groups of people, difficulty in identifying the producer, 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 and more recently, Foote (2014) found that the potential (estimated) cost of environmental externalities to New Zealand in 2012 of $11.6 billion could be in excess of the dairy export revenue .

Resilient businesses cope better with unexpected events, which for dairy 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 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.

Dewes (2014) set out to determine if there are common management factors on dairy farms that simultaneously lower environmental risk and increase economic resilience. Dewes uses return on total capital across years when milk prices and total pasture growth vary. Twenty-five dairy farms with similar geophysical characteristics in the upper Waikato were used to examine how management actions may affect environmental risk and economic resilience. The study identified resilience was highest when fluctuations in milk price were adequately managed concurrently with minimal decrease in capital return and reduced environmental risk. A scorecard measure and N leaching rate (< 30 kg N ha^{-1} $year^{-1}$) were used to assess environmental risk

The most resource - efficient farmers 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.

There was a 100% variation in the cost of production across the study farms. However the return on capital, 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 had the least change to their returns with lower milk prices, as well as having low N leaching and environmental risk. 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 hectare. Low cost of management and staff per cow was also a feature, reflective of the simple, efficient systems used.

Farms were not overstocked relative to historical pasture harvest, with high quality cows fed at lower cost using home grown feed, and had efficient milk conversion (>88% MS/kg bodyweight vs district average of 77%). Between 3.8 -4.4 t DM of home grown feed was consumed by each cow, with the best performer having 4.44 t DM of home grown feed eaten per cow contributing to lower cost structures. The better performers have near optimal stocking rate for the farm, thus cows are "well fed" and productivity high from low cost home grown feed despite a "lower than district average" stocking rate and bodyweight per hectare. The higher productivity per cow (96% body weight as MS) and per hectare was common to these farms also reflecting good genetic merit and strong selection pressure for high performance cows. However, when these farmers were asked about higher genetic merit in particular, their view was that their herds breeding and production indices were not of significance when compared against the industry norm. The general view was their consistent approach to feeding their cows well, with close attention to cow welfare being key factors assisting their performance. The strongest performing farms also had an ability to store and spread effluent at optimum times over much of the farm (>40%) allowing them to 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 also demonstrated practices that reflected their understanding of external forces on their systems and adapted accordingly. There was a very strict approach in business decisions such as the philosophy of “KISS (Keep it Simple Stupid)” 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 that achieved 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 the farm level, leading to increased economic risk (lower equity on balance sheets). Farms may 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 Dewes study, or high stocked, high input - output, with investment in advanced mitigations.

In the Dewes 2014 study it identified that 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 Return on Capital) for lower milk price years ($5.50 and $6.08 kg$MS^{-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 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 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 below in Figure 1.

Increasing milk production and intensity (growth orientated goal setting) (blue line) through greater inputs is not linear.

Figure 1 - Diagram of magnitude of production, risk and 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.

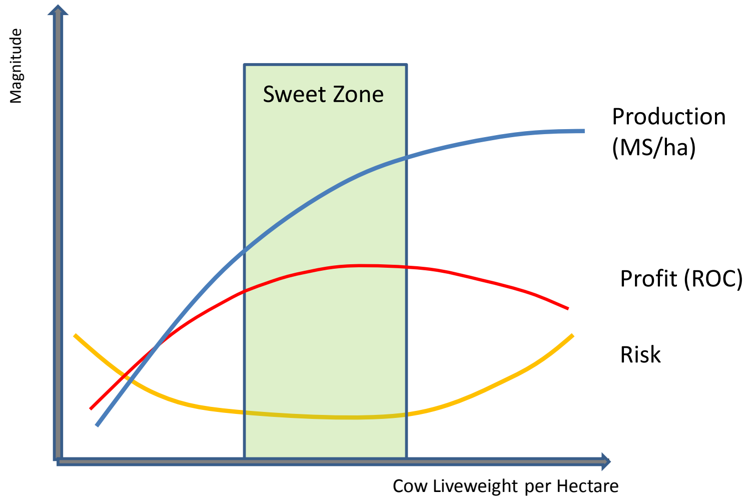
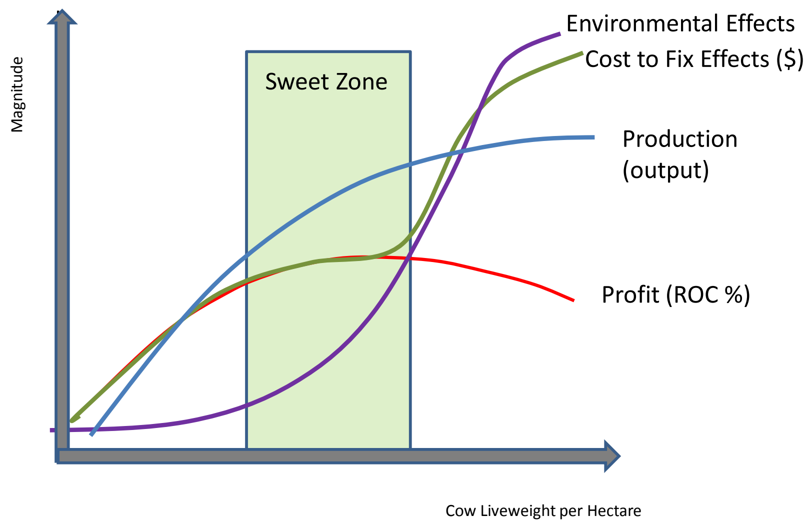


Figure 2 - Conceptual diagram of profit vs environmental effects vs cost to fix effects



According to the conceptual diagram of Figure1, 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 Dewes (2014). If farmers have this information at their disposal (>3 years is more powerful), then the most optimal operational zone for their mix of landscape, cows, and social capability and risk preferences can be determined easily.

