CHAPTER 5

Risks and challenges

This chapter considers the major risks to natural capital, and farming itself, if current trends persist. The major focus is on water. It examines trends in nutrient inputs and water demand to explore the implications of these trends for fresh water quality and quantity in New Zealand.

5.1 Intensification through external inputs

There are many different ways farming systems can be designed to produce more food. It is the particular *way* in which more intensive farming is carried out that needs to be considered in any discussion on sustainability. Nonetheless, intensive farming systems are often characterised by an increasing use of external inputs to maintain or increase production every year. Indeed, as Chapter 3 highlighted, farming systems in New Zealand are generally becoming more intensive through the use of additional material and energy inputs. This is clearly evident in trends relating to the increased use of synthetic fertilisers, increasing demands for irrigation, and the purchase of additional stock feed (such as maize silage) in the dairy sector to boost production.

Although a variety of external inputs are being used to develop more intensive farming systems in New Zealand, this chapter focuses on two key inputs:

- nutrients
- water from irrigation.

We have examined these inputs to explore implications for fresh water quality and quantity and the sustainability of intensive farming in New Zealand (see also our focus in Section 1.3.1).

5.2 Nutrient inputs

5.2.1 Overview of nutrients and potential effects on the environment

In natural ecosystems when plants or animals die, nutrients are cycled back into the soil (see Chapter 2). However, in farming ecosystems, plant or animal biomass is removed with harvesting. Thus to supply essential nutrients for plant growth, farmers add nutrients (particularly nitrogen, phosphorus and potassium) to the soil in a number of ways.

Farmers have been using natural fertilisers to replace nutrients for centuries, relying on such things as guano (bird and bat droppings), bone, compost, human waste and seaweed. As the world's population grew in the 19th century, more nutrients were needed to meet human dietary needs, and processes for manufacturing synthetic fertilisers were developed, with profound effect on farming practices across the globe. Since then, synthetic fertilisers have been added to soils in farming systems the world over to make up for nutrient removal and to increase food production.[1]

In New Zealand most soils developed beneath forests, and hence are acidic and naturally low in nutrients.[2] Therefore, it is common for farmers to add lime (calcium oxide) to soils to reduce acidity, and to add nutrients to aid the growth of pasture grasses and crops. The addition of lime to reduce soil acidity in farming is generally considered environmentally benign or beneficial.[3] Conversely, if nutrients are applied to pasture and crops at a rate beyond which plants are able to assimilate, they will leak to the wider environment causing harm. Damage to the environment may result from nutrients running off into surface waters, leaching into groundwater, or entering the atmosphere. The rest of this section discusses the effects of nitrogen and phosphorus on the environment, particularly in terms of non-point source pollution.

Nitrogen

> ***...today, around the globe, more than half the atoms of nitrogen that are incorporated into green plant material come from fossil fuel energy subsidised fertilisers, rather than from natural biogeochemical processes.[4]***

The input of nitrogen in farming systems is a key focus in this investigation because of:

- the increasingly important role it plays in New Zealand farming
- its mobility in the environment (*via* ground and surface waters and the atmosphere)[5]
- the potential damaging effects that it has.

Plants, animals and humans all need nitrogen for survival, and nitrogen, like other nutrients, cycles through ecosystems.[6] Although we live in a nitrogen-rich atmosphere, most ecosystems rely on nitrogen-fixing bacteria, fungi and algae to access this atmospheric nitrogen.[7] Nitrogen fixation is the conversion of non-reactive atmospheric nitrogen by bacteria, fungi and algae into reactive nitrogen for use by plants and animals.[8] Most natural nitrogen fixation is carried out by symbiotic bacteria, such as the bacteria *Rhizobium*, which penetrate the root hairs of clover and other legumes.[9] In New Zealand the main pasture species, ryegrass, needs large amounts of nitrogen, and is therefore planted alongside clover.[10] Nitrogen, once utilised by animals, is excreted as waste products, primarily as urea (excreted by mammals), ammonia (by fish), or uric acid (by birds, reptiles, insects and mammals). To complete the cycle, denitrifying organisms convert reactive nitrogen to atmospheric nitrogen.[11]

In pre-industrial times nitrogen fixation and denitrification were approximately equal, but this changed with human creation of reactive nitrogen through:

- the advent of a synthetic process for fixing nitrogen[12]
- combustion of fossil fuels (that contain nitrogen)
- the increased cultivation of nitrogen-fixing plants.[13]

These activities have greatly increased the cycling of reactive nitrogen through the atmosphere, hydrosphere, and biosphere and, in the past few decades, production of reactive nitrogen by humans has been greater than reactive nitrogen production from all natural terrestrial systems.[14] As a result, reactive nitrogen is accumulating in the environment because reactive nitrogen creation rates are greater than conversion rates of reactive nitrogen back to non-reactive atmospheric nitrogen.[15]

Nitrogen is easily dispersed by way of hydrologic (water) and atmospheric (air) transport processes.[16] If nitrogen application in farming is not balanced by plant uptake it can create considerable problems.[17] Nitrogen can enter streams (directly, as surface runoff, or indirectly, *via* contaminated groundwater) or leach through the soil into groundwater, eventually ending up in lakes, rivers and coastal waters.[18] This can result in deterioration of groundwater quality and drinking water supply, with risks to human health, and the eutrophication of fresh waters and coastal waters. A recent report by the United Nations Environment Programme (UNEP) has identified the increase of oxygen-starved zones in the world's oceans and seas as an emerging issue that needs urgent attention. These oxygen-depleted zones (termed 'dead zones') are linked to nutrients, mainly nitrogen, originating from agricultural fertilisers, vehicle and factory emissions and wastes.[19]

Leached nitrate can carry with it alkaline elements (such as calcium, potassium and magnesium) from topsoil, lowering soil pH and resulting in acidified soils. Nitrogen in the soil can also be converted to the greenhouse and ozone-depleting gas, nitrous oxide.

Klaus Toepfer, Executive Director of the United Nations Environment Programme recently stated:

> ***Humankind is engaged in a gigantic, global, experiment as a result of the inefficient and often over-use of fertilisers, the discharge of untreated sewage and the ever-rising emissions from vehicles and factories. The nitrogen and phosphorus from these sources are being discharged into rivers and the coastal environment or being deposited from the atmosphere, triggering these alarming and sometimes irreversible effects.***[20]

Once nitrogen is leached to the environment there is no effective way to remove it – it is simply too late, and the consequences must be dealt with. Figure 5.1 lists the effects of reactive nitrogen on human health and ecosystems.

Figure 5.1 Effects of reactive nitrogen on human health and ecosystems

Direct effects of reactive nitrogen on human health include:

- nitrite and nitrate contamination of drinking water leading certain types of cancer and to the 'blue-baby syndrome'[21]
- blooms of toxic algae, with resultant harm to humans
- respiratory and cardiac disease induced by exposure to high concentrations of nitrous oxides, ozone and fine particulate matter.

Direct effects of reactive nitrogen on ecosystems include:

- increased productivity of reactive nitrogen-limited natural ecosystems
- ozone-induced injury to crop, forest, and natural ecosystems and predisposition to attack by pathogens and insects
- acidification and eutrophication effects on forests, soil, and fresh water aquatic systems
- eutrophication and hypoxia in lakes and coastal ecosystems
- nitrogen saturation of soils
- biodiversity losses in terrestrial and aquatic ecosystems and invasions by nitrogen-loving weeds
- changes in abundance of beneficial soil organisms that alter ecosystem functions.

Indirect effects of reactive nitrogen:

- depletion of stratospheric ozone by N_2O emissions
- global climate change induced by emissions of N_2O and formation of tropospheric ozone

Adapted from Galloway and Cowling, 2002.

Phosphorus

Plant growth in many farming systems is limited by the absence of phosphorus, hence its addition as fertiliser.[22] Clover requires a large amount of phosphorus for growth, thus phosphorus fertiliser has traditionally been popular in New Zealand, predominantly as superphosphate.[23]

Phosphorus is far less susceptible to leaching to the environment than nitrogen. This is because it is absorbed by organic matter within the upper metre of the land surface, and it dissolves slowly in water through time.[24] However, as phosphorus is readily mobilised by soil erosion (in particulate form), loss of phosphorus from farmed land is an issue for New Zealand. Soil loss is typically higher in extensive sheep and beef farming than in other farming sectors, due to the steeper slopes farmed and propensity for erosion. However, soil erosion is also an issue in more intensive farming sectors (see Section 5.3.3). Eroded soil enters waterways and soil-bound phosphorus slowly dissolves in water. Phosphorus also enters waterways *via* farm runoff. Increases in phosphorus levels in natural waters in

New Zealand can contribute to eutrophication. Phosphorus from farming sources also contaminates groundwater – the most common source in New Zealand is from agricultural fertiliser.[25]

Aquatic plant growth is typically limited by the absence of phosphorus and/or nitrogen. In lakes overseas, it is predominantly the absence of phosphorus in the water that limits aquatic plant growth.[26] In New Zealand it is noteworthy that plant growth in Lake Taupo and lakes in the Rotorua district tends to be limited by the absence of nitrogen, rather than phosphorus.[27] Plant growth in rivers and coastal waters and estuaries also generally tends to be limited by the absence of nitrogen. But even where nitrogen-phosphorus ratios for waters suggest that the absence of phosphorus is the issue, addition of nitrogen usually promotes growth of plants or algae. Therefore *both* nitrogen and phosphorus addition to natural waters needs to be strictly controlled so as to avoid eutrophication with (usually undesirable) increases in plant growth.[28] If it were the case that phosphorus was the issue, then nitrogen 'leakage' from farming to the environment would not be so much of a concern, because it would be biologically irrelevant. The fact is that plant growth in many lakes and most rivers and estuaries is more likely to be limited by the absence of nitrogen than phosphorus.

... both nitrogen and phosphorus addition to natural waters needs to be strictly controlled so as to avoid eutrophication

5.2.2 Nutrient inputs to New Zealand's farming systems

There are a number of ways that nutrients are added to farming systems in New Zealand, for example *via*:

- spreading fertiliser[29]
- planting nitrogen-fixing clover
- animal excreta, particularly urine
- spraying whey and effluent (both dairy shed and human) onto pasture.

The following sections discuss each of these points in turn.

Nutrient input from synthetic fertilisers

> ***Nutrients are essential for life and growth. In the rural context, nutrients, in the form of fertiliser, are important because of economics and the ability they give farmers to correct soil imbalances and significantly increase productivity. However, if used incorrectly, they are polluters not only of our soils but also of our waterways.***[30]

Synthetic fertiliser use in New Zealand has generally increased through time.[31] Of the more than 2.3 million tonnes of synthetic fertiliser used in New Zealand farming for the year ending June 2002, 52 percent of that was phosphate fertiliser, 33 percent nitrogen fertiliser, and 15 percent potassic fertiliser.[32] Breaking it down on a sector basis, 46 percent of synthetic fertilisers were used in sheep and beef farming, 44 percent in dairy farming, and two percent each in deer farming and vegetable growing.[33] Table 5.1 presents the

Table 5.1 Tonnes of nitrogen fertiliser urea and phosphate fertiliser spread by selected farming sectors in New Zealand for the years ending June 1996 and 2002

Sector	Nitrogen fertiliser urea*			Phosphate fertiliser**			Hectares farmed			Livestock numbers		
	1996	2002	% change	1996	2002	% change	1996	2002	% change	1996	2002	% change
Sheep & Beef cattle	7,444	59,192	**+695**	616,112	778,789	**+26**	10,036,076	10,348,291	**+3**	47,393,907 4,852,179	39,545,609 4,494,678	**-17#** **-7**
Dairying	78,201	207,805	**+166**	661,413	349,749	**-47**	2,017,755	2,048,211	**+2**	4,165,098	5,161,589	**+24**
Deer	858	3,456	**+303**	30,761	27,963	**-9**	291,596	341,447	**+17**	1,192,138	1,643,938	**+38**
Cropping	17,156	20,235	**+18**	24,663	16,757	**-32**	219,470	123,176	**-44**	-	-	-
Vegetable growing	-	8,816	**-**	27,274	11,989	**-56**	59,107	52,721	**-11**	-	-	-
Pipfruit orchards	652	498	**-24**	3,147	1,025	**-67**	16,970	12,680	**-25**	-	-	-
Kiwifruit	603	900	**+49**	7,026	2,389	**-66**	11,640	12,000	**+3**	-	-	-
Grape growing	-	146	**-**	943	1,017	**+8**	7,627	17,400	**+128**	-	-	-
TOTAL##	**119,688**	**311,400**	**+160**	**1,507,395**	**1,223,612**	**-19**	**14,863,897**	**13,769,543**	**-7**	**-**	**-**	**-**

Source: Statistics New Zealand, 1996; Statistics New Zealand, 2003b

***** Because of changes to the way that fertiliser statistics have been categorised between 1996 and 2002, it was not possible to compare *all* nitrogen fertilisers, thus urea figures only were used. Nor could potassic fertiliser comparisons be made.

****** Since 1996 use of phosphate fertilisers in New Zealand farming has decreased by 19 percent, with 1.2 million tonnes applied in the year ending June 2002. However, use of diammonium phosphate (DAP), which contains 18 percent N and 40 percent P but is *statistically counted as a nitrogen fertiliser*, has increased dramatically over the last 20 years.

[#] Although sheep numbers declined in this period, lamb and sheep production rose by 2 percent, due to an increase in the lambing rate and in the average weight of lambs processed.

