VARROA IN NEW ZEALAND: ECONOMIC IMPACT ASSESSMENT

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Abstract

This paper presents an assessment of the economic impacts of varroa on New Zealand agriculture. These impacts include both direct effects on the beekeeping sector and increased costs of production and production losses to industries in the horticultural, pastoral and arable sectors that depend on honey bees for pollination. Given uncertainty as to how adverse the impacts of varroa might be and how rapidly these impacts might spread throughout New Zealand, a range of scenarios are modelled. This economic impact assessment suggests that, under beekeeper management only, varroa is likely to cost New Zealand agriculture at best around $400 million and at worst around $900 million, in present value terms, over the next 35 years.

Introduction

The varroa mite (*Varroa destructor*, formerly known as *Varroa jacobsoni*) is an external parasite of adult and developing stages of the honey bee (*Apis mellifera*). Infested colonies are weakened by a decline in the number of adult bees produced and emerging bees may be less active. Varroa may also act as a vector for a number of bee viruses.

Varroa may impact upon New Zealand agriculture in two ways:

- directly, on the beekeeping sector; and
- indirectly, on sectors that benefit from honey bee pollination.

Varroa may reduce not only the pollination efficiency of honey bees but also pollinator numbers through intermittent crashes of managed hives and the elimination of feral bees. The resulting reduction in pollination activity may affect the production of a number of crops.

Dependence on honey bees for pollination differs according to crop. Grasses and cereals are generally wind-pollinated. Floriculture has little requirement for honey bee pollination. Viticulture and some vegetables have a relatively minor reliance on honey bees. Glasshouse crops, such as tomatoes, are usually pollinated by commercially reared bumble bees. Most dependent on honey bees for pollination are many major horticultural crops, pasture clovers and some small seed and vegetable seed crops.

For some of these crops, there may be minimal crop set without adequate pollination. For others, production may take place but crop yield, size, quality and/or seed development may be adversely affected and/or the season may be delayed.

Alternative pollinators are generally not currently available in New Zealand. Although introduction may be an option, it would take time, following research and capital investment, to generate sufficient quantities for application on a commercial scale. Artificial pollination is generally complementary to, rather than a substitute for, honey bee pollination and, similarly, could not be implemented on a commercial scale immediately. For example, currently there are sufficient materials and equipment for artificial pollination of only 5 per cent of New Zealand's kiwifruit crop. In addition, artificial pollination tends to be less effective than insect pollination, resulting in lower yields and a lower quality crop.

Methodology

Overview

The objective of the economic impact assessment is to evaluate, *ceteris paribus*, the potential impacts of varroa on New Zealand agriculture in the absence of government intervention. This is to provide a baseline against which to assess control options designed to avert some or all of the impacts of varroa. The response to varroa under this baseline is defined to consist of beekeeper management only, given current technology. This economic impact assessment is independent of evaluation of the technical feasibility and operational costs of varroa control options.

The economic impact assessment models the impacts of varroa on four sectors:
- the horticultural sector;
- the pastoral sector;
- the arable sector; and
- the beekeeping (honey bee) sector.

The impacts modelled are:
- for the horticultural sector:
  - increases in pollination charges; and
  - reductions in crop yields;
- for the pastoral sector:
  - increases in nitrogen fertiliser applications;
  - clover reseeding; and
  - some production losses;
- for the arable sector:
  - increases in pollination charges;
  - increases in numbers of hives per hectare; and
  - some reductions in crop yields;
- for the beekeeping sector:
  - varroa management costs;
  - increases in pollination charges to growers;
  - non-pollinator hive industry exits; and
  - increases in the number of pollinator hives supplied to the arable sector.

The effects of varroa are modelled as spreading throughout New Zealand sequentially by region, with the impacts in each region phased in over time.

In modelling the impacts by region, New Zealand is divided into the following areas:

- the upper North Island;
- the lower North Island; and
- the South Island.

Given uncertainty as to how adverse the impacts of varroa might be and how rapidly these impacts might spread throughout each region, three scenarios are modelled:

- a “best” case;
- a “middle” case; and
- a “worst” case.

Assumptions as to the magnitudes of the effects of, and responses to, varroa under each of these scenarios are the consensus of opinion reached by a consultation group. This consultation group comprised technical experts and industry representatives, with particular emphasis on the horticultural and beekeeping industries. In setting the assumptions for the economic impact assessment, the consultation group drew on overseas data and literature, expert opinion and industry consultation. The consultation group met several times to refine these assumptions and the sector models were revised accordingly.

The impacts of varroa are assessed over a 35-year time period, given that the impacts on the pastoral sector are modelled as taking over 30 years to become fully effective. A discount rate of 7 per cent, based on the five-year government bond rate, is applied in expressing future impacts in present value terms (in 2000).

The focus of the economic impact assessment is commercial agricultural production. The potential impacts on private gardens, public amenity and natural ecosystems of the effects of varroa on honey bees are not evaluated. Nor is the “existence value” to society of feral honey bees included.

Impacts on the horticultural sector

For the horticultural sector, the impacts modelled are increases in pollination charges and reductions in crop yields. These impacts are modelled for a range of important fruit and vegetable crops: pipfruit, kiwifruit, summerfruit (stonefruit), citrus, berryfruit (represented by strawberries), avocados, peas and squash. The current hive requirements of these crops are assumed to be the recommended numbers of pollinator hives per hectare. Crop areas and hive requirements are given in Table 1 (in the Appendix to this paper).

