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Some External Costs of Dairy Farming in Canterbury

Paper presented at the 50th Australian Agricultural and Resource Economics Society annual conference, Sydney Australia, 8th – 10th February 2006

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Abstract

Intensification of agricultural practices is occurring in Canterbury. Dairy farm conversions continue with land use increasing 132% since 1995. Current concerns emanate predominantly from issues of water quantity and quality, in particular the degradation of lowland streams. These and other costs are not transmitted through markets for dairy products, these negative externalities represent allocation and equity concerns for regional policy makers. This study canvassed regional policy administrators, assembled available valuation studies and performed rudimentary calculations based on reviewed New Zealand literature to form an estimate of the external costs of dairy farming in Canterbury. External costs are estimated at \$28.7 to \$45 million annually. Using 146,000 hectares of dairy in Canterbury, external costs per hectare is calculated at \$196.59 to \$308.23. Damage to air resources from CO₂ equivalent emissions is the largest category and is estimated to be \$24.2 to \$40.4 million per year.

Keywords: Negative externalities, dairy farming, valuation.

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Introduction

Dairy stock unit numbers in Canterbury have increased far greater than other stock types. From 1990 to 2003 dairy stock numbers increased 390% while sheep numbers fell 24%, Deer numbers rose 178% and Beef numbers increased 73%. Dairy farming produces environment and health costs that are not transmitted through markets for the goods produced, they are negative externalities. Runoff containing effluent and fertiliser contaminate water resources. Methane and nitrous oxide emissions damage air resources. Costs of environmental degradation and human health effects are borne by society at large, they are not taken into consideration when farmers make profit maximising decisions. The price of a litre of milk does not, for example include the cost of mitigating faecal contamination of water resources, some of this cost is borne by Canterbury rate payers. A market in which external costs are identified produces too much at too low a price relative to the efficient level and therefore represents a misallocation of resources.

This paper focuses on externalities that are of public good nature. A good that is non-excludable and non-rival in consumption is defined to be a pure public good. There is little or limited recourse for redress to those affected by these types of externalities. Those affected by externalities of a private nature are far better positioned. Externalities that exhibit public good characteristics therefore usually require public mitigation programmes to be implemented. Damages to resources from non-point sources are common in agriculture and present difficult challenges for policy makers. In Canterbury this is a predominant problem for dairy farming in relation to damage to water resources.

Equity concerns are also significant. Public expenditure mitigating these externalities effectively subsidises the profits of dairy farmers. Bewsell and Kaine (2005) gather data from dairy farmers in four New Zealand catchments to identify the factors that influence dairy farmers' propensity to adopt sustainable management practices. The authors find that attitudes of dairy farmers to sustainability and the environment have at best a limited role in influencing their propensity to adopt sustainable management practices (Bewsell and Kaine, 2005).

Framework

The framework and methods used in this study draw on the work of Pretty et al. (2000) who assessed the total external costs of UK agriculture, and Tegtmeier and Duffy (2004) who did the same in the United States. Both papers compiled data and available studies to estimate costs for total agricultural production categorised by damages to natural capital and human capital. Together the two papers provided the basis for cost categories used here resulting in a framework of four cost categories being used; Damage to Water resources, Damage to Air Resources, Damage to Ecosystem Biodiversity and Damage to Human Health.

Pretty et al (2000) estimate total external costs of UK agriculture for 1996 to be £208 per hectare. Tegtmeier and Duffy (2004) calculate that in 2002 total external costs for United States agriculture were \$29.44 to \$95.68 per hectare. External costs per

hectare for dairy in Canterbury are calculated at \$196.59 to \$308.23 which falls between the two above.

Methods

Using Pretty et al (2000) and Tegtmeier and Duffy (2004) as a basis for international literature on externalities of agriculture we reviewed New Zealand literature seeking relevance to dairy farming. Where some direct method of valuation of an externality is not available an excepted method is to use as a proxy the expenditure which society incurs in dealing with that externality (Hill and Crabtree, 2000). In this instance the expenditure is by Canterbury rate-payers. Data and information were obtained from Environment Canterbury (ECan), Ministry for the Environment (MfE), Ministry of Agriculture and Forestry (MAF), Animal Health Board (AHB) and the Canterbury District Health Board (CDHB). Interviews with, and information provided by, staff formed the basis for estimates of damage to water resources, damage to ecosystem biodiversity and Bovine Tb costs.