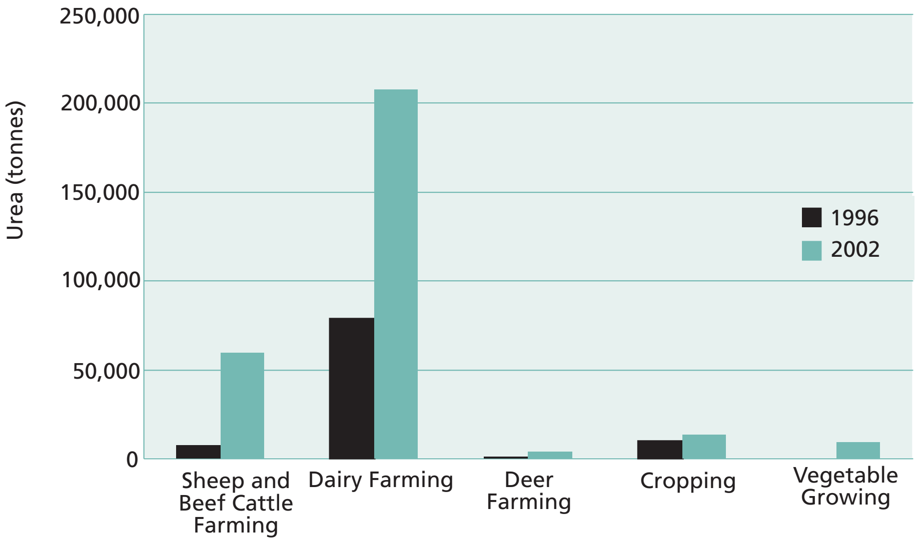
[##] These totals include *all* farming sectors; forestry is excluded.

change in nitrogen fertiliser urea and phosphate fertiliser spread by selected farming sectors in New Zealand between 1996 and 2002. Hectares farmed and livestock numbers are taken into account as well.

Nitrogen fertiliser

The use of nitrogen fertiliser in New Zealand has soared in recent years (Figures 5.2 and 5.3 illustrate the increase in urea application). In all, more than 770,000 tonnes of nitrogen fertiliser was applied in New Zealand in the year ending June 2002 – more than ten times that used in 1983.[34] The proportion of total fertiliser being applied as nitrogen in New Zealand farming is also increasing – for example in 1996, urea made up six percent of all fertiliser use, and by 2002 accounted for 13 percent of the total.[35] Fifty-four percent of nitrogen fertiliser applied in 2002 was used in dairy farming, 19 percent in sheep farming, eight percent in beef cattle farming, four percent in sheep-beef farming, four percent in vegetable growing and two percent in deer farming.

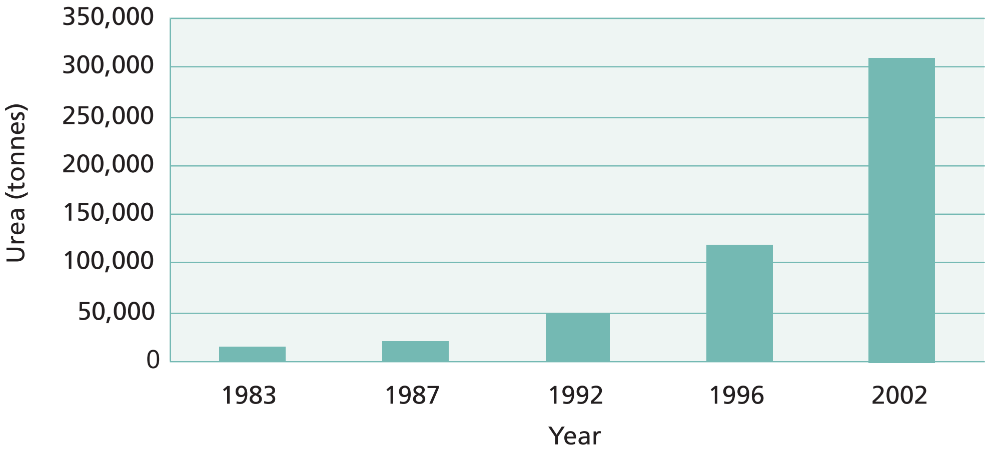
Figure 5.2 Tonnes of nitrogen fertiliser urea spread by selected farming sectors in New Zealand for the years ending June 1996 and 2002*



Source: Statistics New Zealand 1996; Statistics New Zealand 2003b

*Because of changes to the way that fertiliser statistics have been categorised between 1996 and 2002, it was not possible to compare *all* nitrogen fertilisers, thus urea figures only were used.

Figure 5.3 Tonnes of urea fertiliser applied in New Zealand 1983–2002



Source: Statistics New Zealand, 2003b; Statistics New Zealand INFOS service

Between 1983 and 2002, there was an 18-fold increase in the amount of urea fertiliser applied in New Zealand agriculture, to 311,000 tonnes (Figure 5.3). Use of diammonium phosphate (DAP) has increased more than four-fold since 1983 to almost 183,000 tonnes, and use of ammonium sulphate has doubled since 1983 to 43,000 tonnes. The sectoral change in kilograms of urea spread per hectare is illustrated in Table 5.2.

Table 5.2 Kilograms of urea fertiliser spread per hectare, by sector, for the years ending June 1996 and 2002*

Sector	1996	2002	% change
Sheep and beef	0.7	5.7	+ 670
Dairy	38.8	101.5	+ 160
Deer	2.9	10.1	+ 240
Cropping	78.2	164.3	+ 110
Vegetable growing	-	167.2	-
Pipfruit	41.2	42.6	+ 3
Kiwifruit	51.8	75.0	+ 45
Grape growing	-	8.4	-

Source: Statistics New Zealand 1996; Statistics New Zealand 2003b

*These figures have been assessed by dividing the 'kilograms of urea spread by each sector' by the 'number of hectares farmed by each sector' for 1996 and 2002. A similar methodology was used by Holland and Rahman (1999) to assess sectoral pesticide use in New Zealand on a per hectare basis for 1998. It is important to note that figures have been rounded to 1 decimal place. The '% change' column was calculated from these figures before rounding.

Why has there been such a large increase in nitrogen fertiliser application in the past decade? Reasons include:

- nitrogen fertiliser application enables an increase in farm productivity and profitability – for example, in the dairy sector the resulting provision of extra feed throughout the year allows the farmer to increase stocking rate, calve earlier, and make more high quality silage (thus extending lactation)
- the tactical use to overcome seasonal feed shortages, and ensure a steady supply of forage
- the cost of nitrogen fertiliser as a percentage of milk fat price (or farm income) has decreased[36]
- the loss of clover in pasture due to clover root weevil.[37]

As dairying in New Zealand has become more intensive over the last decade and stocking rates have increased, nitrogen fertiliser has been increasingly added to pasture to supplement nitrogen supplied by clover, and provide increased grass growth so as to produce more milk. Some farmers are reported as using nitrogen fertiliser to replace clover entirely, rather than to supplement it (see next section). Intensity of nitrogen fertiliser use has also increased in deer farming, cropping and kiwifruit growing.[38]

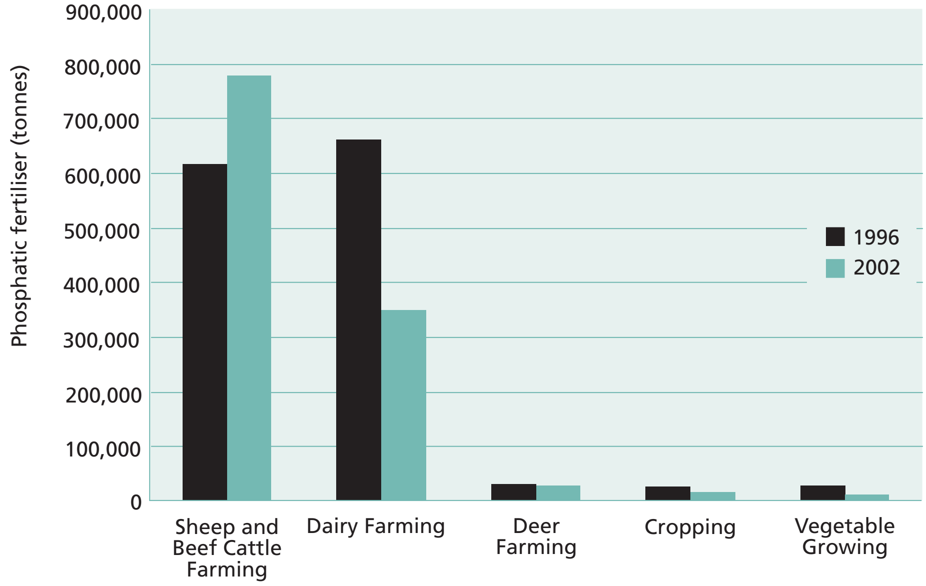
The huge increase in nitrogen fertiliser use in sheep and beef farming, and the resultant increase in pasture growth, is attributed in part to the growing trend in lamb and beef fattening systems, an approach that is more intensive than the more traditional forms of sheep and beef farming.[39] Also, high lamb prices have led to a focus on lamb production, with farmers increasing lamb live weight, and thus average lamb carcass weight. There also has been a 25 percent increase in the lambing rate.[40] Although there has been a huge increase in urea use by this sector, per hectare use is still *far below* that of the dairy sector or some horticultural sectors (Table 5.2).

However, results of sheep grazing trials undertaken over two years in Hawke's Bay hill country, in which very high rates of nitrogen fertiliser were applied (400 kg N/ha annually, in 8 x 50 kg applications), suggest that there is potential for greatly increasing production levels.[41] Consequently, there was a 25 kg/ha increase (to 31 kg/ha) in nitrogen leaching annually, or six percent of the total fertiliser N applied (compared to the 'control' paddocks which received no nitrogen fertiliser and leached 6 kg N/ha). The authors expressed caution about adopting this approach commercially without undertaking further investigation to determine whether high nitrogen input rates would affect long-term sustainability of the farming system, due to the potential on- and off-site impacts such as effects on nitrate and greenhouse gas emissions, soil and pasture condition, and nutrient cycling. This caveat is significant given the huge amount of grazed hill country in New Zealand, and the potential for cumulative negative environmental effects.

Phosphate fertiliser

Since 1996 use of phosphate fertilisers in New Zealand farming has decreased by 19 percent, with 1.2 million tonnes applied in the year ending June 2002. However, use of diammonium phosphate (DAP), which contains 18 percent nitrogen and 40 percent phosphorus but is statistically counted as a nitrogen fertiliser, has increased dramatically over the last 20 years. Figure 5.4 provides a sectoral breakdown of phosphate fertiliser application comparing 1996 with 2002.

Figure 5.4 Tonnes of phosphate fertiliser spread by selected farming sectors in New Zealand for the years ending June 1996 and 2002.



Source: Statistics New Zealand 1996; Statistics New Zealand 2003b

Nitrogen input from clover

Annual nitrogen fixation by clover in New Zealand is estimated at 1.57 million tonnes, and valued at $1.49 billion,[42] but the discovery of the clover root weevil, *Sitona lepidus*, in the Waikato in 1996 threatens this productivity. The clover root weevil is now one of New Zealand's most serious pasture pests. It is rapidly spreading throughout the country, feeding on clover nodules and roots, causing root loss, disease and a reduction in nitrogen fixation.[43] Broadcast insecticide treatments to control the larvae in the soil are untenable for environmental and economic reasons.[44] A research programme for pest control is underway – possible control options include a small parasitic wasp and a fungus that both attack the weevil. Unfortunately, the weevil's spread across New Zealand may encourage further increases in nitrogen fertiliser application to maintain grass growth.

Nutrient input from animal excreta

With the addition of nitrogen fertiliser by the farmer comes the ability to increase stocking rates. Increased stocking rates lead to greater inputs of animal excreta into the farming system, placing greater pressure on the environment. It has been estimated that "the waste generated by the 3000 dairy herds in the Waikato River catchment is equivalent to the waste from about five million people or nearly 50 cities the size of Hamilton." [45]

With the addition of nitrogen fertiliser by the farmer comes the ability to increase stocking rates. Increased stocking rates lead to greater inputs of animal excreta

Although animals graze grass-clover pastures, they do not convert the nitrogen they ingest efficiently. Thus, the largest input of nitrogen in New Zealand pasture-based farming is from animal excreta, *particularly urine*. O'Hara *et al*. note that:

> ***On average only 10.5 percent of the nitrogen in grass, silage or other feedstuff is converted into milk, meat, eggs or wool. The remainder is excreted in dung and urine. Thus the bulk of the nitrogen added to New Zealand soils comes from the excreta of animals, which contributes to nitrogen leaching.***[46]

Cattle urine, in particular, has high concentrations of nitrogen, and urine patches swamp plants' nitrogen uptake capacity, which then results in nitrate leaching.[47] Although not nearly as significant as urine, animal dung is a contributing factor in nitrate leaching, and cattle dung has the greatest nitrogen content compared to other livestock.[48]

The suitability of intensive dairy farming on pasture where tile and mole drains[49] have been laid underneath has been questioned in Waikato, Southland and South Otago. The drains provide a fast route to waterways for nitrogen:

> ***...tile drains are commonly used on many poorly drained pasturelands in the Waikato watershed and can rapidly transport nitrogen to stream channels with little removal by natural attenuation processes.***[50]

Nutrient input from dairy shed effluent application

In recent years effluent has increasingly been spread onto pasture in New Zealand as a way to add nutrients for pasture growth *and* dispose of waste.[51] Effluent was sprayed onto almost 170,000 hectares of pasture in New Zealand in the year ending 2002,[52] and almost 80 percent of dairy farms in the Waikato apply effluent to land.[53] In some parts of New Zealand, whey, a by-product of milk powder processing, is also sprayed onto dairy pasture as fertiliser.