The pollination charge to growers, currently around $80 per hive for a three-week pollination season in kiwifruit production, is assumed to rise partly to cover varroa management costs to beekeepers, partly as a return-on-risk to beekeepers, given some degree of risk-aversion to moving hives into or close to infested areas, and partly due to market forces under a reduction in pollinator numbers.

In the absence of New Zealand data on the role of honey bees in the pollination of horticultural crops, estimates are derived using United States data on proportionate dependence on insect pollination and the proportion of insect pollinators that are honey bees for a range of crops. Together, these two variables provide an indication of the proportion of crop-set that is dependent on pollination by honey bees. A slightly lower value for the proportion of insect pollinators that are honey bees is assumed for pipfruit given differences between United States and New Zealand varieties. For peas, estimates are based on New Zealand industry opinion, given no United States data for this crop. Table 2 indicates the proportion of crop-set assumed to be dependent on honey bee pollination for each of the horticultural crops modelled.

For simplification, it is assumed that the level of pollination activity is directly proportional to the number of pollinators. Reductions in yields are therefore calculated by multiplying the proportion of crop-set dependent on honey bee pollination by the reductions in honey bee pollinator numbers due to varroa. The reductions in pollinator numbers assumed vary according to scenario. Reductions in crop yields are valued in terms of orchard/farmgate income forgone, calculated as the farmgate value of forgone output less picking, packing and other variable costs saved, allowing for some regional differences. Data on average yield, value and cost per unit are provided in Table 3.

For kiwifruit, it is assumed that a reduction in pollinator numbers affects fruit size only. Reduced fruit size and rejection of misshapen fruit are assumed to reduce the average value of kiwifruit by 5 per cent per tray.

Initially, the horticultural sector was modelled as increasing the numbers of pollinator hives per hectare in order to mitigate the effects of reduced pollinator numbers on crop yields. The consultation group subsequently decided that no increase in hive numbers should be modelled for this sector, on the grounds that beekeepers would maintain the strength of hives supplied to growers and therefore hive requirements would remain constant.

Scenarios

For the best case, the impacts modelled are:
- a $75 increase in pollination charge per hive; and
- no reduction in pollinator numbers (based on the assumption of no hive crashes) therefore no fall in crop yields.

The impacts modelled for the middle case are:
- a $120 increase in pollination charge per hive; and
- no reduction in pollinator numbers for kiwifruit and avocados, an average annual reduction in pollinator numbers of 1.4 per cent for other crops (based on the assumptions of no hive crashes for kiwifruit and avocados and 50 per cent of hives crashing per 35 years for other crops). The effects on yields of this reduction in pollinator numbers, given the proportions of crop-set dependent on honey bees, are shown in Table 4.

For the worst case, the impacts modelled are:
- a $120 increase in pollination charge per hive; and
- average annual reductions in pollinator numbers of 10 per cent for kiwifruit and avocados and 5 per cent for other crops (based on the assumptions of 50 per cent of hives crashing per 5 years for kiwifruit and avocados and 50 per cent of hives crashing per 10 years for other crops). The effects on yields are shown in Table 4.

Impacts on the pastoral sector

For the pastoral sector, the impacts modelled are increases in nitrogen fertiliser applications, clover reseeding and some production losses. Different effects in summer moist and summer dry areas are modelled, given that pasture in the latter, particularly in summer dry hill country, is more dependent on annual clovers and other trefoils that must set seed and regerminate each year. In South Island high country, the main pollinators of clover are feral bees, which are assumed to be eliminated by varroa even for the best case. Farm numbers and areas by region are given in Table 5.

For the pastoral sector model, reductions in pollinator numbers due to varroa are not quantified. Instead, the assumptions adopted address directly the effects on this sector of reduced pollination activity. Although grasses are wind-pollinated, clover and related legumes depend on honey bees for pollination. A reduction in pollinator numbers would lead to a decline over time in pasture clover content. Clover contributes to both pasture growth, through the fixation of atmospheric nitrogen, and pasture quality, clover representing a higher quality feed than grass. Given the stoloniferous nature of clover and the store of seeds in the ground, the effects on clover nitrogen fixation and clover growth are likely to be minimal in the first ten years. Once these effects become significant, the pastoral sector is likely to respond by increasing nitrogen fertiliser applications and sowing clover seed in order to mitigate production losses.

The effect of varroa on pollinator numbers is assumed to result in a reduction in atmospheric nitrogen fixation by clover of up to 5 per cent, depending on scenario. It is assumed that on all dairy farms and 75 per cent of sheep and beef farms nitrogen fertiliser applications are increased to compensate for reduced clover nitrogen fixation. The “Overseer” nutrient balance model (AgResearch) indicates that, under normal conditions, nitrogen fixation by clover contributes typically 106 kilograms of nitrogen per hectare per annum on a Waikato dairy farm (given a pasture clover content of 17 per cent) and 40 kilograms of nitrogen per hectare per annum on a King Country sheep and beef farm (given a pasture clover content of 8 per cent). It is therefore assumed that a 5 per cent reduction in clover nitrogen fixation would reduce average annual nitrogen fixation by around six kilograms per hectare on dairy farms and two kilograms per hectare on sheep and beef farms. Additional nitrogen fertiliser applications are assumed to consist of urea on dairy farms and to be split equally between urea and diammonium phosphate (DAP), in lowland and hill country areas respectively, on sheep and beef farms. Urea is 46 per cent nitrogen and DAP has an N.P.K.S. level of 18.20.0.2, implying additional annual nitrogen fertiliser applications of 13 kilograms per hectare on dairy farms and 4.4 kilograms per hectare on sheep and beef farms to compensate for a 5 per cent reduction in clover nitrogen fixation. The average cost of urea is set at $310/tonne plus $45/tonne for cartage and spreading and the average cost of DAP is set at $474/tonne plus $65/tonne for cartage and spreading.

