# Clover Root Weevil

## Economic impact assessment

## Report to Biosecurity New Zealand, Ministry of Agriculture and Forestry

**August 2005**

## Preface

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## Authorship

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# Executive Summary

## Background

Clover root weevil larvae reduce nitrogen fixation in the soil from white clover by attacking the root system, ultimately lowering the quantity and quality of pasture grasses for livestock feed. Adult clover root weevil eat the white clover foliage (a high nutrient feed) reducing the foliage available for grazing livestock. Clover root weevil is already widespread in the North Island of New Zealand, there is no means currently available for controlling it and it is unlikely that a pest of this type could be eradicated.

The impact of clover root weevil infestation on the grazing sector is modelled by assuming farmers maintain production rates at pre-infestation levels through the application of synthetic nitrogen and supplementary feed. This approach was adopted after discussion with a panel of experts in a Technical Advisory Group (TAG) convened by MAF to provide expertise in clover root weevil biology, soil nitrogen dynamics, agronomy and pasture management to model the likely impacts on production. The TAG participants are listed in Appendix A and further consultation was conducted with other experts, in particular Rob Davies-Colley from NIWA, Tony Petch Environment Waikato and Stewart Ledgard from AgResearch to understand the nature of the relation between nitrogen pollution in waterways and its relationship to farm soil nitrogen levels.

Other implications were identified in the apiary sector and through increased atmospheric emissions of nitrous oxide:

- Clover and clover blended honey account for a large proportion of total honey production. Reductions in clover coverage on pasture will also reduce honey production.

- The greenhouse gas emissions from fertiliser application and urea production are also accounted for and costed in the economic assessment.

## Spread and Impact Scenarios

There is considerable uncertainty about the rate of spread of clover root weevil and its subsequent impacts on grazing once established in a region. Advice provided by the TAG on anticipated rates of spread based on known weevil biology, three scenarios have been modelled:

- A medium impact scenario using best estimates of the likely spread of clover root weevil and its impacts on production. In this scenario clover root weevil spreads nationwide by 2010. Nitrogen fixation and pasture coverage of white clover is reduced by 50 percent.

- A low impact scenario using optimistic assumptions for rates of spread and impacts on production. In this scenario clover root weevil spreads nationwide by 2015. Nitrogen fixation and pasture coverage of white clover is reduced by 20 percent.
- A high impact scenario using combinations of pessimistic assumptions for rates of spread and impacts on production. In this scenario clover root weevil spreads nationwide by 2008. Nitrogen fixation and pasture coverage of white clover is reduced by 80 percent.

### Nitrogen and feed costs

The analysis is based on the economic costs of farmers applying the correct levels of nitrogen fertiliser to offset the reductions in natural nitrogen fixed by clover due to the infestation and the costs of providing additional supplementary feed to offset the reduction in the high quality feed component of white clover foliage. The net present value (using a discount rate of 10 percent) over a 35 year period from 2004/2005 of both these impacts on the grazing sector is estimated to be:[1]

- $3.3 billion under the medium impact scenario;
- $1.3 billion under the low impact scenario; and
- $5.9 billion under the high impact scenario.

Based on current values, this would equate to an annual impact of between $200 million to almost $1 billion once the weevil was distributed throughout New Zealand.

Under these scenarios there are no net losses to agriculture production. However, there are significant costs of nitrogen and additional supplementary feed.

The results reported above do not include the other costs associated with increased greenhouse gas emissions, and are only the direct costs of replacing nitrogen on farms.

### Other impacts

Nitrogen from dairy farming is a significant source of nitrogen pollution in waterways and the atmosphere. However, increases in the application of nitrogen fertiliser attributable to clover root weevil were not identified as contributing to increased water pollution. Nitrogen pollution in waterways is largely due to cattle urine and other animal wastes, which is predominantly linked to stocking rates. The source of nitrogen, whether naturally fixed by clover or added using synthetic fertilisers, does not affect this.

[1] Net Present Value is a method which converts future values into present values. Future values are discounted (cumulatively) using a discount rate of 10 percent (consistent with MAF's Incursion Response Policy).

Nitrous oxide emissions from the addition of synthetic fertiliser is a significant source of greenhouse gas emissions from the agriculture sector. The fertiliser manufacturing process also produces greenhouse gas emissions during the conversion of natural gas into urea. The total net present value (using a discount rate of 10 percent) of the emissions attributable to increased application of nitrogen fertiliser is $196m, $27m and $600m for the medium, low and high impact scenario. The total net present value of greenhouse gas emissions attributable to increased urea production is $165m, $23m, and $505m for the medium, low and high impact scenarios. These figures are based on the assumption that farmers respond to clover root weevil infestations offsetting reductions in naturally fixed nitrogen with synthetic nitrogen, and the increased urea usage is domestically supplied.

The impact on the apiculture sector is modest relative to the impact on the grazing sector but significant for the sector itself. The total net present value of the impact on it (with a discount rate of 10 percent over 35 years) is $133m, $15m, and $1,061m under the medium, low and high impact scenarios. The annual impact would be $16.5m under the medium impact scenario after 2016 when the full impacts of clover root weevil are assumed.

### Total costs

The total economic impact of clover root weevil in net present value terms over 35 years at 10 percent discount rate is:

- $3.8 billion under the medium impact scenario;
- $1.4 billion under the low impact scenario; and
- $8.1 billion under the high impact scenario.

Under the medium impact scenario full annual costs are reached in 2017 and are $610m per year, under the low impact scenario the full annual cost is not reached until 2022 and is $220m, and under the high impact scenario the full annual costs are reached in 2015 and are $1215m.

### Sensitivity

The results were found to be most sensitive to the estimates of level of nitrogen fixation used and the percentage reductions in nitrogen fixation due to clover root weevil.

- There were divergent views on the level of nitrogen fixed annually in New Zealand by while clover in the absence of clover root weevil. The sensitivity of results to nitrogen fixation estimates for white clover was tested in section 6.1.6 and was found to increase the total costs (valued in net present terms) by $551m or 14 percent compared against the medium impact scenario.

- The reduction in nitrogen fixation due to clover root weevil is highly uncertain. The uncertainty around the reductions in fixation account for +/- $1.8bn or nearly half the impact under the medium impact scenario.

The range of uncertainty is due to a lack of scientific research into the soil nitrogen cycles and impacts of clover root weevil on nitrogen fixation, and has been addressed here through high and low impact scenarios and sensitivity testing.

# Contents

# 1. Introduction

Clover root weevil (*Sitona lepidus*) was first detected on a Waikato dairy farm in 1996. Since then the weevil has been identified in the Bay of Plenty, Northland, Hawkes Bay and some parts of Taranaki. During the preparation of this study the presence of clover root weevil was confirmed in the Wairarapa.

Clover root weevil is wide spread across Europe, Asia and America. To date how it became established in New Zealand is unknown. Scientists have been undertaking research into the DNA profile of local weevils to determine the likely country of origin. The feasibility of eradication was considered when the weevil was first identified in New Zealand. However it was quickly determined that no suitable eradication tools were available[1].

Clover root weevil attacks white clover during two stages of its life cycle. The larvae of the clover root weevil feed on the root system of white clover reducing its nitrogen fixing capability and vigour. This in turn reduces the level of clover available for livestock feed. The adults feed on the foliage, and may eliminate clover seedlings from new pastures, but generally do not cause significant damage in established pastures.

White clover is a large source of nitrogen for pasture, fixing nitrogen from the atmosphere, and the damage to the root system results in a reduction in nitrogen inputs to soils, which reduces the quantity and quality of pasture grass for livestock feed.

White clover foliage has also been found to be a high value feed component, increasing livestock productivity by more than the equivalent volume of dry matter of other pasture grasses. Reduced white clover foliage therefore reduces the productivity of livestock.

Farmers have been responding to the presence of clover root weevil by applying increased quantities of synthetic nitrogen and buying in additional supplementary feed to maintain livestock outputs at pre-infestation levels.

The impact of clover root weevil is likely to extend across all sectors of grazing in New Zealand including dairy, beef, sheep, deer and equine, as well as apiculture. Additional costs from increased nitrogen pollution are possible by adding fertiliser and feed to farms, and that increases the export of nitrogen from land.

Research to mitigate the impacts of clover root weevil has focussed on biocontrol agents, exploring alternative pasture crops to provide the same

[1] Personal communication with Dr Ruth Frampton (formerly MAF), Critique Limited.

level of nitrogen input and development of more resistant strains of white clover.