The cost categories provided in this paper do not represent the entire range of external costs of dairying, only those that were able to be valued readily. The Consumer Price Index (CPI) is used to update values. Table 1 presents our resulting Canterbury estimates.

Table 1: Annual external costs of Canterbury dairy farming

Damage category		\$000's
1	<i>Damage to water resources</i>	
1a	Surface water	115
1b	Loss of angler values	9-16
1c	Groundwater	40
2	<i>Damage to air resources</i>	
2a	CO ₂ equivalent emissions	24,269- 40,449
3	<i>Damage to ecosystem biodiversity</i>	
3a	Loss of shelterbelt	2,947
3b	Sediment in surface water	18
4	<i>Damage to human health</i>	
4a	Cost of pathogen related illnesses	39 - 152
4b	Bovine TB	1,265
Total		28,702 – 45,002

1. Damage to water resources

1a. Surface water

Surface water ways are susceptible to contamination by run-off exacerbated by increasing irrigation both of water and effluent, or directly through direct effluent discharge or by the stock entering the water way. The majority of water ways on farmland do not incorporate riparian buffers and are not fenced off from stock.

Over the 2004/05 summer 71% of river sites monitored in Canterbury were not suitable for contact recreation (ECan, 2005b). This is made up of 57% having a 'very poor' grading and 14% a 'poor' grading, sites graded very poor have direct discharges of faecal material and swimming should be avoided, permanent signage is erected informing the public. These sites provided samples with *E. coli* concentrations above the action mode guideline of <550 *E. coli*/100ml.

Davies-Colley et al. (2004) show how a dairy herd crossing a stream temporarily raises *E. coli* concentrations by 100x the contact recreational guidelines. As well as appreciable mobilisation of nitrogen and fine suspended matter causing turbidity.

Inventory of recreational values of rivers and lakes in Canterbury are detailed and show that there are many diverse uses that are enjoyed by many people (ECan, 2004). The loss of these values due to contact guideline breaches has not been estimated and requires further research, and thus is not included in this papers estimate.

The water quality of lowland rivers is the lowest of all the river types and is generally eutrophic (ECan, 2002). Nitrogen and phosphorus concentrations are generally in excess of Ministry for the Environment (2000) guidelines for the management of biodiversity and for recreational/aesthetic values. Reduction of phosphatic fertilisers directly to waterways and prevention of phosphate rich soil erosion is recommended.

Cameron and Di (2004) find that at similar rates of application nitrate leaching losses are greatest for cow urine. When dairy farm effluent is applied to pasture that is grazed (i.e. includes urine) leaching losses are significantly increased (Cameron and Di, 2002). Hamill and McBride (2003) compare water quality trends and changes in stock numbers in Southland. These authors results indicate that increased dairy farming has been associated with increasing concentrations of dissolved reactive phosphorous.

Environment Canterbury's Inventory of Instream Values for Rivers and Lakes (ECan, 2004a) provides qualitative measure of biodiversity values that are at risk. The use of the inventory could be extended if it had a quantitative aspect that could more readily be used to form a monetary estimate of change in biodiversity value.

Environment Canterbury launched the Living Streams project in 2003 aimed at encouraging sustainable land use and riparian management practices to improve the quality of Canterbury's streams. Stream care initiatives, education programmes in schools and the Environment Enhancement Fund (EEF) support this work and the protection of wetlands and bush habitat. Over 350 ha of wetland and bush, and 64 km

of riparian margin protection or enhancement work has been undertaken with support from the EEF (ECan, 2005a).

The Dairying and Clean Streams Accord is a cooperative agreement between Fonterra Co-operative Group, Regional Councils, Ministry for the Environment and Ministry of Agriculture and Forestry. The accord focuses on reducing the impacts of dairying on the quality of New Zealand streams, rivers, lakes, groundwater and wetlands (MfE, 2003). Regional councils will be carrying out work to monitor the environmental effects of implementing the targets of the Accord (MfE, 2004). Estimates of public expenditure under this accord are additional to that currently incurred and are not yet available but are anticipated to be substantial.