Reduced pasture clover content is modelled as prompting clover reseeding once every five years in summer moist areas, depending on scenario, and annually in summer dry areas. The cost of clover seed is set at $13 per kilogram, with no additional sowing cost (the seed can be dispersed at the time that fertiliser is applied).

Despite clover reseeding, some loss in production in summer dry areas due to reduced pasture clover content is assumed. Reduced pasture clover content, due to the effect of varroa on pollinator numbers, is assumed to result in a 5 per cent reduction in pasture growth and quality. The “Stockpol” sheep and beef model (AgResearch) indicates the effects of a 5 per cent reduction in pasture growth and quality in summer dry situations to be 7 per cent reductions in sheepmeat, wool and beef production. These are valued in terms of a 7 per cent reduction in the weighted average annual gross revenue per hectare net of cost savings from reduced stock numbers. Gross revenue and variable cost data for sheep and beef farms in selected summer dry areas are given in Table 6.

Scenarios

For the best case, the impacts modelled are:
- no impacts in summer moist areas (based on the assumption on no reduction in pollinator numbers in these areas);
- in summer dry areas:
  - additional nitrogen fertiliser applications of 4.4 kilograms per hectare per annum (based on the assumption of a 5 per cent reduction in clover nitrogen fixation);
  - clover reseeding of two kilograms per hectare per annum; and
  - annual production losses resulting from a 5 per cent reduction in pasture growth and quality.

The impacts modelled for the middle case are:
- in summer moist areas:
  - additional nitrogen fertiliser applications of 3.25 kilograms per hectare per annum on dairy farms and 1.1 kilograms per hectare per annum on sheep and beef farms (based on the assumption of a reduction in clover nitrogen fixation of 25 per cent of the reduction assumed for the worst case);
  - clover reseeding of one kilogram per hectare per five years; and
  - no production losses;
- the same impacts in summer dry areas as for the best case.

For the worst case, the impacts modelled are:
- in summer moist areas:
  - additional nitrogen fertiliser applications of 13 kilograms per hectare per annum on dairy farms and 4.4 kilograms per hectare per annum on sheep and beef farms (based on the assumption of a 5 per cent reduction in clover nitrogen fixation);
  - clover reseeding of two kilograms per hectare per five years; and
  - no production losses;
- the same impacts in summer dry areas as for the best case.

Impacts on the arable sector

For the arable sector, the impacts modelled are increases in pollination charges, increases in numbers of hives per hectare and some reductions in yields. These impacts are modelled for: white clover (Huia and proprietarys), brassica seeds, fodder radish, phacelia, borage, chicory, lotus, red clover, seed multiplication areas, yarrow, lucerne and hybrid vegetables. Crop areas vary annually. The model uses 1999/00 crop areas, which reflect a decline in traditional small seeds production and an expansion in production of higher value crops. These crop areas are given in Table 7. Of the total area, 95 per cent is in Canterbury.

The increase in pollination charge to growers is as assumed for the horticultural sector model, but from a current charge of around $120 for a three-month pollination season for South Island small seeds production.

The reduction in pollinator numbers assumed varies somewhat according to scenario for this sector also.

Given the importance of pollination to the arable seed industry, it is assumed that producers respond to a reduction in pollinator numbers by increasing the numbers of hives per hectare in order to mitigate adverse effects on crop yields. In modelling this increase in hive numbers, an allowance is made for some movement of hives between crops within a season, given that flowering times differ (the "use factor"). This use factor and the typical number of hives per hectare required currently for each crop are given in Table 7.

It is assumed that the increase in hive numbers is insufficient to compensate fully for the effects of varroa on pollinators and therefore some reduction in yields occurs. The relationship between pollinator numbers and yield is unlikely to be linear. A small reduction in pollinator numbers may have a relatively minor effect on yield, whilst more severe reductions in pollinator numbers are likely to have more marked effects on yield, particularly under adverse climatic conditions. At the reductions in pollinator numbers assumed for the arable sector, less-than-proportionate reductions in yields are modelled.

This reduction in yields is valued in terms of farmgate income forgone, calculated as the value of output forgone net of variable costs saved. Data on average yield and net value per unit are provided in Table 7. Constant prices are assumed throughout. In reality, a decrease in production could cause a rise in price of crops of which New Zealand is a major producer. For some crops, however, a reduction in pollination would also affect quality. For the arable sector this could reduce seed values and may have the potential to undermine New Zealand's developing seed export industries.

Scenarios

For the best case, the impacts modelled are:

- a $75 increase in pollination charge per hive;
- no increase in numbers of hives per hectare; and
- no reduction in pollinator numbers, therefore no fall in crop yields.

The impacts modelled for the middle case are:

- a $120 increase in pollination charge per hive;
- a 30 per cent increase in numbers of hives per hectare; and
- an average annual reduction in pollinator numbers of 5 per cent, resulting in a 1.67 per cent reduction in crop yields.

For the worst case, the impacts modelled are:

- a $120 increase in pollination charge per hive;
- a 100 per cent increase in numbers of hives per hectare; and
- an average annual reduction in pollinator numbers of 5 per cent, resulting in a 1.67 per cent reduction in crop yields.