This report is intended to assist decision makers assess the level of resources that should be applied to combating the impacts of clover root weevil relative to other pests and disease. However, it is assumed that no effective methods of management, eradication or control are developed over the 35 year time horizon of the analysis.

Clover root weevil is now well established in New Zealand and if populations continue to show existing trends without intervention, the abundance of white clover and naturally fixed nitrogen that traditionally existed in New Zealand prior to clover root weevil is not likely to continue to be available at the levels that New Zealand agriculture has been accustomed too.

# 2. Methodology

## 2.1 Introduction

The potential impacts on farm activity, and the affected sectors and regions were determined in consultation with the Technical Advisory Group (TAG), comprising scientists, technical experts, farmers and farm consultants, and MAF staff (Appendix A ). Expert opinion from the TAG was also used to consider the potential rate of spread and rate of establishment of clover root weevil across New Zealand. The TAG was involved as follows:

- AgResearch scientists, farmers and farm consultants from affected regions agreed parameters to represent the impacts of clover root weevil for the first draft of the economic impact assessment;
- the draft report was circulated to the TAG for review; and
- a second meeting of the TAG was convened to refine assumptions and resolve previously unidentified issues.

A third party review of the final draft found there is a lack of agreement among soil scientists across New Zealand on the level of soil nitrogen fixation by white clovers, and this was confirmed through consultation with Stewart Ledgard (AgResearch) and the other soil nitrogen experts (including MAF experts).

The discussions revealed that there is still an incomplete understanding of the behaviours of nitrogen in pastures, which leads to some uncertainty in this area. The range of opinion has been assessed through sensitivity analysis using alternative estimates for soil nitrogen fixation on farms using white clover.

## 2.2 Baseline Scenario

The responses to clover root weevil infestation modelled for the economic impact assessment of clover root weevil assumes:

- The weevil spreads unabated throughout New Zealand with no effective control or eradication measures or containment measures provided by government or farmers.
- The costs of adding synthetic fertiliser and supplementary feed is many times lower than the cost of lost revenue from doing nothing.
- Farmers adjust for losses in nitrogen fixation by adding synthetic nitrogen fertilisers to maintain their pre-infestation levels of nitrogen and therefore production. There are direct costs in nitrogen fertiliser, and external costs of nitrogen pollution.
- Farmers adjust for losses in the feed quality of white clover foliage by adding more supplementary feed to maintain their pre-infestation levels

of livestock productivity. The direct costs are the additional costs of feed.

Experience in regions already infested with clover root weevil is that the increased application of synthetic nitrogen and supplementary feed is used to offset the impact. There may be less fertiliser application and less additional supplementary feed (and some production losses) through limited information, or non-application to marginal land (where 'saved' production would not justify fertiliser application). Commentary by farmers affected by clover root weevil populations indicated that failure to intervene with nitrogen inputs has led to major impacts on production, and this aligns with known information on population densities of larvae in the soil and their feeding on clover root nodules.

## 2.3 Scenarios

There is considerable uncertainty over the likely impacts of clover root weevil. The rate of spread through New Zealand, the relationship between levels of infestation, reductions in nitrogen fixation and clover foliage, and the response by farmers in adapting their management practice are notable areas of uncertainty. In consultation with the TAG, the following three scenarios are modelled to assess the level of uncertainty around these core assumptions mentioned above:

- A medium impact scenario using best judgement of the likely spread of clover root weevil and its impacts on nitrogen fixation and white clover foliage. In this scenario clover root weevil spreads nationwide by 2010. Nitrogen fixation and pasture coverage of white clover would be reduced by 50 percent.
- A low impact scenario using optimistic assumptions for rates of spread and impacts on nitrogen fixation and white clover foliage. In this scenario, clover root weevil spreads nationwide by 2015. Nitrogen fixation and pasture coverage of white clover would be reduced by 20 percent.
- A high impact scenario using combinations of pessimistic assumptions for rates of spread and impacts on nitrogen fixation and white clover foliage. In this scenario, clover root weevil spreads nationwide by 2008. Nitrogen fixation and pasture coverage of white clover would be reduced by 80 percent.

## 2.4 Other impacts

The impact on **apiculture** will be significant. Clover is a significant source of pollen and nectar for the bee keeping industry and reductions in clover will impact on the production of honey. Most honey produced in

New Zealand is up to a 60 to 70 percent clover blend and so reductions in white clover could be expected to have a large impact on honey production[2].

Pastoralists in the South Island are large producers and exporters of **white clover seed**. The TAG agreed the seed production industry is not expected to be impacted by clover root weevil, as clover root weevil is not likely to be associated with seed and therefore does not pose any threat to export markets through biosecurity trade requirements of importing countries. In fact, during an infestation of clover root weevil, white clover responds by increased flowering and seeding, and there may be an increase in production (Gerard (2001)).

Increased synthetic nitrogen usage will increase New Zealand's **greenhouse gas emissions** through increased atmospheric release of nitrous oxide emissions from oxidation of nitrogen fertiliser and through some process emissions in the production of urea. New Zealand ratified the Kyoto Protocol in December 2002, and as a result all New Zealand greenhouse gas emissions will be priced at the international price of carbon from 2008.

[2] Personal communication with AgriQuality.

# 3. Pattern of infestation

Climatic conditions across New Zealand are suitable for clover root weevil to become established. The weevil may be present for a couple of years before reaching a noticeable population in areas where clover is grown. The Cook Strait is not considered a barrier to clover root weevil becoming established in the South Island.

Clover root weevil is assumed to occur throughout New Zealand within five years under the medium impact scenario, appearing in the upper South Island by 2008 and established nationwide by 2010. Under the high impact scenario it is assumed that clover root weevil is already present in the South Island and clover root weevil will be well established across New Zealand within three years. The low impact scenario assumes infestation will be widespread within ten years. Table 1 shows the assumptions used for the first year of clover root weevil colonisation by region.

During the preparation of this report, the presence of clover root weevil was confirmed in the Wairarapa so the year of first occurrence for the Wellington region is modelled as 2005.

***Table 1: Year of first occurrence of Clover Root Weevil by regional council area***

| | Low impact | Medium impact | High impact |
|---|---|---|---|
| North Island | | | |
| Northland | 1996 | 1996 | 1996 |
| Auckland | 1995 | 1995 | 1995 |
| Bay of Plenty | 1995 | 1995 | 1995 |
| Hawkes Bay | 2005 | 2005 | 2005 |
| Waikato | 1995 | 1995 | 1995 |
| Taranaki | 2004 | 2004 | 2004 |
| Manawatu-Wanganui | 2004 | 2004 | 2004 |
| Wellington | 2005 | 2005 | 2005 |
| South Island | | | |
| Nelson/Marlborough | 2009 | 2008 | 2005 |
| West Coast | 2010 | 2009 | 2005 |
| Canterbury | 2010 | 2009 | 2005 |
| Otago | 2012 | 2009 | 2008 |
| Southland | 2015 | 2010 | 2008 |

Source: NZIER

The results for these regions should be interpreted as losses against a case where there is no clover root weevil in New Zealand.

### 3.1.1 Rate of impact

The level of spread and the rate at which clover root weevil becomes established is correlated with climatic conditions. Clover root weevil breeds more rapidly in warm moist environments and more slowly in cooler environments.

When clover root weevil first colonises a new area, it may take up to two years for the population to become apparent and a few years for any effects to be observed on pasture quality and grazing production. During the initial colonisation numbers may peak at high levels before settling down to a lower equilibrium level, but research to date indicates that impacts may not decline as a result of this.

Table 2 shows the assumptions used to phase in the full impact of clover root weevil in each climatic region. For moderate to warm moist regions it is assumed that only 70 percent of the full impact of clover root weevil on productivity is observed after five years. The assumptions were based on research by:

- AgResearch on the reproductive responses of the clover root weevil to climatic conditions; and
- Anecdotal evidence from affected areas, where the clover root weevil has become well entrenched (such as Waikato).

The economic impact assessment was tested for sensitivity to different levels of phase in of establishment, and the results were found not to be sensitive to faster rates of establishment (Section 6.1.4).

***Table 2: Impact on productivity from first occurrence to full impact by climatic condition***

Percent

| Year | Moderate to warm moist | Dry Summer | Cool moist |
|---|---|---|---|
| 1 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 |
| 3 | 10 | 10 | 0 |
| 4 | 40 | 25 | 10 |
| 5 | 70 | 50 | 25 |
| 6 | 100 | 75 | 50 |
| 7 | 100 | 100 | 75 |
| 8 | 100 | 100 | 100 |

Note: Year 1 is year of first occurrence

The climatic conditions assumed for each region is shown in Table 3.