It is estimated that the dairy shed effluent from 100 cows is worth $1,200 to $1,500 in fertiliser value a year.[54] Applying agricultural effluent to land, rather than discharging it directly into water, can help reduce the impacts of farming on water quality, as well as retaining nutrients on the farm. However, there are concerns over the safety of spraying raw effluent onto pasture without any pre-treatment of the effluent. Risks associated with this practice include nutrients entering groundwater and surface water in bad weather. Also, care must be taken that the effluent is applied over sufficient area and at a rate that does not allow runoff or seepage into water systems.[55] Soil, slope and climatic combinations in several areas of New Zealand do not favour land disposal. Even where land disposal *is* favoured by environmental conditions, it is much safer to spray irrigate pond-treated effluent than raw wastewater from the milking shed wash-down with its high microbial contaminant content and high biochemical oxygen demand (BOD) (see Section 5.3.2).[56]

5.2.3 Nitrogen contamination of New Zealand's environment

There is evidence that nitrogen from farming sources enters and contaminates New Zealand's surface waters, groundwater, soils, and atmosphere. Unfortunately, there is little nationally consistent data available on *levels* of nitrogen contamination in New Zealand. Section 5.3 looks at nitrate contamination of rivers, lakes and groundwater in detail. The rest of this section looks at nitrogen contamination of New Zealand's soil and the atmosphere.

Nitrogen saturation of soils

Scientists at Landcare Research have identified nitrogen saturation of soils as an emerging issue.[57] There are limits to any soil's capacity to store nitrogen and once reached, nitrate leaching is expected to increase markedly if nitrogen continues to be applied at the same rate. Research indicates that the nitrogen storage capacity of agricultural soils in New Zealand is declining with time. The rate of this decline is dependent on a number of factors, including soil type, soil carbon to nitrogen ratio, current soil nitrogen levels, the nitrogen storage rate of the soil, and land use (particularly fertiliser and effluent application, urine input, and nitrogen fixation). Further work will focus on defining some of these factors to more accurately assess the extent of the issue, but it is expected to have implications for long-term nitrogen budgeting for different land uses.[58] Land managers need some indication of how long soils can continue to store nitrogen so that fertiliser is not wasted and risks to groundwater are minimised.[59]

Nitrogen pollution of the atmosphere

Greenhouse gas emissions contribute to global warming and climate change, and the farming sector contributes more than half of New Zealand's greenhouse gas emissions – nitrous oxide and methane in particular. The farming sector is responsible for more than 90 percent of New Zealand's nitrous oxide (N_2O) emissions. The global warming potential of nitrous oxide is 310 times that of carbon dioxide (based on a hundred-year horizon).[60] Nitrous oxide is emitted from soil when soil bacteria convert nitrogen from animal urine and fertiliser. Nitrate lost *via* leaching or surface runoff can also be converted to nitrous oxide in water bodies. Nitrous oxide is also converted from volatilised ammonia (originating from animal excreta and fertiliser) that has been deposited back to land.[61]

5.3 Risks for fresh water quality and aquatic habitats

Intensive farming poses risks to fresh water quality and aquatic ecosystems. It must be noted that the following risks arise from farming in general, but the more intensive a farming system is in terms of external inputs, such as fertiliser and irrigation (and any consequent increases in stocking rates), the higher are the risks.[62] This is because the key water quality concerns stemming from farming relate to the three major non-point (or 'diffuse') pollutants:

- nutrient contamination from livestock wastes and fertiliser application
- microbial contamination from livestock faeces

- sediment impacts (reduced water clarity and sedimentation).[63]

These three pollutants and their effect on water quality in New Zealand are examined in more detail later in this section, after a more general discussion on water quality.

New Zealand's waters are a limited, fragile resource coming under increasing pressure from farming activities

New Zealand's waters are a limited, fragile resource coming under increasing pressure from farming activities, both in terms of the effects on water quality *and* the increasing demand for water (see Section 5.4). Although pollution of rivers from point sources, such as factory outfalls, has declined over the last 20 to 30 years, pollution from non-point sources is a major and increasing problem. Farming has been identified as the main source of pressure on water quality in New Zealand. Research indicates that rivers in lowland areas with intensive farming are in particularly poor condition, and that groundwater quality is also compromised. As the Ministry for the Environment notes:

> ***Agricultural runoff...is difficult to measure and control. Unlike point source discharges (those discharging through a single point, such as a stormwater or effluent pipe), non-point source discharges (pollution from wide areas such as runoff from pastures or hillsides) are relatively complex systems to measure and control. Most agricultural sources of contamination are from non-point discharges.***[64]

As noted in Chapter 3, water quality in areas of intensive pastoral farming is poor relative to standards in the RMA[65] and supporting guidelines prepared by MfE and ANZECC, a fact known for many years.[66] Water quality is particularly poor in lowland stream and river catchments dominated by pasture. 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). Nutrient enrichment of lakes from farming activities is a growing concern, and is not only affecting shallow lakes but deeper lakes too, such as those in the Rotorua area. The lag time taken for nutrients to enter these lakes suggests that the problem will get worse before it gets better, even if measures are put in place to reduce nutrient inputs. Furthermore, groundwater quality in aquifers that lie under pastoral farming, in particular under dairying, tend to have elevated nitrate concentrations.[67] The Ministry for the Environment notes that:

... the problem will get worse before it gets better, even if measures are put in place to reduce nutrient inputs.

> ***Urban and agricultural runoff is lowering the water quality and degrading aquatic ecosystems in New Zealand. A significant source of contamination in our streams, rivers, lakes, wetlands and coastal waters is runoff from agricultural land. This is a major impediment to achieving the sustainable management of water resources.***[68]

A 2002 review of the environmental effects of farming on New Zealand's fresh waters noted that the proportion, intensity, and types of farming within a catchment are all factors that affect stream health.[69] Arable and horticultural activities can have severe impacts on local water quality (with regard to sediment loss and nitrate leaching to groundwater), but pastoral grazing has the greatest impact on water quality in New

Zealand because of the scale of the sector and the volume of water affected.[70] It is acknowledged that streams in areas of sheep, beef and intensive dairy farming are in poor condition, and are faecally-contaminated to the extent it may be unsafe for livestock to drink. A decade ago, Smith *et al*. noted that:

> ***Intensive dairying areas are typified by rivers in poor condition. The most common problems are excessive nutrient concentrations and faecal contamination. The extreme case is the Waikato region while areas within Taranaki, Southland and Northland are additional examples. Lowland rivers in these areas are naturally more productive than those in sparsely developed regions. Agricultural development has accentuated pre-existing differences in water quality.***[71]

Recent work on national and regional river water quality trends carried out by NIWA on behalf of the Ministry for the Environment confirms these earlier findings on the poor state of lowland rivers.[72] This work notes:

> ***Water quality in low-elevation source-of-flow [river] classes in Canterbury, Southland and Waikato regions generally failed to meet recommended guidelines; median E. coli concentrations in all low elevation classes in each region exceeded the guideline value, and median DRP, NO_x and NH_4 concentrations***[73] ***exceeded the guidelines in all low-elevation [river] classes but one.***[74]

Another recent report prepared for MfE by NIWA on the effects of rural land use on water quality stated quite simply:

> ***Unless mitigation measures are simultaneously put in place to prevent (so far as possible) entry of pollutants to waters, intensification of land use will further degrade water quality.***[75]

In a recent assessment of the state of water quality in low elevation rivers across New Zealand, median concentrations of *E. coli* and dissolved nitrogen and phosphorus exceeded guidelines recommended for the protection of aquatic ecosystems and human health.[76] These parameters were two to seven times higher in pastoral and urban classes than in native and plantation forest classes, and water clarity was 40 to 70 percent lower.[77] The study highlighted the lack of a *nationwide* assessment of the links between low-elevation land cover and water quality in lowland rivers in New Zealand, despite land use pressures on these rivers. It noted that:

> ***Such an assessment would entail examining… whether water quality is improving or getting worse over time, and whether such trends are occurring in catchments dominated by particular land uses.***[78]

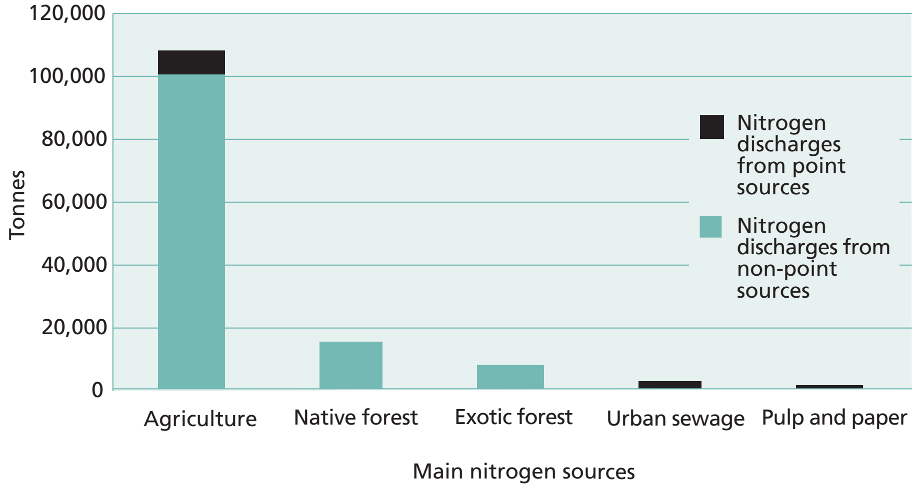
5.3.1 Nutrient contamination of water

Low-level inputs of nutrients from farmed land may have a beneficial impact on natural aquatic communities by increasing primary and secondary production.[79] However, higher levels of nutrient input into waterways and groundwater cause ecosystem stress to develop. There may also be risks to human health, particularly where groundwater aquifers used as sources of drinking water become contaminated with nitrates. This section focuses on nitrate-nitrogen contamination of ground and surface water in New Zealand.

Nitrate contamination of rivers and streams

It is estimated that 75 percent of the total nitrogen input to surface waters in New Zealand is from agricultural non-point source pollution (Figure 5.5).[80] More than 90 percent of streams in intensively farmed catchments in the Waikato region have moderate to high levels of nitrogen.[81] There is a strong relationship between the number of cows stocked per hectare and nitrogen loss from dairy land (Figure 5.6).

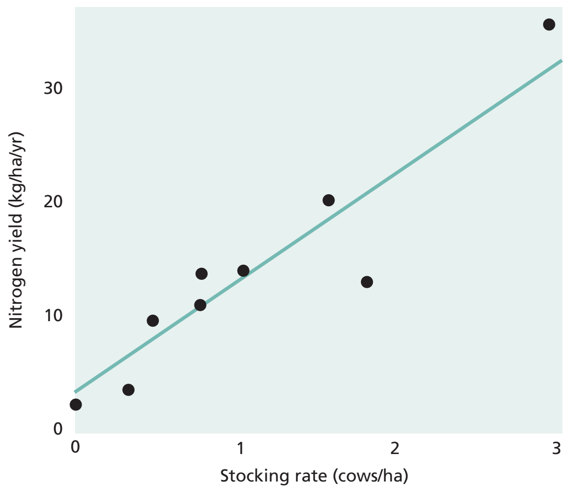
Figure 5.5 Estimated yearly nitrogen loadings to New Zealand surface waters



Source: Cooper, 1992 in MfE, 1997a

In a study of the trends in river water quality in the Waikato region between 1987 and 2002, data from 110 sites were analysed.[82] Ten of these sites were situated along the Waikato River (19 water quality variables were investigated); the other 100 sites were situated along other regional rivers and streams (14 water quality variables were investigated). Along the Waikato River there were improvements in some aspects of water quality – ammonia, BOD, arsenic, and boron levels declined significantly at nine or more of the ten sites. These improvements are attributed to decreases in *point source* pollution along the river. Total nitrogen and nitrate-nitrogen declined at four of the 10 sites, representing an improvement in water quality. In three of the four cases this decline occurred at sites along the upper river, and thus may be the result of land use changes.

Figure 5.6 Relationship between dairy cow stocking rate and nitrogen loss



Source: Environment Waikato, 2003a

Results for the other rivers and streams revealed patterns across the region as a whole between 1990 and 2002. The majority of the trends indicate a decline in water quality (increased total nitrogen, total phosphorus and conductivity, decreased dissolved oxygen and pH). Some trends indicate an improvement (increased visual clarity, decreased turbidity and ammonia levels). Environment Waikato suggests that the significant decline in ammonia levels at 20 of the sites may be the result of the move to land disposal of dairy shed effluent, and that the significant increase in total nitrogen at 46 of the sites may be the result of increased stock numbers and farming intensity over the past decade or more. The magnitudes of the trends in total nitrogen, ammonia, total phosphorus, dissolved reactive phosphorus and visual clarity were significantly correlated with the proportion of the catchment area that was in pasture.