Impacts on the beekeeping sector

For the beekeeping sector, the impacts modelled are varroa management costs, increases in pollination charges to growers, non-pollinator hive industry exits and increases in the number of pollinator hives supplied to the arable sector. These impacts are modelled for registered hives only, according to apiary register location, given in Table 8. Given the mobility of hives, this provides only an approximate indication of the regional distribution of impacts.

The average annual cost to beekeepers of managing varroa is set at $55 per hive, including the costs of miticide and additional labour, transportation and recolonisation. In reality, varroa management costs are likely to differ by region and according to beekeeper expertise, and may fall over time as best practice is adopted.

The increases in pollination charges to growers are as assumed for the horticultural and arable sector models. The numbers of pollinator hives supplied to the horticultural and arable sectors, according to scenario, are taken from these models.

It is widely considered that varroa is likely to lead to the disappearance of most hobbyists, the majority of below average performance beekeepers and many honey producers, located largely in the South Island, who are unlikely to have sufficient profit margins to be able to meet the additional costs of managing varroa. For the best case, it is assumed that there is no change in hive numbers, given the pastoral and arable sector impacts modelled. For the middle and worst cases, however, industry exits are modelled, comprised of non-pollinator hives - hives not earning pollination revenue - and concentrated in the South Island.

Non-pollinator hive industry exits are valued in terms of honey revenue forgone less hive operating costs saved. The annual honey revenue forgone for hives exiting the industry is set at an average of $65 per hive, given average annual production in Canterbury of around 30 to 35 kilograms per hive worth $2 to $2.20 per kilogram. The average annual budgeted cost of operating hives is set at $75 per hive. Additionally, in exiting the industry, varroa management costs are avoided.

Providing additional hives to the arable sector in the middle and worst cases is modelled as costing beekeepers the average annual budgeted hive operating cost of $75 per additional hive and adding to pollination revenue by the total pollination charge under these scenarios of $240 per additional hive. In reality, annual operating costs may be higher for pollinator hives than for non-pollinator hives. The arable sector model indicates the numbers of additional pollinator hives supplied to the arable sector. On the advice of the consultation group, it is assumed that beekeepers face no capital cost in providing additional hives, given the availability of salvageable hives.

The combined effect of non-pollinator hive industry exits and increases in the numbers of pollinator hives supplied to the arable sector is a structural shift in the industry away from keeping hives solely for honey production towards greater emphasis on the provision of paid pollination services to growers.

A number of other potential impacts on the beekeeping sector not addressed by the consultation group are not modelled. These include the effects of varroa on honey output, honey price (including the potential loss of the premium earned from association with New

Zealand's "clean, green" image), the output and value of other bee products, and live bee exports, as well as multiplier effects on upstream and downstream industries.

Scenarios

For the best case, the impacts modelled are:
- a varroa management cost of $55 per hive per annum;
- a $75 increase in pollination charge per hive; and
- no change in hive numbers.

The impacts modelled for the middle case are:
- a varroa management cost of $55 per hive per annum;
- a $120 increase in pollination charge per hive;
- exit from the industry of South Island non-pollinator hives, representing 24 per cent of all hives; and
- a 30 per cent increase in the number of pollinator hives supplied to the arable sector.

For the worst case, the impacts modelled are:
- a varroa management cost of $55 per hive per annum;
- a $120 increase in pollination charge per hive;
- exit from the industry of South Island non-pollinator hives and the least profitable 25 per cent of North Island non-pollinator hives, representing a total of 28 per cent of all hives; and
- a 100 per cent increase in the number of pollinator hives supplied to the arable sector.

Rate of spread of varroa and its effects

In modelling the rate of spread of varroa and its effects by region, the North Island is divided on the basis of regional council areas. The upper North Island is defined to comprise the Northland, Auckland, Waikato, Bay of Plenty and Gisborne regions. The lower North Island is defined to comprise the Hawkes Bay, Taranaki, Manawatu-Wanganui and Wellington regions. The Gisborne region is included in the lower North Island for the horticultural and beekeeping sector models, for which four regional areas are defined - Northland, an Auckland, Waikato and Bay of Plenty region, the lower North Island and the South Island.

It is assumed that varroa is already established in the Auckland, Waikato and Bay of Plenty region and that it becomes established in Northland in 2001, in the lower North Island in 2003 and in the South Island in 2004. "Established" denotes a sufficient presence of varroa to begin to have significant effects on agriculture the following year, as distinct from initial, isolated incursions.

For each region, the impacts on agriculture are modelled as commencing the year following the year in which varroa becomes established and are phased in over time, according to scenario, reflecting the time taken for the sector impacts to come into full effect across the region.

Scenarios

For the best case, sector impacts are phased in over:
- one year in the Auckland, Waikato and Bay of Plenty region;
- five years in Northland;
- five years in the lower North Island; and
- seven years in the South Island.

For the middle case, sector impacts are phased in over:
- four years in the Auckland, Waikato and Bay of Plenty region;
- four years in Northland;
- four years in the lower North Island; and
- six years in the South Island.

For the worst case, sector impacts are phased in over:
- four years in the Auckland, Waikato and Bay of Plenty region;
- four years in Northland;
- four years in the lower North Island; and
- five years in the South Island.

The timing of the impacts modelled for the horticultural, arable and beekeeping sectors is shown in Table 9. The timing of the impacts modelled for the pastoral sector is shown in Table 10. All impacts for each region are phased in on a straight-line basis.