## *Table 3: Climate assumptions by region*

| North Island | | South Island | |
|---|---|---|---|
| *Region* | *Climate* | *Region* | *Climate* |
| Northland | warm moist | Nelson/Marlborough | warm moist |
| Auckland | warm moist | West Coast | cool moist |
| Bay of Plenty | dry summer | Canterbury | dry summer |
| Hawkes Bay | dry summer | Otago | cool moist |
| Waikato | warm moist | Southland | cool moist |
| Taranaki | warm moist | | |
| Manawatu-Wanganui | warm moist | | |
| Wellington | warm moist | | |

Source: NZIER

# 4. Impacts

In this response it is assumed farmers apply the appropriate level of nitrogen fertiliser to maintain their nitrogen inputs at current levels.

Experience to date in the Waikato has demonstrated farmers have reacted by increasing the use of nitrogen fertiliser and supplementary feed. The most likely response is that as clover root weevil becomes entrenched in other parts of New Zealand, farmers once they become aware of the problem will respond in the same way rather than incur the production losses, which significantly outweigh the cost of applying more nitrogen and supplementary feed.

Nitrogen pollution is becoming a serious environmental issue worldwide. Nitrogen runoff contributes to increased instances of toxic algal blooms and increases the density and size of water plants. Nitrous oxide is also a potent greenhouse gas, with a global warming potential 310 times more than that of carbon dioxide. The cost of nitrogen based pollution in waterways and as a greenhouse gas emissions is also considered.

## 4.1 Nitrogen fertiliser

Additional fertiliser is added assuming farmers apply the correct levels of synthetic fertiliser to offset the reductions in naturally fixed nitrogen. Table 4 below presents the level of clover fixed nitrogen by region. Urea is assumed to be used to replace nitrogen losses due to clover root weevil because it is the cheapest source of synthetic nitrogen by content of elemental nitrogen.

The cost of urea is set at $550/tonne (including GST) and is made up of 46 percent elemental nitrogen. Cartage rates for fertiliser is set at $12/tonne (including GST).

The cost to spread fertiliser is dependent on the form of spreading. Ground based spreading is cheaper per tonne of fertiliser applied than aerial fertiliser. It was assumed that pasture of greater than 15 degree slope requires aerial application of fertiliser. Table 4 provides the proportion of pasture by region with slopes of greater than 15 degrees from spatial databases held at Landcare Research.

The cost to spread fertiliser is set at $78 (inc GST) per tonne of fertiliser per year for truckable spreading and $210 (inc GST) per tonne of fertiliser per year for aerial spreading.

**Table 4: Fertiliser applied by region**

| Region | Pasture area | Nitrogen fixed by clover | Nitrogen fixed by clover | Pasture with slopes greater than 15 degrees |
|---|---|---|---|---|
| | *hectares* | *Kg/hec/year* | *tonnes* | *percent* |
| Northland | 620099 | 45 | 27658 | 42 |
| Auckland | 248780 | 32 | 7895 | 46 |
| Waikato | 1287287 | 62 | 79643 | 48 |
| Bay of Plenty | 263394 | 75 | 19670 | 44 |
| Gisborne | 389927 | 46 | 17998 | 81 |
| Hawkes Bay | 717143 | 53 | 38034 | 71 |
| Taranaki | 389103 | 70 | 27296 | 43 |
| Manawatu-Wanganui | 1273189 | 54 | 68961 | 64 |
| Wellington | 387959 | 47 | 18254 | 60 |
| *North Island* | *5576882* | *55* | *305407* | *57* |
| Tasman | 127185 | 44 | 5630 | 42 |
| Nelson | 5940 | 26 | 154 | 68 |
| Marlborough | 324814 | 29 | 9345 | 72 |
| West Coast | 160425 | 35 | 5681 | 5 |
| Canterbury | 1906649 | 37 | 71066 | 38 |
| Otago | 1468862 | 36 | 52237 | 46 |
| Southland | 967323 | 56 | 53764 | 23 |
| *South Island* | *4961197* | *40* | *197878* | *38* |
| *New Zealand* | *10538079* | *48* | *503285* | *48* |

Source: R Parfitt Landcare Research

A medium, low and high scenario was constructed using the assumptions for rates of spread and establishment of clover root weevil as were shown in Table 1 and Table 2.

If farmers perfectly adjust for the losses in nitrogen fixation attributable to clover root weevil, then the total cost by region could be assumed to be capped at the cost of replacing naturally fixed nitrogen with synthetic nitrogen.

## 4.2 Future of nitrogen prices

There are three main sources of price variations in fertiliser prices: the cost of natural gas, the quantity of energy required in production and exchange rates.

### 4.2.1 Natural gas

The main source of nitrogen fertiliser used in New Zealand is ammonia and urea produced by Ballance Agri-Nutrients (Kapuni) Ltd. Ballance uses natural gas from Taranaki fields as a feedstock. Ammonia and urea production in the year to September 2004 accounted for an estimated 4.8 percent of total gas production (MED 2005, pp86-91), an estimated 7.2 PJ (NZIER estimate from MED *ibid*).

Imports of nitrogenous fertilisers are also significant, and have risen substantially from $39 million in the year to March 1995, to $219m in the most recent March year. Given the increase in fertiliser use over the period[3], this suggests increased demand has been met predominantly from imports rather than domestic production.

Unless there are significant new discoveries of gas, total gas production in New Zealand will decline substantially in future years with the depletion of the Maui field and limited replacement from production from other smaller known fields. However this does not necessarily pose any risks to locally-produced supplies of ammonia and urea, given the small share of New Zealand-produced gas used for domestic production.

Moreover, recent experience suggests that the supply of fertilisers at the margin is from imports, and the magnitude of increased fertiliser use implied in these projections (approximately 50 percent under the medium impact scenario) means that supply is likely to be primarily from imports.

While supply is not an apparent problem, the question is what future prices will be. Internationally, natural gas is used as a feedstock in 71 percent of ammonia production capacity (EFMA undated, Table D), and this is likely to be a key determinant of ammonia prices (and an important influence on substitute products).

Natural gas is projected to be the fastest growing component of world primary energy consumption over the next two decades (USEIA undated). However reserves are relatively abundant, with the global reserves-to-production ratio estimated at 60.7 years (i.e. known reserves provide for over 60 years' production/use at current levels). Reserves have been increasing in recent years, as prospective increases in use have prompted investment in exploration, extraction, refining and distribution. In this regard, the gas supply situation is considerably less uncertain than for oil.

[3] Application of urea increased by 160% between 1996 and 2002 (PCE 2004 pp 43-44).

USEIA (*ibid*) analysis indicates that US import prices have increased from $US3.21 per thousand cubic feet in 2003, to $US5.17 in 2004, and forecasts further increases to $5.64 in 2006. It then expects prices to fall to about $US4.00 in 2010-2012, and increase thereafter to $US5.11 in 2025 (still marginally below 2003 levels). Its review of other forecasters' gas price forecasts (for US domestic production) confirms this scenario, with most forecasters expecting lower prices over the next twenty years.

In light of this track for gas prices (over the first half of the time horizon of this analysis), we have applied an unchanged price for fertiliser. Moreover, any substantial and sustained increase in gas prices would be likely to result in use of other feedstocks (e.g. coke and coal).

### 4.2.2 Energy

A related issue is energy costs. Production of nitrogen fertiliser is (like most chemical refining processes) relatively energy-intensive. Wells (2002) estimates energy requirements of 30 MJ per kg of urea, equivalent to 65 MJ per kg of nitrogen. He concludes that fertilisers, and nitrogen fertilisers in particular, are the most significant indirect energy inputs into dairy farming.

EFMA (undated, p24) state that the energy requirements of ammonia production using the Haber-Bosch process are 27 MJ per kg of ammonia, close to the theoretical minimum of 25 MJ per kg. This suggests that there are limited prospects for technical improvements to reduce energy usage, and any increase in energy costs would be reflected in costs and prices.

In the absence of robust data on energy use by type, energy relative to total production costs, and future prices for different energy sources, we have not incorporated this into fertiliser prices.

### 4.2.3 Exchange rates

The above implies no material change in world fertiliser prices. However, as future supply will be sourced primarily from imports, the New Zealand dollar exchange rate is a potentially significant influence on domestic prices.