Nitrate contamination of lakes

> ***… more than 700 lakes [in New Zealand] are shallow and between 10 percent and 40 percent of these are nutrient enriched (eutrophic). Most of the eutrophic lakes are in the North Island and in pasture dominated catchments. A number are subject to fish kills or are no longer capable of supporting fish life…development of their catchments, primarily for agriculture, is almost certainly responsible, due to the substantially increased nutrient loads that result.***[83]

New Zealand's larger, deeper lakes are also at risk of becoming eutrophic – the amount of nitrogen entering Lake Taupo from rural and urban sources has increased considerably over the past 50 years. As discussed in Section 5.2.1, Lake Taupo is extremely sensitive to nitrogen – the addition of nitrogen (rather than phosphorus[84]) results in aquatic plant growth – and monitoring trends indicate that water quality is gradually worsening.[85] Add to this the fact that groundwater transporting much of the nitrogen from the land to the lake is stored underground for several decades before entering the lake, and it appears that things will get worse before they get better.[86] Chapter 6 includes discussion of the *2020 Taupo-Nui-a-Tia Action Plan*, which aims to reduce the manageable sources of nitrogen flowing into Lake Taupo by 20 percent over the next 15 years. Environment Waikato states that:

> ***Scientists agree that the lake is under threat from increasing nitrogen leaching from land uses in the catchment. To just maintain the lake's current water quality, we need to reduce the amount of nitrogen coming from farmland and urban areas by 20 percent.***[87]

Also of national significance, the Rotorua Lakes are experiencing similar issues with declining water quality, but the situation there is even more critical. Nutrients from farming practices and septic tanks are entering the lakes, reducing dissolved oxygen levels, and in some lakes triggering toxic blue-green algal blooms. The lakes have been in decline for 30 to 40 years and suffer the same time delay issues as Lake Taupo between land use and its effects on water quality.[88] A strategy for protection and restoration of the Rotorua Lakes has been developed by Environment Bay of Plenty, Rotorua District Council and Te Arawa Maori Trust Board. It sets out 14 goals with regards to protection, use, enjoyment and management of the lakes,[89] and in June 2004, the Government committed $7.2 million toward improving Lake Rotoiti's water quality.[90] Water quality is declining in many other New Zealand lakes because of increased nutrient levels from farming practices – Lake Omapere, Lake Brunner and Waikato's peat lakes to name just a few. Chapter 6 discusses the importance of taking a catchment-scale approach in attempting to work through these kinds of complex issues.

Nitrate contamination of groundwater

Nitrogen in the form of nitrate from rural land use is a principal contaminant of New Zealand's groundwater.[91] Around 50 percent of New Zealand's population depends totally or partially on groundwater as a source for drinking water.[92] For example, Christchurch City sources its drinking water, which is untreated, from underground aquifers.

Around 50 percent of New Zealand's population depends totally or partially on groundwater as a source for drinking water.

Over 30 years ago, Baber and Wilson reported that some groundwater supplies in the Waikato were badly polluted by nitrate originating from the 'highly productive clover/grass' farming system of the region.[93] Many shallow aquifers beneath dairying or horticultural land have elevated nitrate levels. Shallow groundwater (down to 60m) commonly shows an accumulation of nitrate concentrations especially in areas where stock densities are high and groundwater is vulnerable to contamination from surface drainage.[94]

Irrigation can exacerbate the situation:

> ***The addition of water to farm systems can have greater adverse effects on water quality than the taking of water for irrigation. This is because additional water input such as irrigation of grazed dairy pasture accentuates nitrate leaching by increasing annual hydrological recharge. Careful assessment of the need for and potential impacts of irrigation can therefore help reduce adverse effects on water quality.***[95]

As rivers recharge groundwater, so groundwater discharges to rivers providing their baseflow (i.e., the flow between rainfall events).[96] Nitrates, being very mobile, move between surface and groundwaters.

Nitrate levels in Canterbury groundwater

In 2002, Environment Canterbury (ECan) carried out a review of nitrate concentrations in Canterbury groundwater, using existing data in ECan's water quality database.[97] Concerns over the suitability of Canterbury plains groundwater as a continued source of drinking water were expressed in the 1980s, because of a predicted increase in nitrate concentrations due to new irrigation schemes and more intensive land use.[98] More than 14,000 samples were taken from 2,350 wells. The range of nitrate-nitrogen concentrations found in samples was below detection levels (0.05 to 0.1 mg/L) up to 89 mg/L[99]:

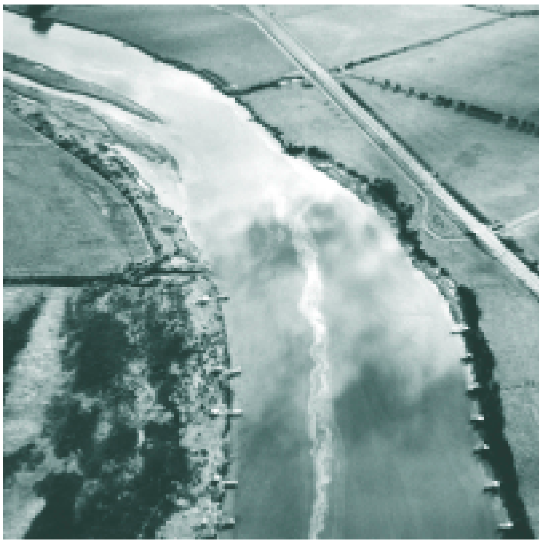
- 942 or 6.7 percent had nitrate-nitrogen concentrations higher than the maximum accepted value (MAV) of 11.3 mg/L[100]
- More than a third of samples had nitrate-nitrogen concentrations higher than 5.65 mg/L (half the MAV)[101]
- More than a quarter of samples had nitrate-nitrogen concentrations less than 1 mg/L.[102]

In an analysis of long-term trends, 17 percent of wells included in the test (43 out of 255 wells) had increasing nitrate concentrations through time.[103] These wells were distributed across the Canterbury Plains, but mostly on the lower, seaward, half of the plain. Land use in these areas includes intensive farming activities, e.g. effluent spreading, dairy farming and horticulture.[104]

A subsequent study of nitrate contamination of Canterbury groundwater was published by ECan in 2004, testing groundwater in the vicinity of a well in the Chertsey-Dorie area, south of the Rakaia River, which has shown increasing levels of nitrate-nitrogen since testing began at the well in 1991.[105] An increase in irrigation in the area over the last 25 years has allowed more intensive cropping and pastoral farming. Dairying in the area has increased markedly in the last five years, and there are at least 20 consented discharges of effluent to land.

Overall, the nitrate contamination extended over several square kilometres, generally increasing toward the coast, reaching levels of between 15 and 20 mg/L.[106] ECan concludes that "there are no large point-source discharges that are likely to generate such widespread contamination in the area", and that the "contamination is likely to be the result of a range of agricultural activities in the area" such as fertiliser use, cultivation and pastoral farming, and may be exacerbated by increased irrigation.[107] The council also stated "if current land uses are more intensive with greater potential to leach nitrates, concentrations in groundwater can be expected to increase further."[108]

The report states that groundwater in the Ashburton-Rakaia area, widely used for private drinking water supplies, is now no longer suitable for human consumption in some parts without treatment.[109]



Nitrate levels in Waikato groundwater

Environment Waikato monitors nitrate levels in regional groundwater, sampling 112 wells less than 30 m deep.[110] Results show that:

- nitrate concentrations commonly exceed drinking water guidelines
- high nitrate concentrations are related to intensive land use, particularly market gardening (e.g. Pukekohe area) and livestock farming (e.g. Hamilton area)
- nitrate concentrations are increasing in many areas.

Across the region, 17 percent of groundwater samples had excessive nitrate levels (i.e. exceeding the 11.3 mg/L National Drinking Water Guideline), 15 percent had elevated levels (5.65-11.3 mg/L, requiring increased monitoring) and 68 percent had low[111] levels (less than 5.65 mg/L). In the sub-region of Hamilton-Mangaonua, 49 percent of groundwater samples had excessive nitrate levels, 21 percent had elevated levels and 30 percent had low levels. The data was also broken down by land use (see Table). Environment Waikato also found low nitrate-nitrogen concentrations:

> *The low category may still include some land uses that may affect sensitive environments. For example, in the Lake Taupo catchment* ***even slightly raised nitrate concentrations will affect water quality.***[112]

Groundwater nitrate levels in the Waikato region, 2002

Land use	% Low	% Elevated	% Excessive
Market gardening	46.2	***30.8***	***23.1***
Dairying	68.5	***22.2***	***9.3***
Drystock farming	76.2	***14.3***	***9.5***
Orcharding	100	***0***	***0***
Domestic and other use	90	***10***	***0***

Source: Environment Waikato, 2004d

The council lacks long-term records to indicate nitrate trends across the region, but data collected since the 1950s from some school water supplies show a steady increase in nitrate at these sites.[113]

5.3.2 Faecal contamination of water

In a 1993 report on the influence of farming on fresh water quality, faecal contamination was identified as the most prevalent problem,[114] and current research indicates that it is widespread.[115] Faecal contamination of waters poses a public health risk. Illnesses may be contracted as a direct result of ingesting bacterial, viral, and protozoal pathogens in faecally contaminated waters. Faecal contamination of waterways can stem from a number of sources such as:

- direct deposition of faecal matter in streams by livestock
- faecal matter from livestock entering waterways *via* surface and sub-surface flows
- wild animals and waterfowl
- point-source discharge of wastewater from sewage treatment and meat processing plants
- discharge of effluent to land contaminating soil and soil water, which could flow to surface waters.[116]

A wide range of pathogens may be present in waters contaminated by livestock faeces, and one of particular concern in New Zealand is the bacterium *Campylobacter*. *Campylobacter* is the most commonly notified disease in New Zealand, accounting for nearly 50 percent of notifications in 2001.[117] New Zealand has the highest reported incidence of campylobacteriosis in the developed world (at about 400 cases per 100,000 people per year), with the annual economic cost of the disease estimated to be $61.7 million (1999 $NZ).[118] The risk of infection exists in fresh waters used for recreational purposes and for human consumption. Shellfish in downstream estuaries can also become contaminated.[119] Faecal contaminants are also a potential health risk to livestock, and their consumption of contaminated waters may result in reduced growth, morbidity or mortality.

In recent years, the contamination of New Zealand's fresh waters by a range of indicator and pathogenic micro-organisms has been studied under the Freshwater Microbiological Research Programme carried out by the Ministry of Health, the Ministry of Agriculture and Forestry, and the Ministry for the Environment.[120] This programme confirms that microbial contamination of lakes and rivers is widespread. A high proportion of samples in this survey contained *Campylobacter* (60 percent) and viruses (59 percent). The results of this and earlier studies indicate that concentrations of the faecal indicator *E. coli* often exceed 1000 colony forming units (cfu) per 100 ml,[121] which far exceeds the *E. coli* guideline for fresh water recreation (median of 126 cfu/100ml).

The results of the research programme formed the basis of a risk assessment, the main outcomes of which were that:

- of the pathogens assessed in the study, *Campylobacter* and human adenoviruses are most likely to cause human waterborne illness to recreational fresh water users
- using data from all sites, an estimated four percent of notified campylobacteriosis in New Zealand could be attributable to water contact recreation
- *Campylobacter* is moderately correlated with *E. coli*, and the critical value for *E. coli* as an indicator of increased *Campylobacter* infection is in the range of 200-500 *E. coli* per 100ml
- infection risks of other pathogens examined have not been able to be related to *E. coli* concentrations in fresh waters.[122]

Faecal contamination in the Ashburton district

The Institute of Environmental Science and Research Ltd (ESR) recently carried out a three-year pilot investigation for the Ministry of Health on the transmission routes of human campylobacteriosis.[123] The study was undertaken in the Ashburton area, within the South Canterbury Health District where the incidence of campylobacteriosis is higher than average. The study's aim was to advance the understanding of potential reservoirs and transmission routes, from the environment to humans, in order to help prioritise the development of risk management strategies. The main conclusion drawn was that "for the population sampled, bovine animal contact, direct or indirect, was the highest risk factor identified."[124]

The study results indicate that cattle may be an important reservoir and source of infection in New Zealand. ESR note some limitations to the study, such as a small sample size and rural location, and recommend caution in applying the results throughout New Zealand. Urban dwellers are far less likely to be exposed to farm animals, untreated water and unpasteurised milk – identified sources of infection in the study – and thus urban sources of *Campylobacter* will likely differ. However, it does highlight the risks to people of water contamination caused by increasing cattle numbers.

Faecal contamination in Waikato

Research based on data from 73 stream sites across the Waikato region found that median *E. coli* concentrations ranged from 1 to 1300 cfu/100ml and 53 of the 73 sites sampled exceeded the guideline for fresh water recreation (median of 126 cfu/100ml).[125]

> *The pattern of [E. coli] 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. Conversely, the lowest median values are found in forested catchments, although E. coli concentrations are always measurable, indicating contamination by wild animals.*[126]

This research also established a relatively strong relationship between the median *E. coli* concentration and the percentage of poorly drained soil in the catchment:

> *This is probably attributable to the generation of a relatively large volume of surface runoff on these soils that is able to entrain faecal material and quickly transport it to the stream network. It is also probable that the installation of sub-surface drains and drainage ditches in poorly drained soils accelerates the transport of faecal microbes to streams. The bacterial water quality of streams draining such soils is likely to be particularly sensitive to livestock grazing and the application of effluent to land.*[127]

Water quality and public health

On August 7, 2003, it was confirmed that the water supply for Masterton, the Wairarapa town of 19,000, was infected by the parasitic micro-organism *Cryptosporidium*. *Cryptosporidium* causes gastroenteritis and is transmitted by ingestion of oocysts excreted in human or animal faeces. It is potentially lethal, particularly to people with weakened immune systems. In this instance there were only two reported cases of cryptosporidiosis. The town's residents had to boil their drinking water until October, when the water supply was declared safe to drink. It could have been a lot more serious – a *Cryptosporidium* outbreak in the U.S. city of Milwaukee's drinking water in 1993 claimed 53 lives and caused 403,000 cases of intestinal illness.