Results

Total economic impacts

Aggregation of these impacts across sectors and regions, by scenario, indicates the estimated total economic impacts of varroa on New Zealand agriculture. The total impacts to 2035 are illustrated in Figure 1. These represent accumulation of the annual impacts illustrated in Figure 2. The dominant feature of Figure 2 is the contribution of production losses and clover reseeding costs in the pastoral sector after 2020.

The economic impact assessment indicates that, under beekeeper management only, varroa is likely to cost New Zealand agriculture between $400 million and $900 million, in present value terms, over the next 35 years. From Figure 1, it is clear that the middle case, with estimated impacts over 35 years of around $470 million, does not represent the mid-point between the best and worst cases, but is skewed towards relatively moderate impacts. This is largely due to the relatively moderate magnitudes of impacts assumed for this case for the horticultural sector.

The present value total economic impacts on New Zealand agriculture to selected years are given in Table 11 for each scenario. Beyond 2035, with all four sectors fully affected, the total impacts continue to accumulate but at a decreasing rate, due to the effect of discounting.

At a lower discount rate of 5 per cent, the present value of the total impacts to 2035 is increased by between 52 and 63 per cent, depending on scenario. At a higher discount rate of

10 per cent, the present value of the total impacts to 2035 is reduced by between 42 and 48 per cent, depending on scenario. The worst case impacts are less affected given the more rapid rate of spread modelled. A change in discount rate most affects the pastoral sector impacts, given the time taken for these come into effect.

Total economic impacts by sector

Table 12 indicates the distribution of the total economic impacts to 2035 across the four sectors modelled. This distribution is illustrated in Figure 3. In the best and middle cases, the pastoral sector is the most adversely affected. In the worst case, it is the horticultural sector that suffers the greatest impacts, largely as a result of the production losses arising from the effects of reduced pollination on kiwifruit size. For the beekeeping sector, net benefits are indicated in the middle and worst cases, in which the impacts are dominated by the increases in sector revenue from providing paid pollination services to growers. The sector to which these net benefits accrue, however, is structurally different to that which exists in the best case, given industry exits.

Total economic impacts by region

The distribution of the total economic impacts by region is indicated in Table 13 and illustrated in Figure 4. In the best and middle cases, the greatest impacts are in the South Island. In the worst case, similar magnitudes of impacts occur in the upper North Island and the South Island. The impacts in the South Island are relatively large because of greater pastoral sector impacts in the South Island, the concentration of the arable sector in the South Island and, in the best case, more adverse impacts on the beekeeping sector in the South Island. In the worst case, the impacts in the upper North Island are dominated by the impacts on the horticultural sector.

Horticultural sector impacts by region and crop

The regional distribution of impacts on the horticultural sector is indicated in Table 14. The largest impacts are suffered in the Auckland, Waikato and Bay of Plenty region in all three scenarios. Almost 80 per cent of the total area of land in kiwifruit production is located in this region. Table 15 indicates how kiwifruit is the most adversely affected of the horticultural crops modelled. Given the higher number of pollinator hives required for kiwifruit than for other crops and the relatively large total area of land in kiwifruit production (second only to pipfruit), the increase in pollination charge is felt most acutely for this crop. The major impact on kiwifruit in the worst case is the production loss resulting from the effect of reduced pollination on fruit size. Lesser impacts on pipfruit are indicated, but low margins in this industry may limit its capacity to absorb additional costs or production losses. If there is a shortfall in the number of pollinator hives available, pipfruit and other crops may lose out to kiwifruit.

Pastoral sector impacts by region

The regional distribution of impacts on the pastoral sector is indicated in Table 16. Over 60 per cent of the impacts on the pastoral sector occur in the South Island, attributable to the relative importance of this region for sheep and beef farming, particularly in summer dry situations for which more adverse impacts are modelled.

Beekeeping sector impacts by region

The regional distribution of impacts on the beekeeping sector, according to where hives are registered, is provided in Table 17. In the best case, the most adverse impacts occur in the South Island, dominated by varroa management costs for the large number of non-pollinator hives in this region. In the middle and worst cases, however, there are indicated to be net benefits in the South Island, resulting from increases in total pollination revenue outweighing total varroa management costs in this region, given that varroa management costs are not incurred for non-pollinator hive industry exits. In the middle and worst cases, the most adverse impacts occur in Northland where there is a relatively small demand for pollination services relative to the number of hives registered and a lower rate of exit from the industry of less-profitable non-pollinator hives than in the South Island. Beekeepers in the Auckland, Waikato and Bay of Plenty region are indicated to benefit in all three scenarios due to increases in revenue from pollination of horticultural crops outweighing varroa management costs.

The impacts on the beekeeping sector are sensitive to the varroa management cost and the rise in pollination charge assumed, especially in the best case. The impacts on each of the horticultural and arable sectors are also sensitive to the rise in pollination charge assumed, although less so. The total impacts on New Zealand agriculture, however, are not very sensitive to this coefficient given that the pollination charge is effectively a transfer between sectors. For example, a 10 per cent smaller increase in pollination charge (i.e. increases of $67.50 in the middle case and $108 in the worst case) reduces the total impacts to 2035 by less than 0.02 per cent.