The New Zealand dollar reached a quarterly low of 47.8 against the trade-weighted index (TWI) in the December 2000 quarter (0.409 against the US dollar), and has risen consistently since that time, reaching 69.5 against the TWI and 0.716 against the USD in the March 2005 quarter.

At these levels it is considered over-valued, and some moderate falls are expected over the next two years. The exchange rate against the TWI has risen further since that time, although the rate against the USD has fallen. These trends are expected to continue over the next two years, with the TWI peaking in the June 2005 quarter and then falling over the next four years, to an average of 63.6 in the year ended March 2009. The USD rate is forecast to fall over the next three and a half years, and stabilise at about 0.600 in the December 2008 quarter (NZIER June 2005).

## 4.3 Nitrogen pollution

Nitrogen pollution is becoming a global environmental issue. Nitrogen pollution levels have been increasing in waterways locally and internationally. Nitrogen is also a potent greenhouse gas. The OECD (2004) reports that nitrogen pollution is becoming a serious source of water pollution in countries with intensive dairy farming. Trade liberalisation is likely to lead to increases in nitrogen pollution in countries such as New Zealand, Australia, and some central European countries.

### 4.3.1 Nitrogen pollution in waterways

The Parliamentary Commissioner for the Environment (PCE, 2004) reported significant increases in nitrate pollution across waterways in New Zealand. Lake Taupo and the Waikato River have shown long term trends in increased nitrate levels. Groundwater testing in Canterbury and the lakes district in the Bay of Plenty has also started to show increases in nitrates.

Sources of nitrogen pollution in waterways include point sources or direct discharges from water treatment plants, storm water, farm effluent and industry. Non-point sources include run off and leaching from rural and urban land.

Nitrogen pollution from point sources has declined over the last few decades as water treatment technology has improved and treatment standards have become more stringent. Dairy farmers have begun using effluent from milking sheds as a fertiliser because it is a high value fertiliser and restrictions on dumping effluent in waterways have been imposed. Estimates by Environment Waikato show nitrogen from point sources now contributes only 30 percent of total nitrogen in the Waikato River. Environment Waikato (www.ew.govt.nz) states "The rest [70 percent] probably comes from pasture – mostly from cow urine, which leaches into ground water and eventually flows into the river".

PCE (2004) reports that farmers apply nitrogen to increase stocking rates and farm returns. Some farmers have even adopted synthetic nitrogen as the sole source of nitrogen to increase their stocking rates. This has led to increased animal excreta in the farming system. The waste generated by the dairy herds in the Waikato catchment is equivalent to 50 cities the size of Hamilton.

Nitrogen leaching and run off into waterways have long lead times, and can take decades to pass from land through waterways. Once in the waterways there is no effective treatment process to remove nitrogen.

Environment Waikato is exploring options to reduce nitrogen run-off into waterways with the objective of capping nitrogen pollution at 20 percent below current levels. The cap will apply to all sources of nitrogen. Nitrogen budgets for dairy farmers will include both naturally fixed nitrogen and synthetic nitrogen.

It is the conclusion of this report that clover root weevil will not lead to increased nitrogen pollution in waterways. Nitrogen run-off and leaching is largely due to cattle urine and other animal waste. If nitrogen is lost through clover root weevil and replaced through addition of synthetic nitrogen there will be no net change in nitrogen based pollution in waterways. The conclusion has been tested and confirmed with experts involved in the issue at NIWA, AgResearch and Environment Waikato. Ledgard et al. (1999) confirm that nitrogen pollution in waterways attributable to dairy is due to the surplus of the total nitrogen budget (naturally fixed and added) and not to the direct application of synthetic nitrogen alone. What matters for nitrogen pollution in waterways is stocking rates. Higher nitrogen applications have been used to increase the total nitrogen budget to increase stocking rates and therefore farm returns. Clover root weevil will not increase nitrogen pollution in waterways if nitrogen fertiliser is added appropriately and only if sufficient to offset the loss of naturally fixed nitrogen, if applied in accordance with good practice guidelines for fertiliser application.

### 4.3.2 Atmospheric nitrogen pollution

Nitrous oxide is a potent greenhouse gas with a global warming potential 310 times that of carbon dioxide, and in 2002 contributed 26 percent of New Zealand’s net emission. The primary source of nitrous oxide in New Zealand is agriculture accounting for 97 percent of total nitrous oxide emissions in 2002 (MfE 2004). Addition of synthetic nitrogen contributed 12 percent of total agricultural nitrous oxide emissions, and 4 percent of total greenhouse gas emissions from the agriculture sector (measured in carbon dioxide equivalents).

New Zealand has ratified the Kyoto Protocol and the Kyoto Protocol has since entered into force. The Kyoto Protocol caps national greenhouse gas emissions during the first commitment period (2008-2012) relative to each country’s base year of 1990. Parties to the Kyoto Protocol who are not in compliance are required to purchase emissions units from Parties that have surplus emission units. Emissions units are rights to emit greenhouse gas emissions, each unit is equivalent to one tonne of carbon dioxide. Under the Kyoto Protocol New Zealand is required to cap national emissions on average at 1990 levels during the first commitment period.

Increases in emissions from higher fertiliser production and applications would either reduce the emission units available to sell on the international trading market if there is a surplus of units or New Zealand would be required to purchase additional units in the event of a deficit. Either way increased greenhouse gas emissions from increased application and production of nitrogen fertiliser would reduce New Zealand's foreign income by the value in which the emissions units would otherwise sell on the international market.

The price of emissions units during the first commitment period is uncertain. Prior to the Kyoto Protocol entering into force New Zealand emissions units were purchased by the Netherlands' Government in a competitive tendering process for 5.5 Euro/tonne carbon dioxide equivalent (approximately $7.15 US/tonne carbon dioxide equivalent) (NZCCO 2004). The Australian Bureau of Agricultural and Resource Economics has undertaken extensive modelling of the economic impacts of the Kyoto Protocol and estimates a price for emissions units during the first commitment period of $28 US ($NZ40)/tonne carbon dioxide equivalent (Jakeman et al. 2002). The price of carbon dioxide is already trading above 17 Euro ($NZ30)/tonne carbon dioxide equivalent (NZIER 2005) on the European Union Emissions Trading Scheme.

Biologically fixed nitrogen is currently excluded from the greenhouse gas accounting methodology because of scientific uncertainty and lack of necessary time series data on biologically fixed nitrogen. If additional nitrogen is added to a farm by way of synthetic fertiliser there will be a measured increase in greenhouse gas emissions for which New Zealand will have to account.

A medium, low and high impact scenario for the cost (post 2008) of additional nitrous oxide emissions attributable to the additional application of synthetic nitrogen is presented in Table 5. The levels of nitrogen added are based on estimates of additional nitrogen fertiliser derived in section 4.1 and different assumptions for the price of carbon (in US dollars) and the rate of exchange between the US and New Zealand.

The production of urea also produces greenhouse gas emissions in using natural gas as a feedstock (not through combustion). Increased usage of fertiliser will likely increase domestic production and therefore cause some additional upstream greenhouse gas emissions. If the increased urea usage is from domestic production then national greenhouse gas emissions under the medium, low and high impact scenarios will increase by 0.8 Mt $CO_2$-e, 0.3 Mt $CO_2$-e, and 1.3 Mt $CO_2$-e, once the effects of clover root weevil are entrenched across New Zealand.