Environment Canterbury spends approximately \$100,000 on investigation of land use on water quality per annum as direct result of dairy intensification (Hayward pers. comm. 10/8/2005). Regional monitoring expenditure on water quality is approximately \$190,000 per annum. We attribute all of the \$100,000 and 8% (percentage of dairy stock numbers out of sheep, dairy, beef and deer) of the \$190,000 to dairy farming, yielding \$115,200.

1b. Loss of angler values

Water extraction for agricultural irrigation is considered to degrade fishing values of rivers by lowering water levels and quality. Dairy farming requires larger amounts of water than other agricultural activities to maintain the quality and quantity of pasture (Memon and Selsky, 2005). Fish and Game members have reported anecdotal evidence of flows in lowland rivers, particularly in the Selwyn area. This reduction has been accompanied by a degradation of lowland streams flowing into lake Ellesmere (Millichamp, 2005). Declining angler quality of the Selwyn River is perceived by anglers to be a result of low flows due to excessive water abstraction for irrigation (Jellyman, Unwin and James 2003).

Between 1994/95 and 2001/02 there has been a 70% decline in the total number of angler days for Lake Ellesmere and its tributaries (L2, Sewyn, Irwell, Harts Creek, Halswell and Hororata. The total number of angler days for Lake Ellesmere and its tributaries for the 1994/95 season was 12,619 and for the 2001/02 season was 3,749 this is a reduction of 8,870 days (Unwin and Brown, 1998; Unwin and Image, 2003).

Kerr, Basil and Sharp (2004) estimate recreational values for the Rakaia river. They provide a range of \$11.33 - \$21.81 per angler visit (2005 dollars). These values are applied to the lake Ellesmere and tributaries angler days data to provide an estimate of the loss of angler value per year. Using the above figures an estimate of the value of average annual losses is \$21,000 - \$39,000

To approximate the proportion of angler loss apportioned to dairying we use the percentage of dairy land area out of total land irrigated. There are approximately 350,000 hectares of irrigated land in Canterbury (Dearnaley, 2001) and 146,000 hectares of land used for dairying (ECan, 2005c) assuming that all dairy land is irrigated, this is approximately 42%. Applying this percentage yields an estimate of the loss of angler value at \$8,820 - \$16,380 per annum.

1c. Groundwater

The Canterbury Plains are particularly susceptible to aquifer intrusion over time due to their physically flat nature exacerbating downward seepage of surface contaminants. Currently there are few immediate contamination issues, however there is evidence that nitrates are penetrating lower over time and it seems inevitable that mitigation costs will be incurred into the future.

The Annual Ions Survey (ECan, 2002b) for 2001/02, shows that Maximum Acceptable Values(MAV) (MoH, 2000) for the health-based standards were not met for: faecal coliforms in 36 samples (15%); *E. coli* in 35 samples (14%); nitrate nitrogen in 5 samples (2%) and manganese in 6 samples (2%). There is evidence of an increasing long term trend of nitrate in groundwater. Trend analysis tests conducted on nitrate concentrations from 255 wells in Canterbury identified long-term increasing trends in 43 wells. These wells were distributed across the Canterbury Plains and in most other areas of Canterbury where groundwater quality is Monitored (ECan, 2002a). Approximately 5% of 151 wells monitored in 2003/04 had nitrate levels above the MAV. A contaminated well can be made deeper to avoid nitrate at considerable cost to the owner. Reverse osmosis is a treatment that is employed at around \$1000 per unit. These costs to private individuals are not recorded in analysis of groundwater surveys.

Four wells in the Levels Plain area between Timaru and the Opihi River have been sampled for pesticides approximately quarterly since 1996. In 2001/02 Simazine and terbuthylazine were detected in at least one sample from each of the four wells. Other pesticides detected included atrazine, MCPA, MCPP, 2, 4-D, and chlorsulfuron. All detections were at concentrations less than 1 microgram per litre, there were no transgressions of drinking-water standards (MoH, 2000). Close and Flintoft (2004) provide a national survey of pesticides in groundwater in New Zealand for 2002. Pesticides were detected in 2 of the 8 wells surveyed in Canterbury, with 3 pesticides detected in one and 4 in the other. None of the wells surveyed had pesticides at levels above the maximum acceptable value for drinking water (MoH, 2000).