5.3.3 Sediment contamination of water

Soil erosion is an issue across much of agricultural New Zealand, from extensive hill country grazing to more intensive types of farming such as horticulture.[128] This is due to the physical nature of New Zealand's terrain and the maritime climate, and is accelerated by land clearance and unsuitable land management practices.[129] In May 1996 a severe storm hit Pukekohe, south of Auckland – one of New Zealand's chief horticultural areas. Rain washed away valuable top soil from cultivated land, damaging property and infrastructure. Manukau Harbour and streams flowing into it were also damaged.[130] In February 2004, storms lashed the Manawatu region with widespread soil loss – some 63,000 irrecoverable landslips affected 20,000 hectares of land. The effects of this storm were reminiscent of Cyclone Bola, which severely affected the East Coast of the North Island in 1988. There is concern at the move toward more intensive cattle grazing systems on rolling and hill land in the North Island, and the implications for soil and pasture damage from treading, including increased sediment loss.[131]

The effects of soil erosion from farmland in New Zealand are twofold – a precious resource is lost from the farm *and* the down-stream effect of eroded sediment entering waterways is enormous.

The effects of soil erosion from farmland in New Zealand are twofold – a precious resource is lost from the farm *and* the down-stream effect of eroded sediment entering waterways is enormous. Thus, sediment 'pollution' and sedimentation are *major* water quality issues in New Zealand. Sediment yields from farmland in New Zealand vary strongly with geological factors, but studies of sedimentation rates in 'sediment traps' such as estuaries and lakes suggest that yields are typically about ten times greater than from the pre-existing native forest.[132] Sediment from farming activities can enter waterways and harm aquatic ecosystems by reducing light penetration and visual clarity (suspended sediment), and by sedimentation.[133]

Reduced light penetration and visual clarity

Suspended sediment in waterways affects the optical quality of water, reducing light penetration and visual clarity, thus causing harm to aquatic ecosystems. Water becomes cloudy due to light being scattered by the particles (a phenomenon called turbidity). Environmental effects of suspended sediment include:

- reduced vision for aquatic animals especially visual predators e.g. fish and semi-aquatic birds

- reduced plant photosynthesis and growth
- reduced visual and recreational amenity
- reduced safety for contact recreation.[134]

There are also non-optical effects associated with high levels of suspended sediment including plant abrasion and damage to the respiratory structures of animals, e.g. fish gills.[135]

Sedimentation

Sedimentation in waterways destroys in-stream habitats by smothering animals, plants and streambeds, and affecting animal lifecycles and food supply. Downstream lakes and estuaries can also be affected. Environmental effects of sedimentation include:

- *degradation of substrates for bottom-dwelling organisms*
- *reduced food quality for bottom-dwelling organisms (in streams)*
- *clogging of fish spawning gravels*
- *smothering of estuarine animals*
- *shoaling of estuaries*
- *infilling of lakes and reservoirs*
- *siltation of water supply intakes.*[136]

Recovery from the impacts of sediment can take years, or be essentially irreversible as in the case of estuary shoaling or lake infilling. Sedimentation can also affect domestic water supply.[137]

5.3.4 Aquatic habitats

In addition to impacting on water quality, farming in New Zealand also has a potentially detrimental effect on aquatic habitat and stream ecology. The more intensive the farming system in terms of external inputs the greater the effect. For example, increasing fertiliser application and introducing irrigation enables a higher stocking rate, which results in the discharge of more contaminants to waterways.

... increasing fertiliser application and introducing irrigation enables a higher stocking rate, which results in the discharge of more contaminants to waterways.

Farming-related activities that increase the risk to New Zealand's aquatic ecosystems, such as rivers and lakes, include:

- the widespread clearance of riparian vegetation
- the entry of livestock into stream channels
- the drainage of swamps and seepage zones
- the installation of mole and tile drains in poorly draining soils
- the clearance of watercourses to promote rapid transmission of floodwaters and the channelisation of rivers for the same purpose

- contaminant discharge (faecal matter, nutrients, pesticides) entering surface and groundwaters.[138]

These activities have a number of consequences for aquatic habitats and their biotic communities:

- increased water temperature, increased algal growth, and the possible elimination of cool-water organisms, due to reduced shade
- reduction in inputs of organic matter such as leaves (used for food and habitat)
- reduced native biodiversity – pollution intolerant species may disappear
- nuisance algal growth and downstream eutrophication due to increased nutrients
- increased sediment load and turbidity from trampling and grazing of stream banks, resulting in stream bed siltation, reduced food quality, and reduced visual clarity (see Section 5.3.3)
- reduction in stream length and habitat diversity, and increase in stream gradient, caused by stream channel deepening and straightening
- increased flow yield, variability and surface runoff.[139]

5.4 Water allocation risks

5.4.1 Overview of water use and allocation

Water is becoming an increasingly critical component of New Zealand's rural economy. The move to more intensive farming systems is usually accompanied by a demand for increased quantity and certainty in water supply. Projections indicate that the dairy, horticulture and viticulture sectors will all expand in the future, and it follows there will be growing demands for water *via* irrigation.[140]

Water consumption in New Zealand is estimated to be nearly 2,000 million cubic metres per year. More than half of our consumption is for irrigation purposes as shown in Table 5.3.[141]

Table 5.3 Estimated annual water consumption in New Zealand[142]

Sector	Water use (million cubic metres)
Households	210
Industry	260
Livestock	350
Irrigation	1,100
TOTAL	1,920

Source: Statistics New Zealand, 2002

Counsell notes in *Achieving efficiency in water allocation* that:

> ***...as New Zealanders, we often take our water resources for granted. New Zealand is relatively well endowed with rainfall and water resources. Despite this, increasing demands on water from competing in-stream and abstractive users, and an uneven distribution of both rainfall and water resources, combine to make the efficient allocation of water an increasingly critical issue.***[143]

Opinions vary as to whether water is scarce in New Zealand. A key problem is inadequate information to make an informed assessment. However, "where there has been a strategic look at increased demand for irrigation water, results indicate that many surface water resources have reached their limit for reliable run-of-river irrigation."[144] Some rivers are clearly over-allocated.

The use of water for irrigation, mainly for pasture purposes, is the main pressure on water availability throughout New Zealand and, in particular, on some South Island rivers and aquifers.[145] The most recent quantitative analysis of water allocation, based on council consent database information found that:

- *70.5 percent of all water allocated in New Zealand is allocated from surface water, 29.5 percent is allocated from groundwater.*
- *77 percent of water allocated is for irrigation, 16 percent is for community, municipal and domestic uses, and 7 percent is for industrial takes.*
- *58 percent of water allocated in New Zealand is allocated from the Canterbury region. The North Island accounts for 17 percent of water allocated.*
- *19 percent of the current weekly allocation has been allocated since 1990. The majority of water in New Zealand was therefore initially allocated under legislation predating the RMA.*
- *There is approximately 500,000 hectares of irrigated land in New Zealand, 350,000 hectares of which is in Canterbury.*
- *41 percent of the irrigated land area is irrigated from groundwater.*
- *The area of irrigated land is increasing at around 55 percent each decade.*
- *The 'at farm gate' value of irrigation water is estimated to be around $800 million.*[146]

The study also found that groundwater allocation, although only representing 29.5 percent of water allocated, was increasing at a faster rate than surface water allocation. Half the water allocated since 1990 has been allocated from groundwater.[147]

As the information for the study came from council consent databases it may not present an entirely accurate picture of actual water usage. The study notes that when actual water use was compared to allocated amounts on a weekly basis, the total take from a water resource was seldom more than 40 percent of allocated volume.[148] Thus actual water usage may be less than the consented allocations. However, because water meters are not mandatory in many places, there is no certainty that water takes are not exceeding the amount allocated. In the absence of water meters there is no accurate way to measure how much water is in fact being taken.

Water allocation has become a significant issue because water is a finite resource and the demand for water for a variety of uses continues to increase. The farming sector requires water both for stock drinking water and for irrigation. Water is vital to many community functions such as power generation, health, industrial processes, recreation, and protection of natural heritage and fisheries, cultural values and mahinga kai. Water is essential for sustaining aquatic ecosystems and biodiversity.

Water allocation and consequent abstraction has the potential for significant environmental impacts. Both surface water, such as rivers and lakes, and groundwater sustain ecosystems. Any removal of water from those water bodies will have an impact on those ecosystems. Generally, the greater the abstraction the greater the likelihood of adverse environmental impact. The environmental effects of water allocation are twofold – the effects of the reduction of water in the water bodies *and* the effects the use of that water may have on water quality.

Abstraction of water from surface water or groundwater, will have an impact on the ecosystems reliant on that water, for example, by reducing the flow of a river, or increasing the temperature of the water. Thus a reduced flow may mean that the river is no longer a suitable habitat or breeding ground for a type of fish.

Water that is abstracted is often used for irrigation. Irrigation enables farmers to grow more pasture, which in turn enables them to have higher stocking rates. To assist with the pasture growth, fertilisers are applied. Thus water used for irrigation enables intensification and diversification of land use. As discussed previously in this chapter, intensification has impacts on water quality, through increased fertiliser use and higher stocking rates. Thus water abstracted for irrigation can lead to impacts on water quality and soil quality through allowing intensification of land use. It also in turn impacts on ecosystems reliant on the water.

A significant issue related to water allocation is the quality and extent of knowledge about groundwater and surface water resources held by councils. The quality of the information can have impacts on the quality of decisions made by councils in setting rules in plans and in granting resource consents. For example if long term records have not been kept in relation to the flow of a river, it can be very difficult to set a minimum flow for that river, or grant water takes that are sustainable.

A significant issue related to water allocation is the quality and extent of knowledge about groundwater and surface water resources held by councils.

A study by Lincoln Environmental on water allocation found that the greater pressure being placed on water resources by the increasing demand for water concerned environmental sector groups.[149] The major concerns arose from:

- consent based planning which does not provide a catchment overview and consequently makes it difficult to manage cumulative effects

- the inadequacy of information on relevant values associated with a resource, on which to base in-stream flows
- a number of technical issues associated with setting minimum flows.[150]

The same study found that abstractive users were concerned:

- that their uses were inadequately considered by councils in setting minimum flows
- about the impact of water allocation processes on the reliability of their water supply
- about the complex and legalistic nature of the planning process and the lack of consistency in the application and interpretation of the RMA between regions.[151]

Water allocation issues are currently the focus of a number of policy development initiatives led by central government such as the Water Programme of Action covered in Chapter 4 and the Resource Management (Waitaki Catchment) Amendment Bill.[152]

The Waitaki River and Project Aqua

The issues surrounding water allocation were brought into sharp focus in the debate surrounding Meridian Energy Limited's Project Aqua and the Waitaki River. In the upper part of the Waitaki River, Meridian currently operates eight hydro electricity stations. Project Aqua proposed to divert approximately two thirds of the mean flow of the Waitaki River, at Kurow, down a 60 kilometre long canal. Six power stations were to be built along the canal to allow production of about 524 MW of electricity.[153]

A large number of applications for consent to take water for irrigation were made before and after Meridian's applications for Project Aqua. Environment Canterbury did not have a plan for water allocation from the Waitaki River. The Minister for the Environment used her call-in powers under the Resource Management Act and called all the applications in. The Government then introduced special legislation, the Resource Management (Waitaki Catchment) Amendment Bill. The Bill proposed to appoint a Board to create a water allocation plan for the Waitaki River. The individual applications for resource consent would then be assessed against this plan. The Bill recognised the current difficulties with the RMA in terms of water allocation, for example: first-in-first-served granting of consents and the lack of ability to compare consents on the basis of merit; what happens to resource consents where there is no operative plan for water allocation; and whether the national interest should be taken into account when considering applications for resource consent.

The debate around water allocation in the Waitaki River highlighted the fact that there is insufficient water to allocate to all those who would seek to use it. In this case the competing abstractive uses were irrigation and hydroelectricity. While most of the debate was focused around whether Project Aqua should proceed, there were some who raised the issues of sustainability and the effect the abstractions, both hydro and irrigation, would have on river flows, ecosystems, and also on water quality.

Meridian Energy announced in March 2004 they would not to proceed with Project Aqua, however, it has not withdrawn its applications for consent and the many irrigation applications remain outstanding. The amended form of the Resource Management (Waitaki Catchment) Amendment Bill was passed in September.

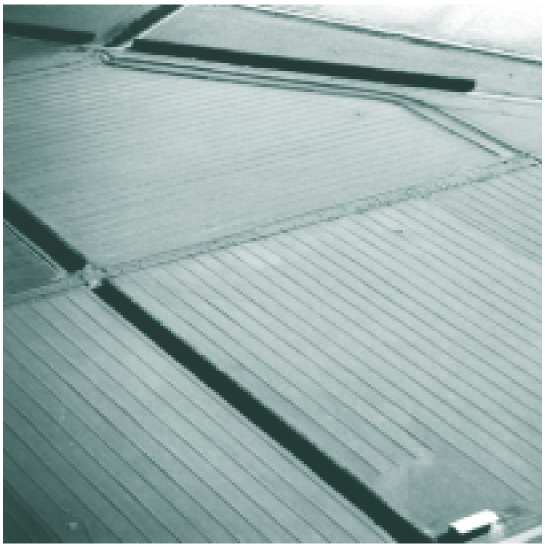
An important issue related to water allocation is the use of water meters. In some regions, water metering is not mandatory. As a result, the following questions can be raised: do farmers know how much water they are applying in the absence of water meters, can councils then accurately determine compliance with resource consents, and are the water resources in fact under more demand pressure than we think? We need more information about actual water use – easily obtained *via* water metering. Without this information, water allocation will continue to be *ad hoc*.

We need more information about actual water use – easily obtained *via* water metering.