The impacts on the beekeeping sector are not particularly sensitive to the rate of industry exits assumed. Reducing the rates of industry exits to 20 per cent (a 17 per cent decrease) and 24 per cent (a 14 per cent decrease) in the middle and worst cases respectively, reduces the net benefits to the sector by 6 per cent and 5 per cent respectively. Increasing the rates of industry exits to 30 per cent (a 25 per cent increase) and 34 per cent (a 21 per cent increase) in the middle and worst cases respectively, increases the net benefits to the sector by 13 per cent and 9 per cent respectively.

Use in cost-benefit analysis of control options

The findings of the economic impact assessment can be used further in cost-benefit analysis of control options aimed at preventing, deferring, or mitigating the impacts of varroa on New Zealand agriculture. The benefits of control options can be evaluated in terms of the extent to which the total economic impacts would be reduced.

If effective immediately, eradication of varroa would avert all of the impacts modelled as described above. The benefits of successful eradication can therefore be evaluated as the prevention of future economic impacts on New Zealand agriculture of $400 million to $900 million, in present value terms.

An alternative to eradication may be to attempt to slow the spread of varroa and delay its arrival in areas that are currently varroa-free. Varroa may have the same impacts on agriculture in these areas, whenever it arrives, but a slower rate of spread would cause these impacts to occur later rather than sooner. Due to the effect of the discount rate, reflecting the rate of time preference, the later the impacts occur, the lower their present value. The benefits of deferring these impacts can be evaluated in terms of these reductions in their present value. This is illustrated in Table 18 for the example of a delay in varroa becoming established in the South Island. The total benefits of a two-year delay in varroa becoming established in the South Island are indicated to be $26 million to $48 million (present value) in deferring future impacts on agriculture in this region. Up to this amount could be spent on securing this delay before the costs would start to outweigh the benefits.

In comparing the costs and benefits of intervention to avert some or all of the economic impacts of varroa, it is necessary to take into account how likely it is that control options will succeed in achieving their objectives and thus securing the estimated benefits. The “expected benefit” - the benefit, if intervention is successful, multiplied by the probability of success - may be lower than the cost of intervention. In pursuing national or regional freedom from varroa, it is necessary to allow also for the probable frequency of reinfestation. The more frequently the control area is reinfested, the more often control costs must be incurred if area-freedom is to continue to be maintained. Ultimately, the total control expenditure required may exceed the benefits of remaining varroa-free. For example, Table 18 indicates that the longer the delay in varroa becoming established in the South Island, the greater the relative benefits. As varroa spreads throughout the North Island, however, the frequency of South Island incursions may rise, incurring increasing expenditure on incursion responses. Ultimately, a point may be reached where the costs of continuing to prevent varroa from becoming established outweigh the benefits. Similarly, the probability of success, where success depends on detecting and responding to each and every incursion, may decline.

Conclusions

This economic impact assessment suggests that, under beekeeper management only, varroa is likely to cost New Zealand’s horticultural, pastoral, arable and beekeeping sectors at best around $400 million and at worst around $900 million, in present value terms, over the next 35 years. Additional to these impacts are effects on employment in agriculture, potential secondary effects on agricultural land, property and business values and multiplier effects on related industries.

These estimates are derived using a range of assumptions as to the likely effects of, and responses to, varroa in New Zealand. These assumptions are based on the best estimates available at the time of conducting this assessment. As further data on the effects of varroa in New Zealand become available, it should be possible to refine these assumptions and develop more sophisticated models.

Appendix

Tables

Figures

Table 1: Horticultural Sector Crop Areas and Hive Requirements

Crop	Area (ha) 1999/00					Hive requirements (hives/ha)
	Northland	Auckland, Waikato and Bay of Plenty	Lower North Island	South Island	Total	
Pipfruit	134	1,788	7,574	7,493	16,989	2
Kiwifruit	652	9,450	935	838	11,875	8
Summerfruit	44	342	1,045	1,469	2,900	1 (NI) / 1.5 (SI)
Citrus	718	755	646	10	2,129	0.5
Berryfruit	-	428	110	793	1,331	-
Avocados	233	573	54	-	860	5
Peas	-	-	2,220	6,438	8,658	-
Squash	-	-	7,155	-	7,155	-

Source: AgriQuality New Zealand Ltd.; Fruitgrowers Federation; HortResearch, Horticulture Facts and Figures 1999.

Table 2: The Role of Honey Bees in Pollination of Horticultural Crops

Crop	Proportionate dependence on insect pollination (I)	Proportion of insect pollinators that are honey bees (B)	Proportion of crop-set reliant on honey bees (IxB)
Pipfruit	1.0	0.75	0.75
Kiwifruit	0.9	0.9	0.81
Summerfruit	0.6	0.8	0.48
Citrus	0.4	0.9	0.36
Berryfruit	0.2	0.1	0.02
Avocados	1.0	0.9	0.90
Peas	0.2	0.2	0.04
Squash	0.9	0.1	0.09

Source: Morse, R.A. and Calderone, N.W. (2000) The value of honey bees as pollinators of US crops in 2000, Cornell University, (available at www.pollinator.com); consultation with industry.