Environment Canterbury spends approximately \$500,000 of rate payers money per annum on groundwater monitoring and management (Hanson pers. comm. 28/7/05). This includes costs of specific investigations, education (e.g. nutrient budgets) and monitoring. Nutrient budgeting educational programmes are currently in their infancy, as they are developed and implemented costs will be incurred. Using the percentage of dairy stock unit numbers out of sheep, dairy, beef and deer, approximately 8% as a proxy of expenditure on dairy. This yields \$40,000 per annum. This assumes that expenditure is equal for each stock type.

2. Damage to air resources

2a. CO₂ equivalent emissions

The agricultural sector emissions represented 49.4% of all greenhouse gas emissions in New Zealand in 2003 (MfE, 2005). Emissions of methane from enteric fermentation dominate the sector producing 63.4% of carbon dioxide equivalent emissions in the sector. Methane emissions from dairy cattle have increased 70.3% since 1990. Nitrous oxide emissions from agricultural soils are the other major component at 34.9% of agricultural emissions.

Dairy farming emissions fall into several components of New Zealand's greenhouse gas inventory that are submitted to the United Nations Framework Convention on Climate Change. Dairy falls into the methane from enteric fermentation, methane from manure management, nitrous oxide from lagoons applied to soil, nitrous oxide from dung/urine deposited on the soil and fertiliser emissions (Brown, pers.comm. 2005).

This paper employs the Implied Emission Factor (IEF) approach to estimate emissions for dairy farming in Canterbury. There has been a gradual increase in the IEF for dairy cattle from 1990 to 2003. Increases in animal performance (milk yield) require increased feed intake by the animal to meet energy demands. Increased feed intake produces increased methane emissions per animal.

The dairy implied emission factor (kg CO₂ equivalent per animal) calculated up to 2002 is estimated at 2406.192 per year (Brown, pers.comm. 2005). A charge of \$15 per tonne CO₂ equivalent has been proposed with a \$25 maximum for the first commitment period (IRD, 2005). This proposed charge is used here as a proxy for damage to air resources. Multiplying the dairy IEF by the number of dairy stock units, approximately 600,000 (MAF, 2005) yields 1,443,715 tonnes of CO₂ equivalent. At \$15 per tonne this equates to \$21,655,725 at \$25 per tonne this equates to \$36,092,875.

Fertiliser use also produces emissions. The fertiliser implied emission factor (kg CO₂ equivalent per tonne of fertiliser) is estimated at 6819.487 (Brown, pers.comm. 2005). The rate of fertiliser use is assumed to be 175 kg N/ha annually (Ledgard and Thorrold, 2003). With 146,000 hectares of dairy (ECan, 2005c) this gives 25,550 tonnes of fertiliser. Applying the IEF yields 174,238 tonnes of CO₂ equivalent. At \$15 per tonne this equates to \$2,613,570 at \$25 per tonne this equates to \$4,355,950.

3. Damage to ecosystem biodiversity

3a. Loss of shelterbelts

The pattern of land use change in Canterbury is particularly evident in the upper Selwyn District, west of State Highway one in a region called Te Pirita, in which Environment Canterbury has been actively monitoring for some time.

Early work on shelter construction in the Te Pirita region was carried out by the North Canterbury Catchment Board and Regional Water Board. Wethey (1984) reviews the Canterbury Regional Windbreak Scheme that had been running since 1949 and had led to significant increases in shelterbelts. The scheme offered subsidies for shelterbelt construction, primarily on the basis of demonstrating erosion vulnerability, however the report also stressed the importance of recognising the value of shelterbelts as wildlife habitat and as pollen sources for bees. As part of Wethey's report a survey of the Te Pirita region was undertaken. This provides aerial photography of shelterbelts constructed with the aid of the windbreak scheme public subsidy.

In 2004 Environment Canterbury carried out a survey of Te Pirita using field inspections and aerial photography to identify/measure the amount of land protected by shelterbelts (Hill, 2005). The survey clearly shows that dairy conversions have had a negative impact on the number of shelterbelts in parts of Te Pirita. Shelterbelts that had been constructed under the old scheme had been removed to allow favourable access to pastures for irrigation.