5.4.2 Irrigation

Irrigation changes the nature of farming. It can be used in virtually all forms of farming, although the irrigation system used and management of its use depends on a number of factors, the most important being crop type and climate. Irrigation enhances the reliability of any farming system and improves profitability. It also makes possible types of farming in areas previously difficult or impossible to carry out under normal climatic conditions. Irrigation has thus allowed diversification of farming and is a key component of intensification in drier regions. As Doak *et al.* note:

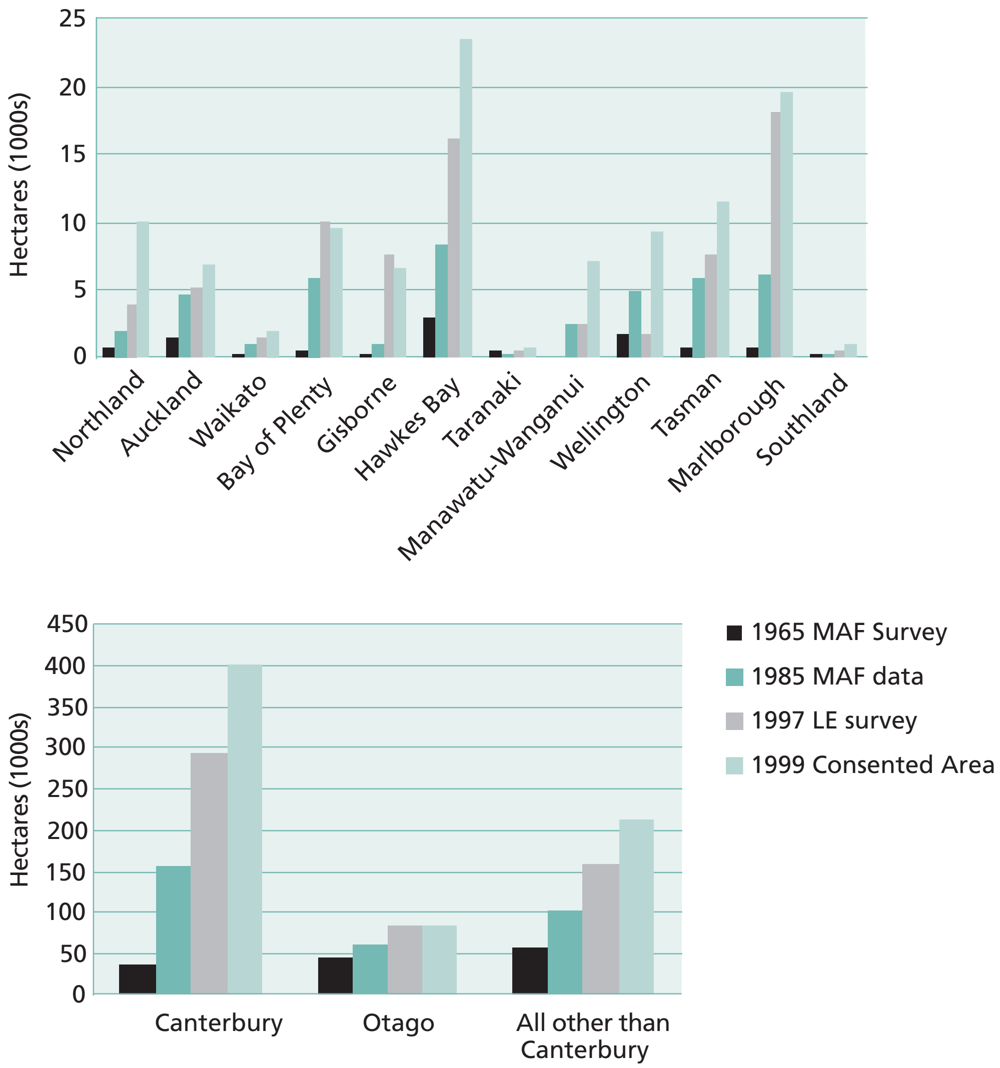
> ***The role of irrigation has also changed from drought proofing or insurance to being the means by which farmers and therefore the economy can diversify, and meet market expectations for quality and quantity of produce because of the increased control irrigation provides over a major production variable.***[154]



Irrigation is used extensively in the drier regions of New Zealand such as Canterbury and Hawke's Bay for horticulture, dairying and arable production. It is estimated that 509,797 hectares of land in New Zealand are irrigated.[155] Thirty-one percent of this is dairy pasture, 34 percent other pasture, 22 percent arable, 11 percent horticulture and 1 percent viticulture.[156] Eighty-one percent of irrigated land is in Canterbury and Otago.[157]

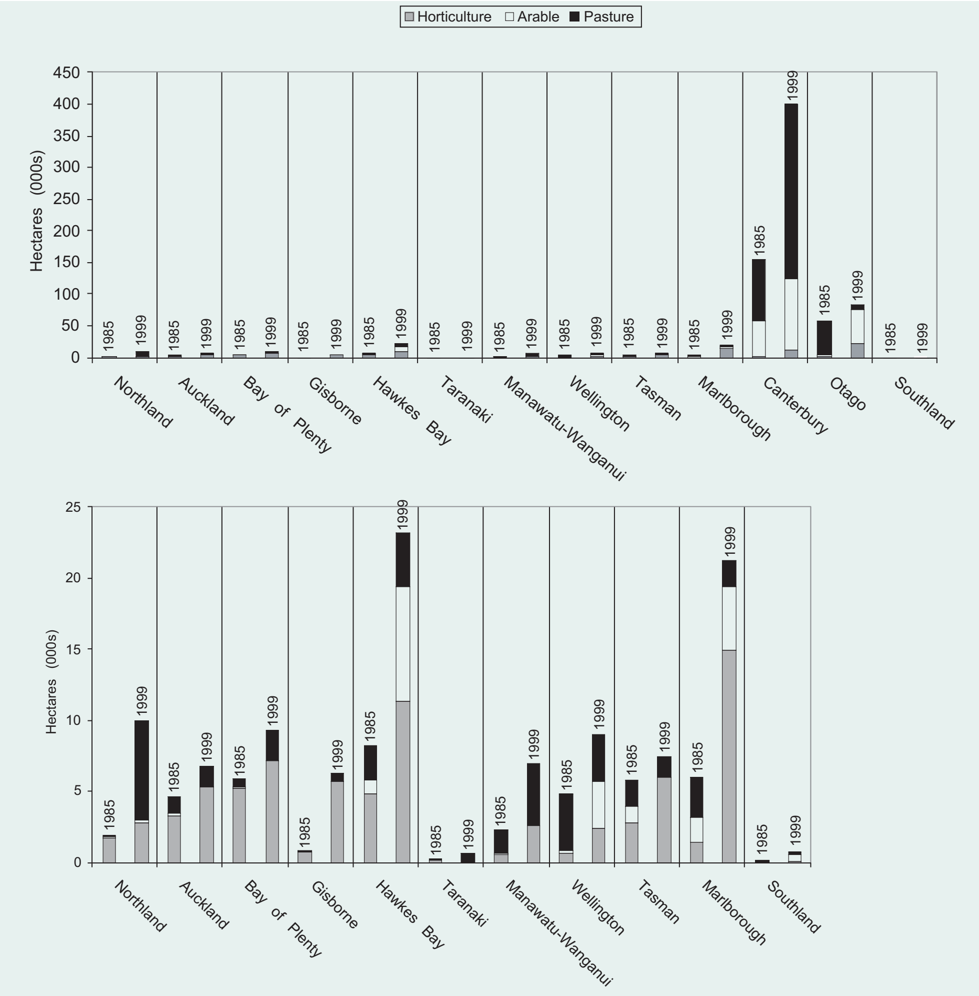
Figure 5.7 shows the regional trends in irrigated area in New Zealand over the last 40 years. Figure 5.8 notes the sectoral trends in irrigated area by region between 1985 and 1999.

Figure 5.7 Regional trends in irrigated area in New Zealand



Source: Lincoln Environmental, 2000c

Figure 5.8 Sectoral trends in irrigated area by region (1985-1999)*



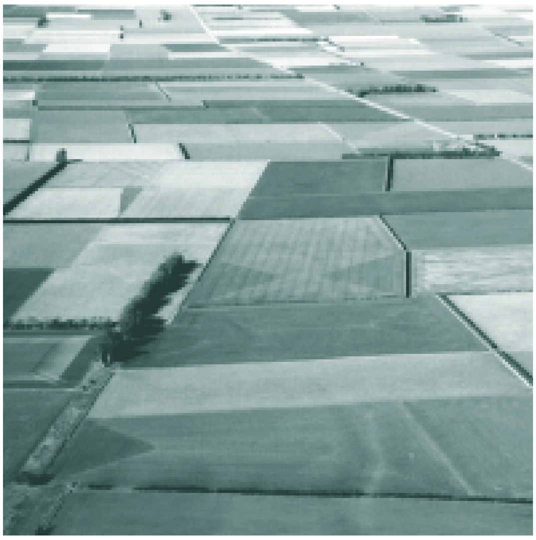
Source: Lincoln Environmental, 2000c

*The second graph portrays the same data as the first, but at a different scale (0-25,000 hectares compared to 0-450,000 hectares)

One recent study has estimated that irrigation demand is projected to increase 28 percent in the period to 2010, on current levels.[158] This would bring the total irrigated area to an estimated 650,000 ha. The same study did, however, note:

> ***The projected growth in demand for water resources will increase the competition between agricultural, amenity, industrial and recreation uses raising calls for further environmental preservation. Rising concerns over water quality and the impact of various intensive land uses will undoubtedly act as a counter to the increased agricultural demand.***[159]

Land use and social change



Research indicates that eventually irrigation leads to significant land use and social change in rural areas through changes in farm type and ownership. The Waitaki area experienced a 16 percent population gain as a result of the development of the community irrigation scheme.[160] Irrigated farming is much more demanding and highly technical than dry land farming. It requires extra work and the development of new farming systems to maximise its usefulness. Recent research based on community case studies has developed a descriptive model of the successive waves of interlinked changes in land use and farm ownership under irrigation.[161]

Benefits of using irrigation

There are a number of factors which encourage the use of irrigation, including:

- improving reliability of existing production systems, i.e. controlling the risks associated with climate particularly in dry areas
- providing for diversification or intensification
- increasing profitability
- producing a more constant income flow from one season to the next
- wanting greater control of production inputs and therefore outputs
- improving viability of the farming business so other members of the family can become involved.[162]

Irrigation generally provides substantial economic benefits for farmers, which also flow through other parts of the farming sector and related economic sectors. The higher returns to individual farmers from irrigated production are undoubtedly a key driver behind decisions to move to irrigated farming. A recent study by MAF suggests that the net contribution of irrigation to GDP at the farm gate in the 2002/2003 year was $920 million.[163] This amounts to 11 percent of the total contribution of primary production to GDP in that year. Table 5.4 identifies estimates of the contribution of irrigation in different regions, and from different types of farming.

Table 5.4 Farm gate GDP value of currently irrigated land uses by region (2002/03)

Region	Irrigated area (hectares)	Dairy benefit ($m)	Pasture benefit ($m)	Arable benefit ($m)	Hort benefit ($m)	Viticulture benefit ($m)	Undefined land use benefit ($m)	Total ($m)	$/ha irrigated ($m)
Northland	7,000	1.7	0.0	0.0	21.0	0.0	6.0	**$28.7**	$4,106
Auckland	7,900	-8.8	0.0	0.0	63.1	0.1	0.0	**$54.4**	$6,883
Waikato	14,500	-3.0	0.0	0.0	58.5	0.2	0.0	**$55.7**	$3,840
Bay of Plenty	11,400	0.0	0.0	0.0	39.3	0.0	0.0	**$39.2**	$3,441
Gisborne	5,600	0.0	-1.5	0.0	27.8	-1.0	0.0	**$25.3**	$4,525
Hawke's Bay	18,100	1.6	0.0	-0.9	83.2	8.3	7.0	**$99.2**	$5,479
Taranaki	2,900	2.6	0.0	0.0	2.3	0.0	1.1	**$6.0**	$2,072
Manawatu-Wanganui	8,000	1.2	-0.6	0.0	12.8	0.0	7.6	**$21.0**	$2,622
Wellington	9,600	6.2	0.0	-0.2	7.3	1.9	6.5	**$21.8**	$2,268
Tasman	10,000	0.9	0.3	-0.8	32.2	2.3	11.7	**$46.6**	$4,656
Marlborough	20,200	3.8	0.0	2.9	10.2	54.0	15.0	**$85.9**	$4,250
Canterbury	287,200	241.9	-21.9	23.2	91.1	0.5	0.0	**$334.7**	$1,166
Otago	68,900	26.8	29.8	0.6	23.5	1.4	5.4	**$87.4**	$1,269
Southland	4,100	-0.1	0.0	-0.1	8.7	0.0	4.5	**$13.0**	$3,173
TOTAL	**475,400**	**$274.6**	**$6.0**	**$24.8**	**$481.0**	**$67.6**	**$64.8**	**$918.9**	**$1,933**

Source: Doak *et al.*, 2004: 55

However, it is important to note that the MAF report has a narrow focus and does not consider any costs to the environment associated with irrigation use in its assessment of the economic value of irrigation. As the forward to the report notes:

> ***...the contribution of water to the national interest has many forms. The socio-economic value of irrigation is only one of them. There are also important conservation, environmental, recreational and cultural values of water. The use of water for irrigation can impact on all these values in various ways, some positive and some negative.[164]***

5.4.3 Irrigation and the environment

While irrigation provides many benefits to farmers, its use also has the potential to create adverse environmental effects. These adverse effects are summarised in Section 5.4.1. Irrigation does not have to create adverse environmental effects – it is *how* and *where* the technology is used that matters. The fundamental question is whether the land use requiring irrigation is environmentally sustainable. A land use dependent upon irrigation in a naturally water limited area may not be sustainable. For example, is dairying in Canterbury, a region with low natural rainfall, light permeable soils, and dependent upon irrigation, sustainable?