Table 3: Horticultural Sector Crop Yield, Value and Cost Data

Pipfruit	North Island	South Island
Yield per ha (carton equivalents)	1,450	1,550
Fruit value per ce (after FAS costs)	11.5	12
Picking cost per ce	1.55	1.34
Packing cost per ce	2.51	2.18
Orchard income loss per ce reduction	7.44	8.48

Kiwifruit	Upper North Island	Lower North Island	South Island
Yield per ha (trays)	5,760	5,500	5,750
Fruit value per tray	6.4	6.4	6.4
Reduction in value per tray due to reduced Fruit size or misshapen fruit	0.33	0.33	0.33

Table 3 continued

Summerfruit	All regions
Yield per ha (kg)	20,000
Fruit value per kg	1.50
Picking cost per kg	0.11
Packing/transport/marketing cost per kg	0.75
Orchard income loss per kg reduction	0.64

Citrus	All regions
Yield per ha (tonnes)	33
Fruit value per tonne	550
Harvesting cost per tonne	150
Freight cost per tonne	40
Orchard income loss per tonne reduction	360

Berryfruit (strawberries)	All regions
Yield per ha (tonnes)	27.5
Fruit value per tonne (after comm.)	3,860
Harvesting cost per tonne	550
Packing labour per tonne	400
Packing materials per tonne	700
Freight cost per tonne	280
Farmgate income loss per tonne reduction	1,930

Avocados	All regions
Yield per ha (tonnes)	7.5
Value per tonne	2,320
Harvesting cost per tonne	227
Packing cost per tonne	582
Farmgate income loss per tonne reduction	1,511

Green Peas (processing)	All regions
Yield per ha (tonnes)	5.25
Value per tonne	300
Farmgate income loss per tonne reduction	300

Squash	All regions
Yield per ha (tonnes)	13.75
Value per tonne	500
Harvesting cost per tonne	90
Packing cost per tonne	85
Transport cost per tonne	25
Farmgate income loss per tonne reduction	300

Source: Agriculture New Zealand, Ltd.; MAF Farm Monitoring Reports, 1999 (using forecasts for 1999/2000); MAF Policy Information.

Table 4: The Impact of Reduced Pollinator Numbers on Horticultural Crop Yields

Crop	Middle case	Worst case
	Reduction in pollinator numbers (%)	
Kiwifruit	0	10
Avocados	0	10
Other crops	1.4	5
	Reduction in yield (%)	
Pipfruit	1.05	3.75
Kiwifruit	0.00	size only*
Summerfruit	0.67	2.40
Citrus	0.50	1.80
Berryfruit	0.03	0.10
Avocados	0.00	9.00
Peas	0.06	0.20
Squash	0.13	0.45

* Reduced fruit size or misshapen fruit resulting in a 5 per cent reduction in fruit value per tray.

Table 5: Pastoral Sector Farm Numbers and Areas

	Upper North Island	Lower North Island	South Island	Total
Summer moist areas				
Dairy				
Number of farms	8,394	3,941	2,027	14,362
Total area (ha)	712,976	326,628	263,510	1,303,114
Sheep and beef				
Number of farms	3,994	2,866	6,510	13,370
Total area (ha)	695,783	699,304	2,322,390	3,717,477
Summer dry areas				
Sheep and beef				
Number of farms	399	1,440	2,010	3,849
Total area (ha)	165,585	351,360	3,713,520	4,230,465

Source: Livestock Improvement Corporation Ltd.; Meat and Wool Economic Service.

Table 6: Pastoral Sector Gross Revenue and Variable Cost Data
(summer dry sheep and beef)

Area	Gross revenue ($/ha)	Variable costs ($/ha)
North Island		
Gisborne	292	49
Hawkes Bay	284	66
Wellington	342	66
Weighted average	297	60
South Island		
Marlborough/Canterbury hill country	155	36
North/Central Canterbury	353	73
Mid/South Canterbury	463	78
South Island Merino	37	9
NorthOtago downlands	351	71
Otago hill country	170	37
Central Otago	193	47
Weighted average	253	50

Source: MAF Farm Monitoring Data 1998/99.

Table 7: Arable Sector Crop Areas, Yield and Net Value Data and Hive Requirements

Crop	Area 1999/00 (ha)	Average yield (tonne/ha)	Farmgate value (net of variable costs) ($/tonne)	Farmgate income (net of variable costs) ($/ha)	Hives per hectare	Use factor
White clover Huia	5,800	0.35	2,600	910	1	1
White clover proprietarys	4,200	0.4	3,400	1,360	1	1
Brassica seeds	5,000	1.5	1,400	2,100	3	0.67
Fodder radish	650	1.6	1,250	2,000	3	1
Phacelia	680	0.6	2,600	1,560	3	1
Borage	5,000	0.3	5,500	1,650	1	1
Chicory	20	0.4	6,000	2,400	3	1
Lotus	120	0.2	8,000	1,600	3	1
Red clover	1,280	0.18	6,500	1,170	3	1
Seed multiplication areas	300	-	-	6,000	3	1
Yarrow	160	0.25	18,000	4,500	3	1
Lucerne	70	0.2	5,500	1,100	3	1
Hybrid vegetables 1	100	-	-	15,000	8	0.5
Hybrid vegetables 2	1,000	-	-	6,000	8	0.5

Source: AgriQuality New Zealand Ltd,; Canterbury Agriculture Ltd.; INFOS; Lincoln Farm Budget Manual; consultation with industry.

Table 8: Beekeeping Sector Registered Hive Numbers

Apiary register location	Number of hives
Whangarei	32,228
Tauranga	50,206
Hamilton	44,464
Palmerston North	41,804
Blenheim	27,139
Canterbury	59,471
Otago/Southland	49,263
Total	304,575

Source: Apiary Registers, as at 26 April 2000, AgriQuality New Zealand Ltd.