**_Table 5: Cost of increased greenhouse emissions from nitrogen fertiliser_**

| Variable | Unit | Medium impact | Low impact | High Impact |
|---|---|---|---|---|
| Global price of carbon | $US/tonne carbon dioxide equivalent | 17.60 | 7.15 | 28.00 |
| Exchange rate | $NZ/$USA | 0.6 | 0.7 | 0.5 |
| Implied emissions factor-synthetic fertiliser | kg $N_2O$/kg N | 0.012 | 0.012 | 0.012 |
| Nitrous oxide emissions | Tonnes | 3020 | 1208 | 4832 |
| Global warming potential | Carbon dioxide = 1 | 310 | 310 | 310 |
| Carbon dioxide equivalent emission from urea manufacture | Million tonnes | 0.79 | 0.32 | 1.26 |
| Carbon dioxide equivalent emissions from fertiliser application | Million tonnes | 0.94 | 0.37 | 1.50 |
| Total carbon dioxide equivalent emissions | Million tonnes | 1.72 | 0.64 | 2.76 |
| Annual cost of greenhouse gas emissions | $NZ m | 50 | 7 | 154 |
| Net present value | $NZ m | 361 | 50 | 1,105 |

Source: Jakeman (2002) et al, NZCCO, NZIER analysis

## 4.4 Supplementary feed

In this analysis it is assumed that farmers respond to the reduction in pasture quality as a result of the clower root weevil infestation by buying additional supplementary food to maintain livestock productivity at pre-infestation levels. The clover foliage is a high nutrient feed that can be replaced by the addition of high nutrient supplementary feed. Evidence to date shows farmers in addition to increasing the use of nitrogen fertiliser have been increasing the use of supplementary feed. The increased use of supplementary feed appears to be driven by the need to maintain livestock nutrient intake at pre-infestation levels when the nutrient was supplied by the clover foliage. Anecdotal evidence from infested regions suggest farmers may be increasing their total feed budget in the order of 10 percent. Low and high scenarios were also constructed around increased feed usage, the low impact scenario was set at 5 percent of total feed costs and the high scenario was set at 15 percent of total feed costs.

Table 6 below provides an estimate of feed costs by region derived from MAF farm monitoring reports.

***Table 6: Feed costs by region***

| | Dairy | | Beef - sheep | | Deer | |
|---|---|---|---|---|---|---|
| | $/kg Milk solid | $m | $/hec | $m | $/stock unit | $m |
| Northland | 0.12 | 8.8 | 24 | 14.9 | 5.40 | 0.1 |
| Auckland | 0.12 | 1.9 | 24 | 6.0 | 5.40 | 0.1 |
| Bay of Plenty | 0.50 | 62.0 | 23 | 15.0 | 5.40 | 0.6 |
| Hawkes Bay | 0.63 | 7.4 | 14 | 10.0 | 5.40 | 0.8 |
| Waikato | 0.50 | 185.7 | 23 | 29.6 | 5.40 | 0.8 |
| Taranaki | 0.63 | 103.6 | 15 | 5.8 | 5.40 | 0.0 |
| Manawatu-Wanganui | 0.63 | 43.5 | 15 | 19.1 | 5.40 | 0.7 |
| Wellington | 0.63 | 36.0 | 15 | 5.8 | 5.40 | 0.1 |
| *North Island* | | *449.0* | | *106.3* | | *3.3* |
| Nelson Marlborough | 0.75 | 18.7 | 21 | 9.6 | 5.81 | 0.3 |
| West Coast | 0.75 | 28.1 | 21 | 3.4 | 5.81 | 0.3 |
| Canterbury | 0.75 | 82.6 | 38 | 72.5 | 5.81 | 2.6 |
| Otago | 0.75 | 39.8 | 33 | 48.5 | 5.81 | 1.2 |
| Southland | 0.69 | 75.6 | 34 | 32.9 | 5.81 | 2.3 |
| *South Island* | | *244.8* | | *166.8* | | *6.7* |
| *New Zealand* | | *693.8* | | *273.1* | | *10.0* |

Source: MAF Farm monitoring reports

## 4.5 Apiculture

White clover is a large source of nectar for the New Zealand apiary industry. Clover and clover blended honey contributes around 60 to 70 percent of total honey production. Honey sourced from clover is a lighter colour and generally receives a higher price than many other forms of honey. Clover based honey is trading around $NZ4.50 to $NZ5.20 per kg and has averaged $NZ4.80 (MAF 2004*d*). The production of honey is highly variable, and six year average production levels by key honey producing regions is used (Table 7).

**Table 7 Honey production by region**
tonnes

| Apiary region | Six year average production | Region applied for establishment and rate of spread |
|---|---|---|
| Northland, Auckland, Hauraki Plains | 862 | Auckland |
| Waikato, King Country, Taupo | 1,301 | Waikato |
| Bay of Plenty, Coromandel, Poverty Bay | 1,388 | Bay of Plenty |
| Hawke Bay, Taranaki, Manawatu, Wairarapa | 1,360 | Hawkes Bay |
| Marlborough, Nelson, Westland | 714 | West Coast |
| Canterbury | 1,943 | Canterbury |
| Otago, Southland | 1,373 | Southland |
| Total | 8,941 | |

Source: NZIER

Reductions in honey production were assumed to be proportional to the losses in clover and the clover content of honey.

Medium, low and high impact scenarios for the apiary industry were derived for the apiary industry using the same assumptions for rates of spread and establishment of clover root weevil for the grazing sector, and with medium, low and high assumptions for the clover content of honey and the impact on pasture. These assumptions are shown in Table 8.

**Table 8 Assumptions for honey production**
Percent

| Scenario | Clover content of honey | Reduction in clover |
|---|---|---|
| Medium | 40 | 50 |
| Low | 20 | 20 |
| High | 60 | 80 |

Source: NZIER

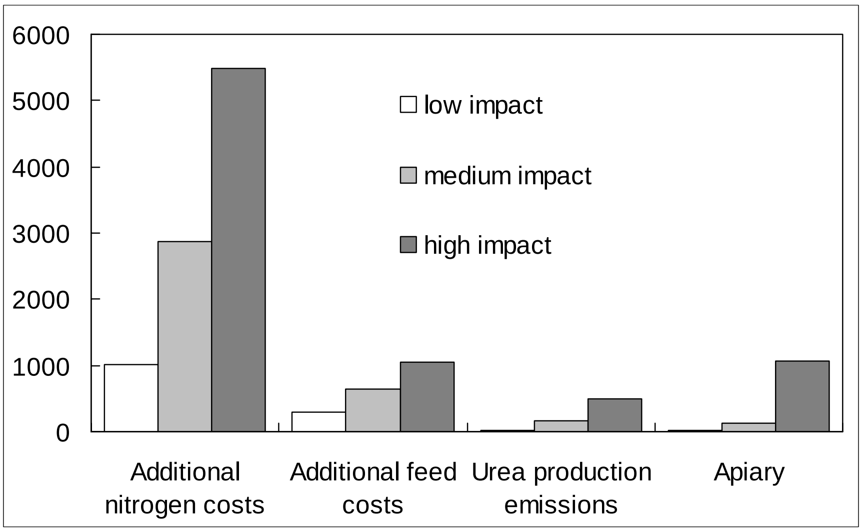
Apiculture is also affected by another recently introduced pest, the Varroa mite (MAF 2000), which has been reducing bee populations and has raised pollination costs and lowered honey production. The economic impact assessment is modelled in the absence of Varroa. If honey production is likely to decline as result of the Varroa mite over the next 35 years then this assessment may overstate the impacts on honey production, however, the impacts are small relative to the impacts on other sectors affected by clover root weevil.

# 5. Results

The impact of clover root weevil is expected to be large under all three scenarios. The net present value[4] of clover root weevil for the medium, low and high impact scenarios using a discount rate of 10 percent is $3.8bn, $1.4bn and $8.1bn in 2003/2004 prices. This includes costs attributable to upstream emissions in the production of urea and assumes the increased application of urea is met entirely from domestic production.

The most significant contribution to the total economic impact of clover root weevil is due to the increased cost of grazing. Under the medium impact scenario the net present value of the grazing costs is expected to be $3.5bn. This is made up of $2.9bn from additional nitrogen application, and $0.6 bn from increased use of supplementary feed.

***Figure 1: Economic impact of clover root weevil by sector***
$million (2003/04 prices)



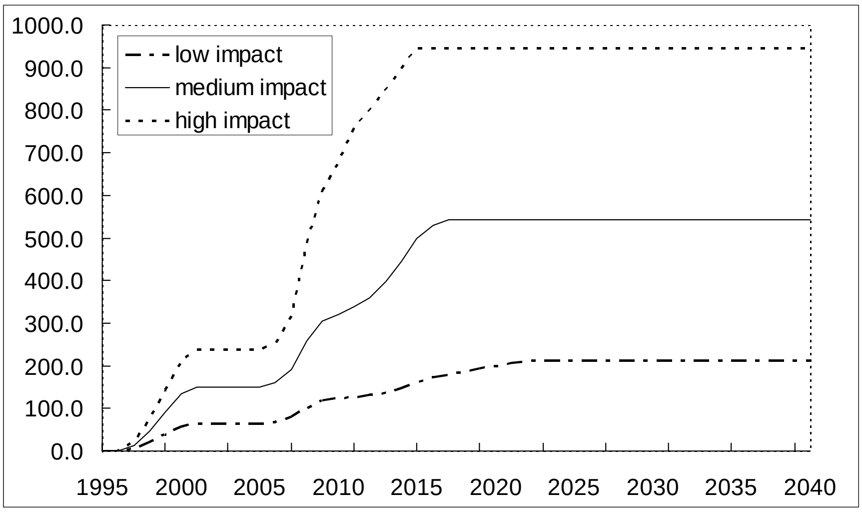

Source: NZIER

The annual cost of clover root weevil to the grazing sector under the medium impact scenario is already estimated to cost $150m per year, and is expected to reach $543m by 2017 when the weevil is fully established throughout New Zealand (Figure 2). Under the low impact scenario the full

[4] Net Present Value is a method which converts future values into present values. Future values are discounted (cumulatively) using a discount rate of 10 percent (consistent with MAF's Incursion Response Policy).

impact of clover root weevil occurs in 2022 and is $211m per year.  The full annual impact under the high impact scenario is reached in 2015, and is $945 million per year.