Irrigation sits within the context of the hydrological resource for a whole catchment or even wider in some cases (see Figure 5.9). Thus the potential for a range of complex impacts on other parts of the environment, activities and the hydrological resource always exists.

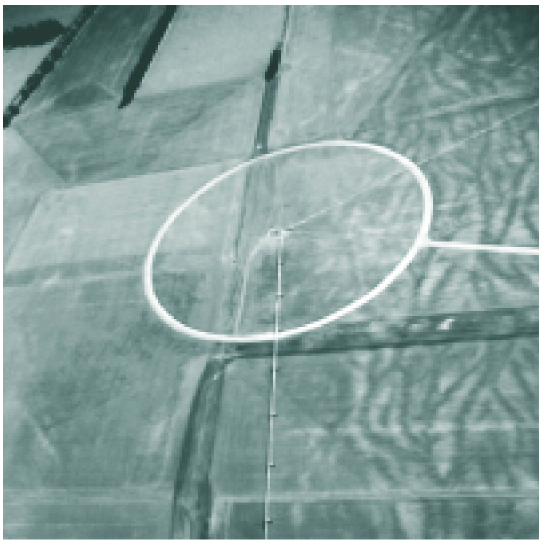
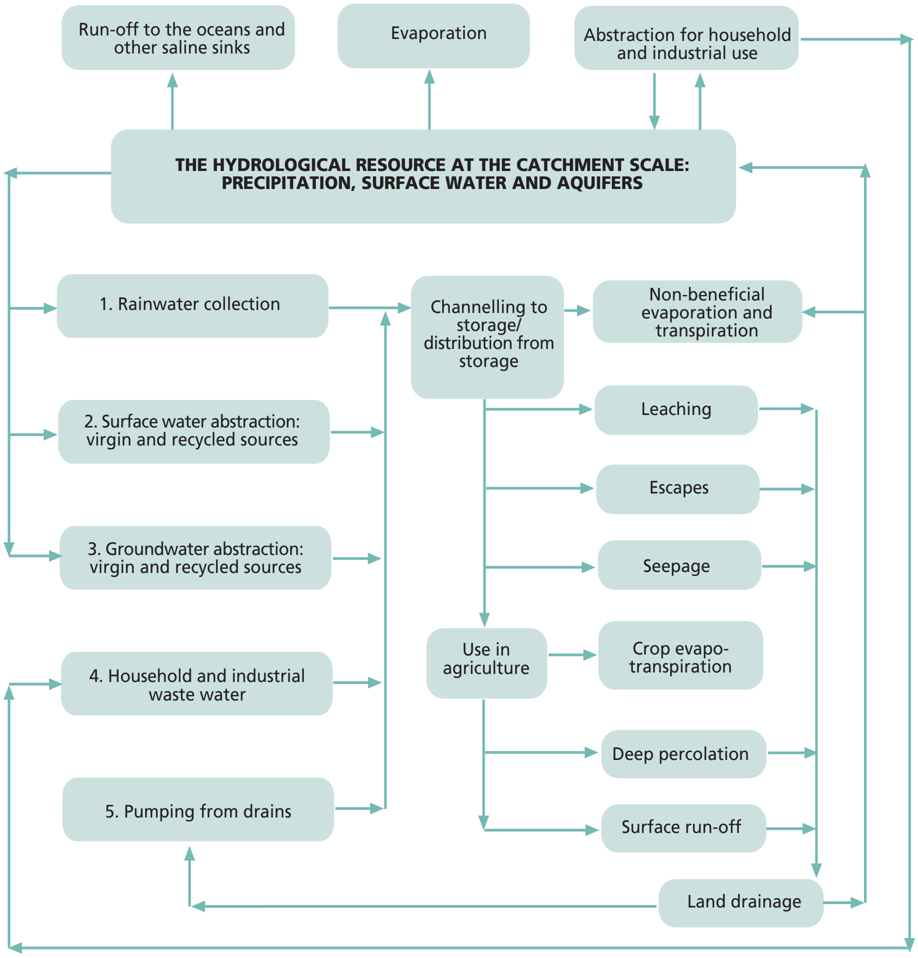


Figure 5.9 The irrigation cycle



Source: Merrett, 2002

Common potential impacts on the environment from irrigation include changes to river flow rates and lowering of groundwater levels as a result of water extraction. Surface water such as rivers and lakes, and *also* groundwater, sustain complex ecosystems.[165] The removal of water from these systems has adverse impacts on those ecosystems, in some cases modifying the ecosystem significantly. Irrigation can also act as a conduit for contaminants (sediment, agricultural chemicals, effluent discharges and fertiliser discharges) from land to surface water and groundwater. It may also change the content of dissolved salts in soils. As irrigation enables higher stocking rates per hectare it can also indirectly lead to impacts on soil, such as soil compaction and soil erosion.

So just how sustainable is irrigation over the long-term? Given appropriate management, it may well be sustainable both environmentally and economically. However, experience overseas suggests that water takes in excess of recharge rates, along with leaching of contaminants, may mean it is neither environmentally nor economically sustainable and in the end will not be socially sustainable either. The example of the Ogallala Aquifer in the US Midwest should serve as a warning.

The Ogallala Aquifer

> *...it's like a lot of people sticking straws into a big common pot of water and sucking up as much as they want.*[166]

The Ogallala Aquifer (also known as the High Plains aquifer) covers 174,000 square miles and underlies parts of Texas, New Mexico, Oklahoma, Kansas, Colorado, Wyoming and Nebraska.[167] The amount of water stored in the aquifer in each state varies. One fifth of all US cropland is irrigated by 90 percent of water from the Ogallala. This amounts to thirty percent of all groundwater used for irrigation in the US. Irrigation is used for crops such as cotton, corn, alfalfa, soybeans and wheat. Some of these crops are used for cattle feed for cattle farms in the Midwest. The Midwest supplies 40 percent of feedlot beef produced in the US.

The use of the Ogallala began in 1900, but increased in the late 1940s with the development of efficient deep-well pumps and low cost energy to run them. At the same time there was an improvement in associated irrigation technology.

> *Irrigation on the High Plains was not merely a response to climate, but its replacement. While in the beginning the farmer tapped groundwater only as a last resort when the rains failed, and often applied water when it was too late, by the 1960s irrigation was integrated into the farming routine as the single most important activity to guarantee big yields. Most consumer of the High Plains groundwater treat it as a 'free good' available to the first-taker at no cost for the water itself.*[168]

It has been conservatively estimated that water has been extracted from the aquifer over the last 30 years at 10 times the rate of natural recharge. As a result there has been a decline in the water level within the aquifer. As the water table drops, more energy is required to pump the water to the surface, thus reducing the profitability of irrigated crop production. The continued decline of the aquifer is threatening the future of irrigated farming in the area and thus impacts on the economy in the area. A study conducted in 1978-80 into the economic life of the aquifer under the Oklahoma Panhandle predicted a conversion to dry land farming as a result of the decline of the aquifer. It concluded that "the eventual economic exhaustion of the aquifer appears inevitable unless dramatic and unforeseeable output price increases or institutional or technological changes occur."[169]

There is, however, disagreement as to the level of decline in the aquifer and whether it can be mitigated. Research and policy development are ongoing.[170]

> *A Faustian bargain with the water is now coming due; it created a prosperous irrigation economy based on levels declining ten times faster than any recharge. But we have no historical experience from which to predict the future of high-production industrial agriculture or the small-time farmer on the High Plains without the continuous massive infusions of groundwater. Nor have pragmatic alternatives been devised, much less tested. Pumping the Ogallala remains a one-time experiment.*[171]

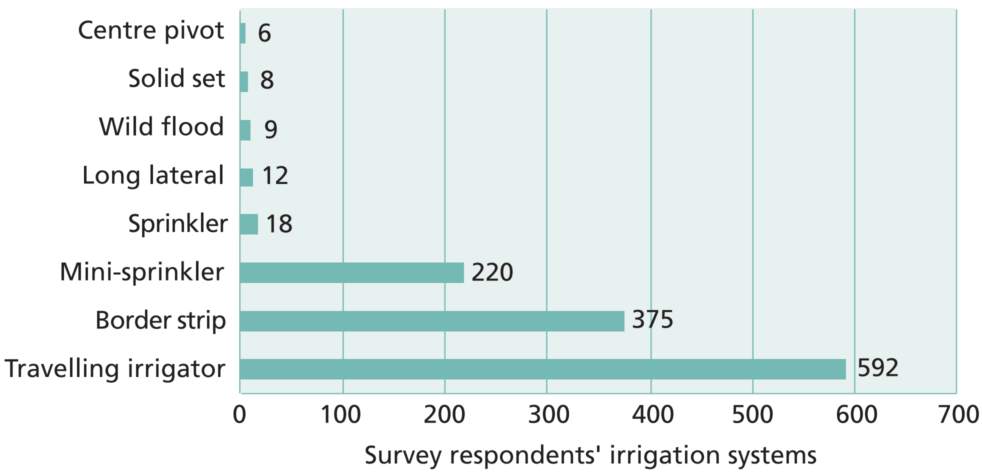
5.4.4 Managing irrigation

Irrigation management is complex and involves assessment of a number of variables, including the irrigation system used, distribution uniformity, uniformity of site, soil type, crop type, climate (including rain and evapotranspiration rate), and soil moisture content. Determining when irrigation should be applied should involve consideration of all these variables. However, this rarely occurs in practice.

Irrigation systems

A variety of different irrigation systems are used in New Zealand. A Lincoln Environmental survey found eight types (Figure 5.10).[172] Travelling irrigators are the most common, followed by border strip and mini-sprinkler.[173]

Figure 5.10 Types of irrigation application systems



Source: Lincoln Environmental, 2000a: 7

Farmer experiences

A survey of farmers' approaches to and perceptions about irrigation management carried out by Lincoln Environmental on behalf of MAF found that:

- *a significant majority of farmers perceive they have few problems with deciding when to irrigate, how much water to apply, and which crops to irrigate.*
- *most farmers appear to recognise the need to base operational irrigation management decisions on soil moisture and crop conditions.*
- *while most farmers claim to monitor soil moisture or evapotranspiration, only a small proportion base their decisions on measured data (probably less than 10 percent).*
- *few farmers know how much water they are using.*
- *the most frequently stated irrigation problem was an insufficient water supply. This is due to either insufficient on-farm capacity or water supply restrictions when river flows or groundwater levels are too low.*

- *the most frequently stated concern was continued access to water for irrigation, under the RMA and in the face of urban needs and opinions.*
- *the most frequently stated constraint on overcoming irrigation problems was cost, or insufficient profitability.*
- *the issue uppermost in the minds of most farmers who irrigate is the effectiveness of irrigation, not the efficiency. This is driven by the desire to maximise production and achieve financial viability.*[174]

In the same survey it was found that farmers did not consider leaching and runoff of nutrients (particularly nitrogen) to be a significant problem (apart from dairy farms).[175] However farmers did express some concern about the effect of irrigation on soils including, salinity in limited areas and soil structure under big guns (a form of travelling irrigator).[176]

The survey concluded that "sustainability of irrigation is not high on farmers list [sic] of priority issues, except where access to water resources is limited."[177]

Irrigation efficiency

Irrigation efficiency has multiple definitions.[178] As noted below:

> ***True measures of irrigation efficiency take account of the spatial uniformity of application depth, the average application depth, and the soil's capacity to store more water at the time of irrigation. Irrigation efficiency varies with each water application throughout the season, and with site, soil type and application system.***[179]

There are many ways to measure the efficiency of irrigation, for example, application efficiency (how much of the applied water is retained in the root zone after irrigation); farm distribution system efficiency (how much of the water supplied to the farm reaches the irrigator); energy use efficiency; and hydraulic efficiency.[180]

A study by Lincoln Environmental into designing effective and efficient irrigation systems found that:

> ***Overall there is a paucity of information relevant to the design of effective and efficient irrigation systems in New Zealand. The lack of accepted performance criteria, particularly related to the efficiency of water use, puts New Zealand agriculture in a weak position with respect to renewing, or obtaining, permits to take water under the Resource Management Act. It also represents a major oversight in the development of information about water resource management in New Zealand, considering that agriculture is the largest consumptive user of water in New Zealand, by a substantial margin.***[181]

One key aspect of irrigation management is knowing when to irrigate and how much water to apply. This requires an assessment of soil moisture content directly or assessing the evapotranspiration rate and calculating how much water has been lost from the soil.[182]

A Lincoln Environmental survey of farmers' approaches to irrigation management found that:

> ***The survey results leave the impression that a large majority of farmers know that soil moisture and evapotranspiration data is the basis of good irrigation management but that for most the monitoring is qualitative. It is likely that respondents included visual inspection in 'measurement' and 'monitoring'. The conclusion is that between 10 percent and 12 percent of respondents regularly measure soil moisture.***[183]

If farmers are not monitoring soil moisture and evapotranspiration data, it is likely that they are not using irrigation efficiently.

If farmers are not monitoring soil moisture and evapotranspiration data, it is likely that they are not using irrigation efficiently, i.e. they are applying either too much or too little water. As water is a finite resource and is coming under increasing pressure from irrigation, irrigation efficiency is vital to ensure sustainable use of our water resources.

While the picture painted by the Lincoln Environmental survey is grim, there appear to be some changes amongst some farmers to use irrigation more efficiently. In some cases this is probably driven by regional councils that require applicants to show they are using the water efficiently and employing models such as Soil-Plant-Atmosphere System Model (SPASMO) in order to gain consent (see Chapter 6). There is also a growing use of professional irrigation consultants who provide advice on irrigation systems and scheduling. This is particularly true in viticulture, where water use is closely tied to wine quality. But it is unclear how widespread is the use of consultants in other farming sectors.