This report uses the data from 1984 and 2004 to form a quantitative measure of the amount of shelterbelt lost per hectare, as a result of a dairy conversion at Te Pirita. This rate is then applied to regional land use data to form an approximation of the total amount of shelterbelts lost in Canterbury. A subsidy per metre of shelterbelt is derived from Wethey (1984) and multiplied by the amount lost to provide an estimate of the cost of shelterbelt losses.

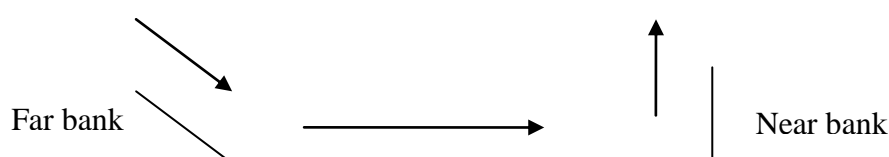
The measurement of actual shelterbelts in both surveys showed that there had been a 46% reduction in shelterbelts on converted land within one dairy farm. The rate of decrease was calculated to be 6.7 metres per hectare (m/ha). The rural land use change report prepared by Environment Canterbury (ECan, 2005c) shows that the amount of land used by dairying has increased from 63,000 ha in 1995 to 146,000 ha in 2004, while total agricultural land used has remained relatively constant. With this in mind the 6.7m/ha rate is applied to the difference between the 1995 and 2004 values *i.e.* 83,000 ha; 6.7m/ha multiplied by 83,000 ha yields 556,100 metres lost.

Using data on completed shelterbelts and costs for 1983/84 a subsidy rate of \$2.11 per metre was calculated, converted to 2005 dollars this is \$5.30 per metre. This amounted to a subsidy of approximately 65% of total costs for that year, subsidy rates differed across years but all were above 65% (Wethey, 1984). Multiplying the subsidy rate and metres loss provides an estimate of the cost of shelterbelt losses and is equal to \$2,947,330.

3b. Sediment in surface water

Sediment in streams is a major concern for water resource managers in Canterbury. There are two main problems; 1: fine sediment stops photosynthesis in turbid waters and subsequently kills plants and starves those dependent on them for food; 2: streams with inadequate flow have sediment fall to the bottom filling up the gaps in the gravel bed and killing the eggs of fish. There are two main contributing factors in Canterbury, large animals eroding river banks and drain cleaning (McGuigan pers.comm. 2005) Consider figure: 1 of a cross section of a river illustrating a typical stream clearing practice. The bucket scoops in the motion indicated by the arrows. The far bank becomes sloped while the near bank becomes vertical as the bucket is drawn up. It is near bank that is prone to erosion by large animals. The bank falls in widening the river, the river slows, and sediment falls to the stream bed relatively easier.

Figure: 1. Typical stream clearing practice



Environment Canterbury manages the Living Streams project which aims to improve the health and life-giving qualities of Canterbury's many rivers, creeks and streams. This will be achieved by helping to keep the water clean and protecting stream beds and banks. Implementation of the living Streams project is based on a framework of Integrated Catchment Management (ICM) in which the focus is on involving all participants of the communities involved. The Living Streams project has an annual budget of approximately \$350,000 with dairy farms being instigators about 5% of the time (McGuigan pers.comm., 2005) inferring that approx \$17,500 can be attributed to dairy farming. This is used as an approximation of the external costs of sediment damage to streams by dairy farming.

4. Damage to human health

In 2003, 2% of deaths and 12% of hospital admitted patients form chemical injuries were caused by agrichemicals. Agrichemicals include all pesticides and licensed animal remedies (from MAF registration list), 20% of all substances detected in injury events were agrichemicals (ESR, 2004).

The National Poison Centre is a service unit within the Department of Preventive and Social Medicine at the Dunedin School of Medicine, University of Otago. Currently,

the Centre is funded predominantly by contracts with the Ministry of Health and the ACC, with support from the University and other agencies. The NPC answers enquiries both from health professionals and from the general public concerning acute poisoning and the toxic effects of chemicals, which may be encountered in emergencies of any sort (NPC, 2001). This service operates 24 hour per day 365 days per year. In 2003, 6 % of enquiries concerned agricultural agents (ESR, 2004).