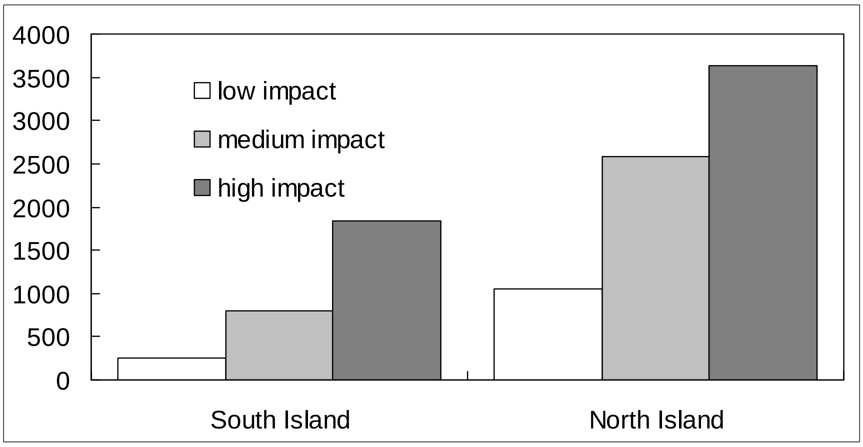
***Figure 2: Annual impacts on grazing sector of clover root weevil***
$NZ million (2003/04 prices)




Source: NZIER

The impacts on the North Island are substantially higher than the South Island, because much of the high nitrogen using grazing industry occurs in the North Island and the clover root weevil is already established across the North Island.  Under the medium impact scenario the net present value of the impact of clover root weevil over 35 years using a discount rate of 10 percent is $2.6bn on the North Island and $0.8bn on the South Island.

***Figure 3: Economic impact on grazing sector by Island***
$NZ million (2003/04 prices)

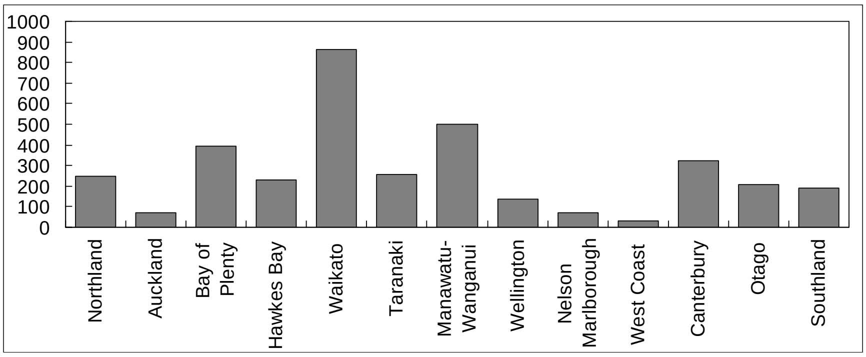



Source: NZIER

The impact on the grazing industry under the medium impact (assuming a discount rate of 10 percent over 35 years) is shown in Figure 4.  The largest impact on grazing is in the Waikato, where the grazing industry (largely dairy) is a high user of nitrogen and the infestation has long been entrenched. In the South Island the Canterbury region is expected to experience the greatest impact again because the area is a large grazing region and relies significantly on nitrogen inputs.

***Figure 4: Economic impact on grazing sector by region***

$NZ million (2003/04 prices)

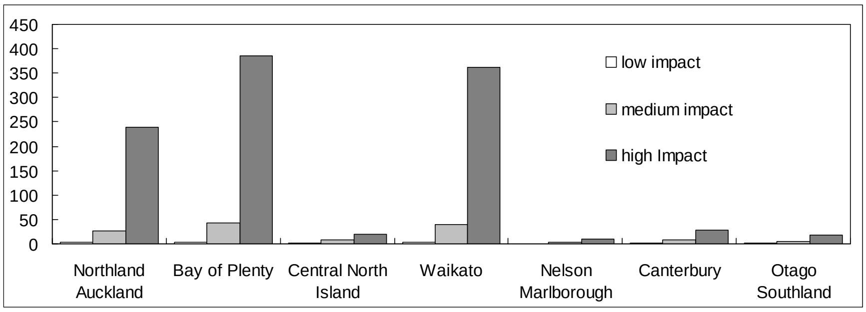



Source: NZIER

The impact on the apiculture industry in net present value under the medium, low and high impact scenarios (applying a discount rate of 10 percent over 35 years) is $133m, $15m and $1,061m in 2003/2004 prices. There is a wide range of uncertainty around the results which represents the range of high and low input assumptions used for the proportion of clover and clover blends in total honey production and the proportion of clover cover that would be reduced. The impact on the industry under each scenario is shown below in Figure 5. As with the grazing industry the areas with the greatest impact are the areas that have long been infested and are traditionally large clover based pasture regions such as the Waikato and Bay of Plenty.

## Figure 5: Economic impact on apiary sector by region

$NZ million (2003/04 prices)



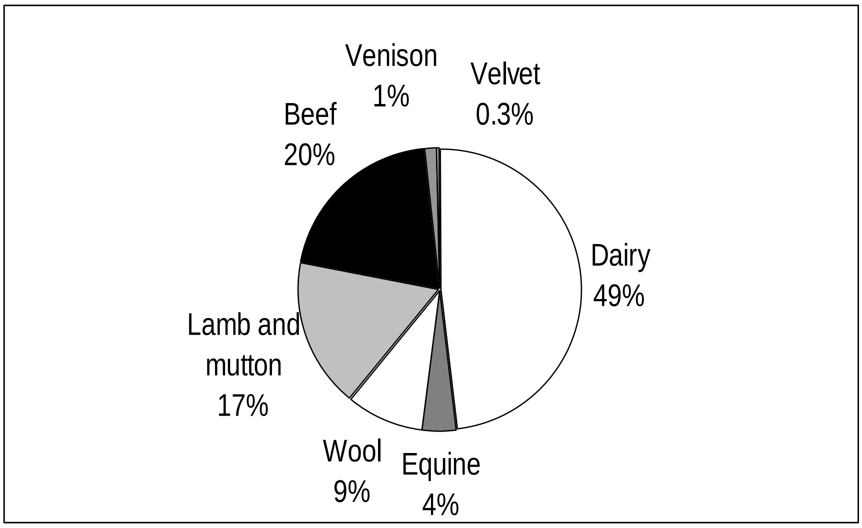

Source: NZIER

## 5.1 Top down impacts on grazing sectors

This economic impact assessment uses nitrogen fixation data based on stock units in a region, and area of pasture from spatial data bases. This does not provide information on nitrogen inputs by grazing sectors. The impact on the grazing sector may be broken down by livestock sector using a top down approximation. The draft economic impact assessment focussed on production losses that would occur if the government and farmers did not respond to the introduction of clover root weevil. The production losses attributable to lower nitrogen fixation and pasture quality due to clover root weevil were spread across livestock sectors proportionally to the farm returns by livestock sector (Figure 6). On this basis, approximately half the economic impact on the grazing sector (through increased feed and fertiliser costs) will be incurred by the dairy sector, 24 percent will be on the sheep sector, 20 percent on the beef sector and only 1 percent on the deer sector.

## Figure 6: Proportion of farm returns by sector

percent




Source: NZIER

# 6. Sensitivity results

The economic impact of clover root weevil is modelled under significant uncertainty. To understand the contribution of each of the assumptions to the overall result a series of sensitivity analyses were performed for each of the core assumptions.