5.5 Other major risks and challenges

Although the focus of this chapter is on the risks and challenges of current nutrient and water demand trends, there are many other risks for natural capital and farming that need to be addressed. This section briefly identifies some further looming issues for the sustainability of farming in New Zealand.

5.5.1 Agricultural policy reforms overseas

As noted in Section 4.2, changes in international trade rules and regulations will continue to drive the direction of farming in New Zealand. Trade negotiations and agricultural reforms are currently taking place, so it is difficult to predict the precise impacts of these changes. Nonetheless, it is useful to explore some different scenarios for what the future may hold. For example, as part of a background report to this investigation Saunders *et al.* estimated the impacts of European Union policy reforms on New Zealand's dairy farming sector.[184] Estimates for four scenarios were undertaken. These scenarios differed according to the degree of reform under Agenda 2000 and the Mid-term review (discussed in Section 4.2.1). The scenarios were:

- *Agenda 2000 reforms implemented* — leading to changes in the prices of milk and dairy products in the European Union and an increase in production quota.
- *Mid-term review reforms implemented* — leading to further changes in the prices of milk and dairy products in the European Union and an increase in production quota.
- *Agri-environmental policies implemented* — leading to a 15 percent decrease in European Union dairy farm production, due to restrictions on stocking rates and constraints on inputs such as fertiliser.
- *Agri-environmental policies implemented* — leading to a 30 percent decrease in European Union dairy farm production, due to restrictions on stocking rates and constraints on inputs such as fertiliser.

The two different scenarios for agri-environmental policies were chosen due to the difficulties involved in establishing the likely impacts of these policies. The authors used the Lincoln Trade and Environment Model to simulate the impacts of these policies until 2010.[185] Estimates for each scenario are identified in Table 5.5.

Table 5.5 Estimated impacts of changes in European Union policy[186]

	Agenda 2000	Mid term review	Agri-environment 15% reduction	Agri-environment 30% reduction
Milk: Producer price (US$/tonne)				
EU	$285	$280	$305	$340
NZ	$225	$220	$240	$260
Butter: Trade price (US$/tonne)				
NZ	$2,030	$2,025	$2,130	$2,300
Milk: Production (000 tonnes)				
EU	120,325	122,745	109,545	95,330
NZ	12,275	12,155	12,925	13,875
Producer returns (US$)				
EU	$34,050	$34,245	$33,190	$32,220
NZ	$2,760	$2,700	$3,090	$3,620

Source: Saunders *et al.*, 2004

As these figures suggest, different scenarios would have significantly different impacts on dairy farmers in New Zealand. According to these estimates, New Zealand farmers would benefit most from the third and fourth scenarios. In these cases, environmental constraints in Europe would lead to a decrease in production in the European Union and an increase in the price of dairy products, benefiting New Zealand producers significantly.[187]

Although future agricultural reforms are likely to lead to many opportunities for the farming sector, New Zealand farmers also risk losing access to lucrative markets if some existing trends persist.

Although future agricultural reforms are likely to lead to many opportunities for the farming sector, New Zealand farmers also risk losing access to lucrative markets if some existing trends persist. As Section 4.2 highlighted, it is possible that future trade restrictions will develop on the basis of production methods. The increasing use of nitrogen fertiliser for farming in New Zealand, as highlighted in this chapter, contrasts remarkably with the focus in the European Union and other OECD countries on reducing nitrogen use. It is important to consider what would happen if New Zealand farmers were required to comply with European standards to gain access to these markets. Recent research suggests that many of New Zealand's waterways would already fail to meet European Union water quality standards for nitrogen and further intensification could exacerbate this situation.[188]

5.5.2 Energy futures

Farming in New Zealand is generally becoming much more energy-intensive (see Section 3.3). Primarily, this is due to the increasing use of fossil-fuel derived synthetic fertilisers. However, the sector also relies heavily on fossil fuels for running farm machinery and for transporting farm products around the globe. Sooner or later, an increasing reliance on fossil fuels is likely to lead to major challenges for farming in New Zealand.

Fossil fuels are non-renewable energy resources. There is currently a major debate occurring worldwide about the economic viability of remaining oil reserves. Some forecasters suggest that global oil production will peak within the next 20 years or less – *not* because there will be no oil left, but because world demand for oil is growing higher and higher and the limited stocks of remaining oil will be more expensive to extract.[189] When world oil production 'peaks' (i.e. when the demand for oil outstrips the capacity to extract it) oil prices will rise significantly. Although this peak will probably be softened by the availability of alternative petroleum sources and some new extraction technologies, the effect of such a peak, when it occurs, will be felt the world over. This is not a matter that New Zealand has any control over – although it is not inevitable for New Zealand to pursue an energy-intensive future. In the meantime, New Zealand farmers are currently becoming more dependent on an energy source that will become much more expensive.

New Zealand farmers are currently becoming more dependent on an energy source that will become much more expensive.

Access to energy sources within New Zealand is also becoming more expensive. For example, there is limited capacity to generate further low-cost electricity in New Zealand, especially if all environmental effects are taken into account. There are limited sites for further hydro generation, gas reserves are finite, and it is likely that future gas discoveries will not match past discoveries enough to sustain current and projected consumption patterns.[190] The price of electricity will therefore rise as more expensive sources of energy are utilised. Electricity is a major cost input for some farmers, especially those who rely on irrigation. For example, the cost of electricity for one farmer in a 2003 case study increased from approximately $200/ha to $650/ha in one season when electricity prices hit an unusual peak.[191] Although this single case does not indicate a trend, it does illustrate the risk and the potential vulnerability of farmers to rising electricity prices.

Although electricity prices will rise, it is important to keep in mind that farmers may not necessarily need to pay more for energy services. After all, farmers do not require electricity *per se* – they merely want the *services* that electricity is often used to provide.[192] For example, while irrigation systems with pumping consume a lot of electricity, gravity fed systems do not. Similarly, it may be possible for many farmers to generate electricity on-site instead of becoming more reliant on electricity provided *via* the national grid. On-site generation, or other forms of 'distributed generation', is likely to become more common as 2013 approaches. From that date, electricity line companies will no longer be legally required to service their customers, including remote rural users, from this year onward.[193]

5.5.3 Climate change impacts

While worldwide energy consumption continues to grow, carbon dioxide and other greenhouse gases are building up in the atmosphere and contributing to global warming (see also Section 3.4.3). This is affecting weather patterns and contributing to climate change.[194] For New Zealand, climate change is likely to lead to drier conditions in eastern regions and wetter conditions in the west. In combination with other climate changes, this is likely to lead to more 'climate events' such as floods and droughts.[195]

A report prepared for the Ministry for the Environment in 2001 highlighted some major risks and challenges for farming over the next two decades.[196] Some of the main findings of this report are that:

- climate change will probably have the greatest impact on farming through changes in climate variability and climate extremes. New Zealand farmers and growers will increasingly need to manage risks associated with climate events.
- eastern regions could experience more frequent, and potentially more severe, droughts through a combination of higher average temperatures, reduced average rainfall, and greater variability of rainfall.
- western regions, and possibly some eastern regions, could be more prone to flooding and erosion from high rainfall events.
- pasture production will generally increase, particularly in southern New Zealand. There may be a reduction in feed quality in pastures as far south as Waikato and feed quality may also decrease further in dry eastern regions.
- arable crops may generally benefit from warmer conditions and higher carbon dioxide levels in the atmosphere. However, potential yield increases may require higher fertiliser inputs. There may also be increasing demand for irrigation to increase yields, particularly in Canterbury where there will be increased drought risk.
- Hayward kiwifruit may become uneconomic in the Bay of Plenty in the next 50 years under mid to high climate warming scenarios. Apple production is unlikely to be

adversely affected, although there could be greater risk of heat damage in future and availability of water for irrigation may be an increasingly critical issue.

- within the farming sector, there are major uncertainties about the impacts of climate change scenarios related to changes in pest and disease profiles in different regions, changes in soil fertility, and changes in water availability.

This report also suggests that the most effective strategies for adapting to climate change in the farming sector are likely to involve "developing a more integrated approach to land management that considers climate change alongside other important issues such as biodiversity, biosecurity, land degradation, and water resource use."[197]

5.5.4 Biodiversity loss

Biological diversity, or biodiversity, describes the richness, diversity and variability among all living organisms and ecosystems. Biodiversity is commonly considered at three levels: genetic (diversity within species), species (diversity between species and within an ecosystem) and ecosystem (diversity between ecosystems).[198]

New Zealand's indigenous biodiversity is important for many reasons.[199] Due to its isolated position in the South Pacific, New Zealand has a high proportion of endemic species (those found nowhere else in the world).[200] This makes New Zealand's native biodiversity special as well as vulnerable. New Zealand's biodiversity also provides many ecosystem services to the farming sector (see Section 2.2.1), even though these services are usually taken for granted. Although the vast majority of farming in New Zealand is based on introduced species, its success still relies on natural biological systems. For example, it was estimated that the total economic value from New Zealand's biodiversity on land was $44 billion in 1994.[201] This compares to national gross domestic product (GDP) of $84 billion that year.

Biodiversity can easily be damaged when farming becomes more intensive. If so, this may also put the ongoing viability of farming at risk. In 1997, the decline in biodiversity was identified as New Zealand's most pervasive environmental issue.[202] The main threats to indigenous biodiversity were identified as:

- habitat destruction – deforestation, grazing, fires, development, wetland drainage, fragmentation and degradation of ecosystems and unsustainable use of resources

- introduced pests and weeds – competing with and preying upon indigenous plants and animals.

As noted in a previous PCE investigation, there is a vital need for indigenous biodiversity on private lands to be sustained and enhanced to improve the sustainability of farming in New Zealand.[203]

5.6 Summary and key points

This chapter has highlighted how natural capital can be degraded as farming becomes more intensive, leading to social and environmental harms that place the future of farming at risk. The main focus has been on fresh water. New Zealand's surface waters (streams, rivers and lakes) and groundwater systems are coming under more and more pressure from intensive farming, with trends of decreasing water quality and increasing demands for water for irrigation.

Many farms are becoming more intensive through the use of two external inputs – synthetic fertilisers and water for irrigation. Farmers add synthetic fertilisers, which contain nutrients such as nitrogen and phosphorus, to the soil to increase plant and pasture growth. Over time, there has been a major increase in the use of synthetic fertilisers to provide these nutrients and to intensify production. In particular, the use of nitrogen fertiliser in New Zealand has soared in recent years. Nutrients can also be added to soil *via* clover, the spraying of effluent onto pasture, and animal excreta (particularly cattle urine).

Nutrient inputs need to be very carefully managed. If excessive nutrients are applied to pasture and crops, they leak into the wider environment. Nitrogen is highly mobile and can easily enter streams or leach through the soil into groundwater, eventually ending up in rivers, lakes and coastal waters. This can lead to the eutrophication of fresh waters and coastal waters and the deterioration of groundwater quality. This can result in contaminated drinking water supplies, with risks to human health. Once nitrogen enters the environment there is no effective way to remove it. Although phosphorus is far less susceptible than nitrogen to leaching into the environment, phosphate fertilisers can also contaminate water.

There are now major concerns about New Zealand's waterways and lakes becoming nutrient enriched and degraded. The lag time taken for nutrients to enter these water bodies suggests that any problems will get worse before they eventually improve. The longer it takes to address these problems, the more likely it is that serious degradation will result.

Faecal matter and eroded sediment from farming sources are other major contaminants of water and aquatic ecosystems in New Zealand. Many of New Zealand's lowland rivers are now unsuitable for swimming due to faecal contamination. Sediment can detrimentally affect water bodies in two ways: sediment can be suspended in water affecting light penetration and visual clarity; and sedimentation in waterways can destroy in-stream habitats by smothering animals, plants and streambeds, and affecting animal lifecycles and food supply. The more intensive the farming system, the more at risk the environment is to contamination from these sources as well.

Water allocation has also become a significant issue in New Zealand. Although water is a finite resource, the demand for water continues to increase. Most of this pressure is coming from the farming sector. There are significant demands for water for irrigation, mainly for pasture purposes, and much of this water is being used inefficiently. While irrigation provides many benefits to farmers, it can also contribute to adverse environmental effects. Both surface waters and groundwater sustain complex ecosystems. Any removal of water from those water bodies will impact on those ecosystems. Irrigation can also act as a conduit for contaminants (such as sediment, farming chemicals, effluent discharges and nutrients) from the land to surface water and groundwater.

By using more synthetic fertilisers and/or using irrigation, farmers can grow more pasture and increase the number of stock on each hectare of land. This can exacerbate many of the environmental impacts discussed above. For example, higher stocking rates in the dairy sector lead to more cow urine (and thus nitrate) leaching to the environment.

The farming sector is likely to face rising public pressure to adequately address the trends.

There are clearly major risks to New Zealand's waters and these are likely to become more critical if current trends persist. The farming sector is likely to face rising public pressure to adequately address the trends. Many New Zealanders rely on secure sources of uncontaminated water for drinking, and they value waterways maintained in a healthy condition. Water is vital to many community functions, and other important economic sectors, such as tourism, rely on high quality water to meet New Zealand's 'clean and green' reputation.

Other looming risks for farming, which are likely to become more serious if current trends continue, include:

- the potential loss of access to lucrative overseas markets if trade becomes restricted on the basis of production methods, including environmental impacts
- a growing dependence on fossil-fuel based fertilisers even though these inputs are likely to become much more expensive in the future
- ongoing loss of biodiversity and the essential ecosystem services provided to farming.

From all of this, it is clear that New Zealand's farming sector faces some enormous challenges. Fortunately, as the next chapter highlights, some attempts are already being made to redesign existing farming systems for the better.