Spray drift events have the potential cause health effects and have been monitored and evaluated in New Zealand since 1998 through the surveillance system, *Driftnet*. Averaging only 14 events per annum it has been considered that such small numbers do not warrant maintenance and support of *Driftnet* software in each public health service provider (ESR, 2004a). Of the four events in 2003, health problems were claimed to have been experienced on two occasions, however there were no exposure/illness reports associated with the complaints. One of the four complaints was in Canterbury.

4a. Cost of pathogen related illnesses

Withington and Chambers (1997) estimate the cost of notified Campylobacteriosis in New Zealand in 1995. The authors used records of Canterbury Health Laboratories and hospital notes to locate all patients admitted with Campylobacteriosis in Christchurch in 1995 and to determine the costs involved. They form an estimate of \$596 per notification. However Withington and Chambers paper does not attempt to estimate costs of cases not notified, and so is used here only for comparison.

Scott et al. (2000) estimate the annual cost to New Zealand of 10 foodborne infectious pathogens, these are; campylobacteriosis; salmonellosis; shigellosis; yersiniosis; listeriosis; verotoxigenic *Escherichia coli* (VTEC) infection; typhoid fever; hepatitis A infection; illness caused by toxins produced by *Clostridium perfringens*, *Bacillus* spp., or *Staphylococcus aureus*, as well as unspecified food poisoning; and small round structured virus (SRSV) infection.

The authors estimated a cost range, first at a minimum infection rate of 32 cases per 1000 population yielding a cost of \$462 per case, and then at a highest likely infection rate of 224 cases per 1000 population resulting in \$261 per case (Scott et al. 2005; Lake et al. 2005). The upper bound estimate includes pathogens that are more typically associated with non-foodborne transmission such as waterborne *Giardia*. *Giardia* is the most commonly notified waterborne disease in New Zealand which has high incidence rates compared to other developed countries (Ekramul et al. 2004). When the total costs of the individual pathogens were analysed the authors found that campylobacteriosis was responsible for 72.9% of the total costs with the cost of days lost being the single largest component of total cost.

Tegtmeier and Duffy (2004) attribute 3% of the totals to total agricultural production. Applying this yields a range of \$256,824 - \$1,015,627. This leaves the problem of what portion to attribute to dairy farming. Multidrug-resistant *Salmonella* has been linked to Dairy herds (Olsen et al. 2004). In New Zealand epidemic type outbreaks of campylobacter have been attributed to both contaminated drinking water, and to

consumption of raw milk (Brieseman, 1984; Anon, 1991). Studies in New Zealand have demonstrated that campylobacter are frequently present in rural waterways (Till et al. 2000). Ross and Donnison (2003) studied farm irrigation with effluent as a mechanism for introducing campylobacter into the environment, the authors demonstrated a consistent presence of campylobacter in farm dairy effluent. The same authors concluded in another study that grazing of irrigated pasture with effluent without an adequate withholding period may contribute to the high level of campylobacter in New Zealand dairy herds and promote ongoing cycles of infection (Ross and Donnison, 2004). The rate of incidence of campylobacter infection notification in New Zealand has risen from 14 cases per 100,000 in 1981 to a high of 396 cases in 2003 (ERS, 2005). In light of the above discussion it is considered that 15% of total agricultural cost may be attributable to dairy farming, resulting in a range of \$38,523 - \$152,344.

New Zealand has recently adopted international practice in an attempt to control food borne disease. Internationally it is recognised that the ideal tool to give assurance of food safety is the Hazard Analysis Critical Control Point (HACCP) system (NZFSA, 2003). There is a cost to food industries and private providers to comply with this rule that has not yet been measured.

4b. Bovine TB

Bovine tuberculosis (Tb) is one of New Zealand's most serious animal health problems, affecting domestic cattle and deer herds throughout the country. It is possible for humans to become infected with Tb, mainly through the consumption of milk or handling infected animals or carcasses. Tb causes thousands of human deaths annually in developing nations, however the probability of contracting Tb in developed nations is very low due to high standards of meat hygiene and milk pasteurisation. Nevertheless, bovine Tb is still regarded as an unwanted disease because of the negative consumer perceptions and adverse market reactions it could generate (AHB, 2005).