A description of the sensitivity analysis and some key conclusions is presented below. Sensitivity testing on the assumptions for rate of spread, rate of establishment and the impact on production were applied one by one against the assumptions used in the medium impact scenarios.

The results of the sensitivity analyses by sector and region are reported in Tables 10 to 12. Table 10 presents the total net present value under each scenario and sensitivity test. Table 11 presents the differences between the medium impact scenario results, and results for each scenario and sensitivity test. Table 12 presents the percentage difference between the medium impact scenario results, and results for each scenario and sensitivity test.

### 6.1.1 Impact on nitrogen fixation

High and low impact assumptions for the impact on nitrogen fixation were applied using medium impact assumptions for the rate of first occurrence and establishment of clover root weevil. This enabled the sensitivity of the results to be assessed for the assumptions of the impact of clover root weevil on nitrogen fixation relative to the medium impact scenario alone.

The sensitivity analysis shows that the results are most sensitive (compared to other assumptions) to assumed reductions in nitrogen fixation attributable to infestation of clover root weevil.

With high reductions in nitrogen fixation assumed, and medium impact assumptions for the rate of first occurrence and establishment of clover root weevil, the impact is $5.6bn.

With low reductions in nitrogen fixation assumed, and medium impact assumptions for the rate of first occurrence and establishment of clover root weevil, the impact is $2.0bn.

### 6.1.2 Impact on clover foliage

High and low impact assumptions for the impact on clover foliage were applied using medium impact assumptions for the rate of first occurrence and establishment of clover root weevil.

With higher feed usage to replace clover foliage losses assumed, and medium impact assumptions for the rate of first occurrence and establishment of clover root weevil, the impact is $4.1bn.

With low feed usage to replace clover foliage losses assumed, and medium impact assumptions for the rate of first occurrence and establishment of clover root weevil, the impact is $3.5bn.

### 6.1.3 Year of first occurrence

The impact of assumptions used for the rate of spread on the results were tested by using medium impact assumptions for pasture losses and rates of establishment and only varying the year of first occurrence, using the assumptions for the high and low impact scenario. The assumptions for year of first occurrence were shown to have a small impact on the final results. Most of the North Island is assumed to already be infested under both the slow and rapid spread sensitivity tests. The rapid spread assumption increases the national costs to $4.1bn, while under the slow spread assumption the national cost of clover root weevil reduced to $3.6bn.

The results for the North Island are the same under each sensitivity test as clover root weevil is now assumed to have occurred across the whole of the North Island.

### 6.1.4 Rate of establishment

The sensitivity of the results to the rate of establishment was tested by assuming that the full impact on nitrogen fixation and clover foliage of clover root weevil occurs as soon as it breaks out in a region. The results were moderately sensitive to the assumptions used for the rate at which clover root weevil becomes established in a region.

Compared to the medium impact scenario rapid establishment of clover root weevil in a new region increased the national cost by $938m.

### 6.1.5 Exchange rate and fertiliser costs

Section 4.2 discussed the sensitivity of fertiliser prices to exchange rates. Any increase in fertiliser usage within New Zealand is likely to be sourced internationally, and therefore subject to exchange rate variation. The New Zealand dollar is considered to be over valued at the moment, and likely to depreciate. The impact of the depreciation was modelled as a 1.2 percent increase in the total price of urea annually from 2005 to 2009, after which urea prices where then fixed at the 2009 price. The model showed the economic impact assessment was not very sensitive to exchange rate variation and the fertiliser prices.

### 6.1.6 Nitrogen fixation by white clover

As noted in section 2.1 there are divergent views among soil scientists as to the levels of nitrogen that are fixed annually by white clover prior to clover root weevil becoming established. The nitrogen fixation from white clover has been reported to be as high as 185 kg N/ha/yr (Hoglund et al 1979) and more recently by Ledgard et al (1999) who measured 99-231 kgN/ha/y in Waikato in 1993-96. Other studies such as those used here and reported in Table 4 are as low as 48 kg N/ha/yr (Parfitt et al 2005). Given the level of uncertainty over the baseline level of nitrogen fixed by white clover in the absence of clover root weevil, sensitivity was performed on the nitrogen fixation by region. Much of the apparent divergence in views appears due to the different basis on which the estimates are reported.

Table 9 shows average white clover nitrogen fixation for dairy, sheep and beef farms. The average nitrogen fixation by white clover for all dairy, beef and sheep farms across New Zealand when weighted by land area is 60 kg N/ha/yr. The average nitrogen fixation by white clover across all agriculture sectors and regions in New Zealand based on Landcare research numbers was 48 kg N/ha/yr (Table 4). The average nitrogen fixation level based on AgResearch estimates excludes other agriculture sectors where nitrogen fixation may be lower compared to dairy, and therefore the national average based on AgResearch estimates is likely to overestimate average nitrogen fixation across New Zealand. The estimate of New Zealand nitrogen fixation of 60 kg N/ha/yr is 25 percent higher compared to the estimate derived from Landcare Research for New Zealand which was 48 kg N/ha/yr. For this sensitivity pre-infestation levels of nitrogen fixation by region were scaled up 25 percent (pro rata).

***Table 9: Alternative nitrogen fixation estimates***

| | Fixation of nitrogen by white clover | Midpoint estimate | Land cover | Contribution to national average |
|---|---|---|---|---|
| | kg N/ha/yr | kg N/ha/yr | Percent of total | kg N/ha/yr |
| Dairy | 100-120 | 110 | 17 | 18.2 |
| Sheep and beef intensive | 60-70 | 65 | 43 | 28 |
| Sheep and beef steeper hill | 30-40 | 35 | 40 | 14 |
| Dairy, beef and sheep total | | | 100 | 60 |

Note: The proportion of sheep and beef farms that are on steep land was derived from the same data and definitions as reported in Table 4

Source: AgResearch, Landcare Research

Relative to the medium impact scenario the higher levels of pre-incursion nitrogen fixation by white clover would imply a national cost of $4.4bn, or an additional $551 million compared to the medium impact scenario using the clover fixation levels provided by Landcare Research.

### *Table 10: Sensitivity analysis, net present value of impacts by region and sector*

$million (2003/2004 prices)

| | Medium impact | Low impact | High impact | Rapid establishment | Slow spread | Fast spread | Low nitrogen effect | High nitrogen effect | Low feed effect | High feed effect | Alternative nitrogen fixation estimates | High fertiliser price |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nitrogen | 2879 | 1010 | 5485 | 3638 | 2734 | 3092 | 1151 | 4606 | 2879 | 2879 | 3390 | 2965 |
| Feed | 641 | 304 | 1045 | 805 | 607 | 697 | 641 | 641 | 320 | 961 | 641 | 641 |
| Urea manufacture | 165 | 23 | 505 | 165 | 165 | 165 | 66 | 264 | 165 | 165 | 205 | 165 |
| Apiary | 133 | 15 | 1061 | 147 | 132 | 141 | 133 | 133 | 133 | 133 | 133 | 133 |
| *Total* | *3818* | *1351* | *8097* | 4755 | *3638* | *4094* | *1991* | *5644* | *3497* | *4138* | *4369* | *3903* |
| | | | | | | | | | | | | |
| Northland | 248 | 95 | 429 | 248 | 248 | 248 | 113 | 383 | 237 | 260 | 322 | 254 |
| Auckland | 72 | 28 | 125 | 72 | 72 | 72 | 34 | 111 | 68 | 76 | 128 | 74 |
| Bay of Plenty | 394 | 157 | 669 | 394 | 394 | 394 | 202 | 585 | 356 | 431 | 402 | 402 |
| Hawkes Bay | 230 | 86 | 407 | 343 | 230 | 230 | 99 | 360 | 224 | 235 | 255 | 236 |
| Waikato | 863 | 349 | 1459 | 863 | 863 | 863 | 470 | 1256 | 759 | 968 | 835 | 881 |
| Taranaki | 255 | 104 | 432 | 328 | 255 | 255 | 150 | 359 | 214 | 295 | 227 | 260 |
| Manawatu-Wanganui | 502 | 190 | 881 | 643 | 502 | 502 | 228 | 775 | 478 | 525 | 544 | 516 |
| Wellington | 137 | 54 | 237 | 194 | 137 | 137 | 71 | 202 | 123 | 151 | 165 | 140 |
| *North Island* | *2700* | *1063* | *4638* | 3085 | *2700* | *2700* | *1368* | *4032* | *2460* | *2940* | *2879* | *2764* |
| | | | | | | | | | | | | |
| Nelson/Marlborough | 69 | 24 | 163 | 119 | 62 | 94 | 35 | 103 | 63 | 75 | 114 | 71 |
| West Coast | 29 | 11 | 75 | 51 | 27 | 44 | 19 | 40 | 23 | 35 | 41 | 30 |
| Canterbury | 323 | 114 | 842 | 502 | 291 | 485 | 169 | 477 | 290 | 356 | 474 | 332 |
| Otago | 206 | 58 | 400 | 355 | 150 | 229 | 103 | 310 | 189 | 223 | 321 | 212 |
| Southland | 192 | 43 | 412 | 331 | 111 | 236 | 99 | 284 | 173 | 210 | 202 | 197 |
| *South Island* | *819* | *251* | *1892* | 1358 | *641* | *1088* | *424* | *1214* | *739* | *900* | *1152* | *841* |
| | | | | | | | | | | | | |
| *New Zealand* | *3519* | *1314* | *6530* | 4443 | *3341* | *3788* | *1792* | *5246* | *3199* | *3840* | *4031* | *3605* |