Dewes (2014) re-enforces work by Ridler et al (2010) showing that dairy system profitability is optimised where technical and biological efficiency combine to provide the best economic and, environmental outcomes. The stronger (most resilient) farms in the Ridler et al study tended to be lower input systems with fewer, well fed cows, that were simple to run, with a low 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 the 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.

This is not to say intensive farms with excellent feed cost control cannot be profitable at a range of milk prices and seasons, but they are riskier to manage, more technically demanding and require more infrastructure to mitigate environmental effects.

Conclusion and Solutions

Dewes (2014) study of 25 dairy farm systems in the Upper Waikato demonstrated that economic resilience is achievable while operating within environmental limits. The top performing systems demonstrated 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 single production orientated goals. That is a consideration of the range of external forces that impact dairy farm systems. This will require taking more of a holistic approach to designing farming systems.

More broadly, the decisions to protect ecosystem health may result in some areas of New Zealand adopting land prices that more accurately reflect inherent values such as natural capital, soils attenuation capability, and environmental vulnerability rather than historical drivers of land price; total output (milk solids). 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 and debt in some cases.

Increasingly the public will likely require primary industries to internalise its effects and risks through the use of legitimate measures for managing diffuse nutrient loss. This will place increased pressure on farmers to know their landscapes, understand their farms' strengths and weaknesses, and adapt their systems to landscape strengths and limitations. Irrigated and more intensive farms will require more mitigation to meet environmental limits, while simpler less intensive systems with optimal stocking rates, high levels of efficiency and low production costs will often be better off. 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 allow comparison between pastoral and industry sectors such as the measures used in this study so there is "assessment on a level playing ground."

Most farm systems (and performance) models that are currently in use are unable to properly compare the marginal value of resource use. This may explain the poor return of investment in dairying over the last decade (almost 300% increase in debt for 64% increase in production) (Fraser et al 2014) and the subsequent increase in nutrients to water (Foote & Joy 2014).

New Zealand farming as a whole is struggling to reform into a truly sustainable system after years of a focus on production rather than profit. During the Dewes study (2014), farmer understanding 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, was seen as better metrics to assess 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.

There is a requirement to use measures that describe economic and environmental performance across agricultural sectors such as dairy, dairy support, sheep and beef, deer and goat farming. (e.g. ROC and resilience test, scorecard metric). At present, a common suite of profit and risk metrics are not being used - but rather there is a focus on gross returns per hectare. As a result, the extensive pastoral sector is being enticed to switch to more intensive and environmentally challenging systems. The absence of a common suite of metrics (KPIs such as ROC to compare profit between industry sectors) has resulted in a trend to dairying where in some cases a similar ROC may have been achievable from an optimised sheep and beef farming system. As this study has shown, it is not single actions or mitigations in a farm system that improves economic resilience when environmental limits are put in place, but rather it is the whole management approach, that combines the strengths of the people, animals and landscapes capabilities.

We are at the point now where farmers and leaders in agriculture need to understand how systems work, and demonstrate to the public that legitimate resource use efficiency is able to occur inside ecological limits. This will require the constructive articulation of the cross disciplinary approaches to development alongside grassroots initiatives by individual farmers. 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 New Zealand, farmers will cope with the required change as long as professional guidance is in such a manner that does not result in them becoming overwhelmed by information overload. Farm-facing professionals such as veterinarians could be utilising their skills to gather essential data and link farm operation to business support networks. This could provide systems, economic, animal welfare and environmental benchmarks and could then support resulting "on farm advice" as to how best to balance competing demands.

It is the author's view that veterinarians will need to broaden their knowledge base in key areas in order to be able to be part of the professional team necessary to assist the transition required in New Zealand. These areas include the development of understanding of nutrient cycles and losses from pastoral agriculture, diffuse pollution effects on receiving environments, and more importantly practitioners will be required to develop a more thorough understanding of how business health and performance is driven by farm system design and reconfiguration.

Funding priorities in New Zealand need to address the water quality – land use challenge. OVERSEER^{TM} is still grossly underfunded ($1.5 M per year is inadequate). There are continual updates to the model resulting in significant (diffuse loss) fluctuations unsettling advisors and farmers who are working on reconfiguring farm systems to meet limits. The model requires further validation (i.e. groundtruthing) in order to provide farmers certainty that any mitigations will deliver improvements to water quality. Regional policies also need to send consistent messages to farmers about how best to balance economic and environmental pressures for the future.

For extension to be successful - the vision and message needs to be clear. Presently there is a limited dataset of successful farm systems to operate within environmental limits. This may be a result of limited engagement in farm performance analysis (at farm level). This is coupled and complicated with limited physical and environmental monitoring (e.g. water takes, ecosystem health, diffuse loads).

For farmers to embrace change they need to know they are going to retain or increase profitability and resilience of their business. Our commodities already receive access to world markets on the perception that New Zealand is clean and green. The agricultural industry will have to continue to strive to make more profit while farming inside ecological limits (win- win scenario). Evidence of innovative farming systems demonstrating "win- win" scenarios is slowly increasing. In depth detail on profit and system reconfiguration on more farms is an urgent requirement. Through the collation of a broader database of key performance information – as in the Dewes (2014) study group for example. These innovative examples will provide new pathways forward.

Evidence based farming is the new model for extension - just as evidence based medicine underpins the veterinary and medical professional approaches. **As the most trusted advisor on farm, veterinarians should position themselves with additional training to support agriculture in adjusting to the new paradigm for 21st century farming.**

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