Regulators have set an international standard of Tb freedom, which is reached when 99.8% of domestic cattle and deer herds have been free of bovine Tb for three years. The Animal Health Board (AHB) is responsible for managing the implementation of the National Pest Management Strategy for Bovine Tb (NPMS), with the aim of achieving Tb freedom in New Zealand by 2013. The key functions of the AHB include: vector control – the major cause of Tb in cattle and deer herds in New Zealand is contact with wild vectors of the disease, mainly possums and ferrets; disease control, and research and communications.

Environment Canterbury manages the vector control programme in Canterbury for the AHB. For the 2003/04 year \$7,395,000 was spent on the Bovine Tb management programme in Canterbury (ECan, 2005).

Some of this funding comes from agricultural industries and some from rate payers. AHB financial statements for year ending June 2004 (AHB, 2004) show that total national expenditure was \$78,884,000 of which \$9,945,000 was a Dairy Insight grant,

\$2,031,000 was contributed by Deer Industry New Zealand and \$31,710,000 came from beef cattle levies. This leaves 45% of funding coming from outside these industries, from rate payers. If we apply this proportion to the Canterbury expenditure the result is \$3,327,750 ($0.45(7,395,000)$).

The Ministry for Agriculture and Forestry (MAF) reports that in 2004 there were 600,000 dairy cattle, 532,000 beef cattle and 453,000 deer in Canterbury (MAF, 2005) this equates to dairy cattle making up approximately 38% of total bovine stock units in Canterbury. Looking at the numbers we can see that contributions per stock-unit for each type (dairy, beef, and deer) are not equal. However, expenditure on Tb control does not discriminate between stock types, benefits are non-excludable and non-rival in consumption and so are assumed to be equal across stock types. With this in mind, taking 38% of Canterbury rate payer contributions results in an estimate of external costs of Bovine Tb control of \$1,264,545 ($0.38(3327750)$). Table 2 summarizes the above information.

Vector control of possums and ferrets has positive externalities for native forest assets and many species. This has been a significant consideration in the decision to contribute rate payer funds.

Table 2: Bovine Tb expenditure summary

Scalars and calculations	Item	000's
a	Total AHB national expenditure	\$78884
b	ECan expenditure	\$7395
c ₁	Dairy Insight grant	\$9945
c ₂	Deer Industry N.Z.	\$2031
c ₃	Beef levies	\$31710
$\sum c$	Total industry contribution	\$43686
$(1 - ((\sum c)/a))b$	Total public Canterbury expenditure	\$3328
d ₁	Dairy stock units	600
d ₂	Beef stock units	532
d ₃	Deer stock units	453
$(d_1/(\sum d))((1 - ((\sum c)/a))b)$	External cost of Bovine Tb	\$1265

Summary

Dairy production in Canterbury negatively impacts surface and groundwater, air, biodiversity and human health at an estimated cost of \$28.7 to \$45 million per annum. These figures present a broad preliminary view and the relative scale of dairying's negative impacts in Canterbury.

Conclusions

There are many reasons why the estimates presented here can be considered conservative. Expenditure incurred in mitigating externalities constitutes only part of the full value of damages done. Estimates using this method therefore underestimate damage incurred. Many damages are irreversible and no level of expenditure will correct the problem. The consequences of the environmental risks of industrial agriculture are not entirely known or understood. Complex ecosystem behaviours are difficult for experts to model and are often not included in political debate. Many damages have non-point and large temporal characteristics making attributing causation a problematic task.

Problems surrounding water use and allocation were identified as key issues going forward. With increasing demand for water allocation for irrigation, water resource values across differing uses and users are going to be impacted.

This study, although brief, acts as a scoping paper for ongoing research into agricultural externalities in Canterbury. Policy debate focusing on internalising external costs of dairy farming is essential to provide incentives for adoption of sustainable practice and achieving protection of environmental and human health.

Acknowledgements

We are very appreciative of information and critique provided by many people in particular the following, in no particular order; Dr Len Brown (Ministry for the Environment), Dr Melvin Briesman (Canterbury District Health Board), Zach Hill (Environment Canterbury), Rob Phillips (Environment Canterbury), Carl Hanson (Environment Canterbury), Andrew Barton (Environment Canterbury), George Griffiths (Environment Canterbury), Phil McGuigan (Environment Canterbury), Shirley Hayward (Environment Canterbury).

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