Source: NZIER

### *Table 11: Sensitivity analysis, net present value of impacts by region and sector*

$million (2003/2004 prices)-Difference against medium impact scenario

| | Low impact | High impact | Rapid establishment | Slow spread | Fast spread | Low nitrogen effect | High nitrogen effect | Low feed effect | High feed effect | **Alternative nitrogen fixation estimates** | **High fertiliser price** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Nitrogen | -1868 | 2607 | 760 | -144 | 213 | -1727 | 1727 | 0 | 0 | 512 | 86 |
| Feed | -337 | 404 | 164 | -34 | 56 | 0 | 0 | -320 | 320 | 0 | 0 |
| Urea manufacture | -142 | 340 | 0 | 0 | 0 | -99 | 99 | 0 | 0 | 40 | 0 |
| Apiary | -118 | 928 | 14 | -2 | 8 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Total* | *-2466* | *4279* | *938* | *-180* | *277* | *-1826* | *1826* | *-320* | *320* | *551* | *86* |
| | | | | | | | | | | | |
| Northland | -153 | 181 | 0 | 0 | 0 | -135 | 135 | -11 | 11 | 74 | 6 |
| Auckland | -44 | 52 | 0 | 0 | 0 | -39 | 39 | -4 | 4 | 56 | 2 |
| Bay of Plenty | -237 | 275 | 0 | 0 | 0 | -191 | 191 | -37 | 37 | 9 | 8 |
| Hawkes Bay | -144 | 177 | 113 | 0 | 0 | -131 | 131 | -6 | 6 | 25 | 7 |
| Waikato | -515 | 596 | 0 | 0 | 0 | -393 | 393 | -104 | 104 | -28 | 18 |
| Taranaki | -151 | 177 | 74 | 0 | 0 | -105 | 105 | -40 | 40 | -27 | 6 |
| Manawatu-Wanganui | -311 | 379 | 142 | 0 | 0 | -273 | 273 | -23 | 23 | 42 | 14 |
| Wellington | -83 | 100 | 57 | 0 | 0 | -65 | 65 | -14 | 14 | 28 | 3 |
| *North Island* | *-1637* | *1938* | *385* | *0* | *0* | *-1332* | *1332* | *-240* | *240* | *179* | *64* |
| | | | | | | | | | | | |
| Nelson/Marlborough | -45 | 94 | 49 | -7 | 25 | -34 | 34 | -6 | 6 | 45 | 2 |
| West Coast | -18 | 45 | 21 | -3 | 15 | -11 | 11 | -6 | 6 | 12 | 1 |
| Canterbury | -209 | 519 | 179 | -32 | 162 | -154 | 154 | -33 | 33 | 151 | 9 |
| Otago | -148 | 194 | 149 | -56 | 23 | -104 | 104 | -17 | 17 | 115 | 6 |
| Southland | -148 | 220 | 140 | -80 | 44 | -92 | 92 | -19 | 19 | 10 | 5 |
| *South Island* | -568 | 1073 | 538 | -178 | 269 | -395 | 395 | -80 | 80 | 333 | 22 |
| | | | | | | | | | | | |
| *New Zealand* | *-2206* | *3011* | *924* | *-178* | *269* | *-1727* | *1727* | *-320* | *320* | *512* | *86* |

Source:NZIER

***Table 12: Sensitivity analysis, net present value of impacts by region and sector***
Percentage difference against medium impact scenario

| | Low impact | High impact | Rapid establishment | Slow spread | Fast spread | Low nitrogen effect | High nitrogen effect | Low feed effect | High feed effect | Alternative nitrogen fixation estimates | High fertiliser price |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Nitrogen | -65 | 91 | 26 | -5 | 7 | -60 | 60 | 0 | 0 | 18 | 3 |
| Feed | -53 | 63 | 26 | -5 | 9 | 0 | 0 | -50 | 50 | 0 | 0 |
| Urea manufacture | -86 | 206 | 0 | 0 | 0 | -60 | 60 | 0 | 0 | 24 | 0 |
| Apiary | -89 | 697 | 11 | -1 | 6 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Total* | *-65* | *112* | *25* | *-5* | *7* | *-48* | *48* | *-8* | *8* | *14* | *2* |
| | | | | | | | | | | | |
| Northland | -62 | 73 | 0 | 0 | 0 | -54 | 54 | -5 | 5 | 30 | 2 |
| Auckland | -61 | 72 | 0 | 0 | 0 | -54 | 54 | -5 | 5 | 77 | 2 |
| Bay of Plenty | -60 | 70 | 0 | 0 | 0 | -49 | 49 | -10 | 10 | 2 | 2 |
| Hawkes Bay | -63 | 77 | 49 | 0 | 0 | -57 | 57 | -2 | 2 | 11 | 3 |
| Waikato | -60 | 69 | 0 | 0 | 0 | -46 | 46 | -12 | 12 | -3 | 2 |
| Taranaki | -59 | 70 | 29 | 0 | 0 | -41 | 41 | -16 | 16 | -11 | 2 |
| Manawatu-Wanganui | -62 | 76 | 28 | 0 | 0 | -54 | 54 | -5 | 5 | 8 | 3 |
| Wellington | -61 | 73 | 42 | 0 | 0 | -48 | 48 | -10 | 10 | 21 | 3 |
| *North Island* | *-61* | *72* | *14* | *0* | *0* | *-49* | *49* | *-9* | *9* | *7* | *2* |
| | | | | | | | | | | | |
| Nelson/Marlborough | -65 | 137 | 72 | -10 | 36 | -50 | 50 | -9 | 9 | 65 | 3 |
| West Coast | -62 | 154 | 72 | -10 | 51 | -36 | 36 | -20 | 20 | 40 | 2 |
| Canterbury | -65 | 161 | 55 | -10 | 50 | -48 | 48 | -10 | 10 | 47 | 3 |
| Otago | -72 | 94 | 72 | -27 | 11 | -50 | 50 | -8 | 8 | 56 | 3 |
| Southland | -77 | 115 | 73 | -42 | 23 | -48 | 48 | -10 | 10 | 5 | 3 |
| *South Island* | *-69* | *131* | *66* | *-22* | *33* | *-48* | *48* | *-10* | *10* | *41* | *3* |
| | | | | | | | | | | | |
| *New Zealand* | *-63* | *86* | *26* | *-5* | *8* | *-49* | *49* | *-9* | *9* | *15* | *2* |

Source: NZIER

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# Appendix A : Technical Advisory Group Participants

***Table 13: Technical Advisory Group Participants***

| Technical advisor | Affiliation |
|---|---|
| Johannah Branson | Biosecurity New Zealand (Chair) |
| Ian Gear | Biosecurity New Zealand |
| Rose Huxley-Jones | Biosecurity New Zealand (Minute Secretary) |
| Barney Stephenson | Biosecurity New Zealand |
| | |
| Joe Clough | Wrightsons |
| Ruth Frampton | Critique |
| Keith Holmes | Waikato Clover Management Group |
| Greg Lambert | AgResearch |
| Roger Parfitt | Landcare Research |
| Amelia Pascoe | Biosecurity New Zealand |
| Frank Portegys | Dexcel |
| Mike Slay | Homelea Ltd. |
| Bruce Withell | Bruce Withell Agricultural Consultant |
| | |
| Simon Wear | NZIER |
| Grant Andrews | NZIER |
| Pip Gerard | AgResearch |
| Han Eerens | AgResearch |