Table 9: Rate of Spread of Varroa and its Effects: Horticultural, Arable and Beekeeping Sectors

	Year		
	Varroa established	**Economic impacts commence**	**Full economic impacts from**
Best case			
Northland	2001	2002	2006
Auckland, Waikato and Bay of Plenty	2000	2001	2001
Lower North Island	2003	2004	2008
South Island	2004	2005	2011
Middle case			
Northland	2001	2002	2005
Auckland, Waikato and Bay of Plenty	2000	2001	2004
Lower North Island	2003	2004	2007
South Island	2004	2005	2010
Worst case			
Northland	2001	2002	2005
Auckland, Waikato and Bay of Plenty	2000	2001	2004
Lower North Island	2003	2004	2007
South Island	2004	2005	2009

Table 10: Rate of Spread of the Effects of Varroa: Pastoral Sector

	Year				
	Fertiliser impact commences	Full fertiliser impact from	Production impact commences	Full production impact from	Clover reseeding impact from
Best case					
Upper North Island	2012	2021	2022	2025	2022
Lower North Island	2014	2023	2024	2027	2024
South Island	2021	2030	2031	2034	2031
Middle case					
Upper North Island	2012	2021	2022	2025	2022
Lower North Island	2014	2023	2024	2027	2024
South Island	2020	2029	2030	2033	2030
Worst case					
Upper North Island	2012	2021	2022	2025	2022
Lower North Island	2014	2023	2024	2027	2024
South Island	2019	2028	2029	2032	2029

Table 11: Total Economic Impacts
($ million; present value, 2000)

Period	Best case	Middle case	Worst case
To 2005	25.91	21.29	79.75
To 2010	64.20	64.64	212.11
To 2020	124.84	127.89	398.78
To 2035	398.53	468.99	907.98
To 2055	808.74	889.00	1387.56

Table 12: Total Economic Impacts to 2035 by Sector
($ million; present value, 2000)

	Horticultural	Pastoral	Arable	Beekeeping	Total
Best case					
Impact	115.82	235.10	22.51	25.10	398.53
% of total	29	59	5.65	6.30	100
Middle case					
Impact	197.91	304.58	65.61	-99.11	468.99
% of total	42	65	14	-21	100
Worst case					
Impact	517.84	402.88	122.37	-135.10	907.98
% of total	57	44	13	-15	100

Table 13: Total Economic Impacts to 2035 by Region
($ million; present value, 2000)

	Upper North Island	Lower North Island	South Island	Total
Best case				
Impact	118.69	75.24	204.60	398.53
% of total	30	19	51	100
Middle case				
Impact	128.67	94.49	245.83	468.99
% of total	27	20	52	100
Worst case				
Impact	385.94	143.17	378.87	907.98
% of total	43	16	42	100

Table 14: Horticultural Sector Impacts to 2035 by Region
($ million; present value, 2000)

	Northland	Auckland, Waikato and Bay of Plenty	Lower North Island	South Island	Total
Best case					
Impact	5.49	80.37	16.27	13.69	115.82
% of total	4.74	69	14	12	100
Middle case					
Impact	9.77	118.50	36.36	33.29	197.91
% of total	4.94	60	18	17	100
Worst case					
Impact	27.38	342.26	76.90	71.29	517.84
% of total	5.29	66	15	14	100

Table 15: Horticultural Sector Impacts to 2035 by Crop
($ million; present value, 2000)

	Kiwifruit	Pipfruit	Summerfruit	Citrus	Berryfruit	Avocado	Peas	Squash	Total
Best case									
Impact	86.30	22.45	2.33	0.86	0.00	3.87	0.00	0.00	115.82
% of total	75	19	2.01	0.75	0.00	3.34	0.00	0.00	100
Middle case									
Impact	126.92	55.83	6.11	2.70	0.14	5.79	0.07	0.35	197.91
% of total	64	28	3.09	1.36	0.07	2.93	0.03	0.18	100
Worst case									
Impact	377.51	104.51	11.91	6.17	0.65	15.64	0.22	1.23	517.84
% of total	73	20	2.30	1.19	0.13	3.02	0.04	0.24	100

Table 16: Pastoral Sector Impacts to 2035 by Region
($ million; present value, 2000)

	Upper North Island	Lower North Island	South Island	Total
Best case				
Impact	32.88	54.71	147.51	235.10
% of total	14	23	63	100
Middle case				
Impact	45.26	63.79	195.53	304.58
% of total	15	21	64	100
Worst case				
Impact	67.80	74.56	260.52	402.88
% of total	17	19	65	100

Table 17: Beekeeping Sector Impacts to 2035 by Region
($ million; present value, 2000)

	Northland	Auckland, Waikato And Bay of Plenty	Lower North Island	South Island	Total
Best case	12.91	-12.95	4.26	20.89	25.10
Middle case	9.97	-54.83	-5.65	-48.59	-99.11
Worst case	5.56	-57.08	-8.28	-75.31	-135.10

Table 18: Benefits of Delaying the Arrival of Varroa in the South Island
($ million; present value, 2000)

	At current rate of spread	Two year delay	Four year delay	Six year delay
Year varroa established in South Island	2004	2006	2008	2010
South Island impact period	2005 - 2035	2007 - 2037	2009 - 2039	2011 – 2041
Best case				
South Island impact	204.60	178.71	156.09	136.33
Reduction in impact		25.89	48.51	68.27
Middle case				
South Island impact	245.83	214.72	187.54	163.81
Reduction in impact		31.11	58.29	82.02
Worst case				
South Island impact	378.87	330.92	289.04	252.46
Reduction in impact		47.95	89.83	126.41
Reduction in impact (%)		13	24	33

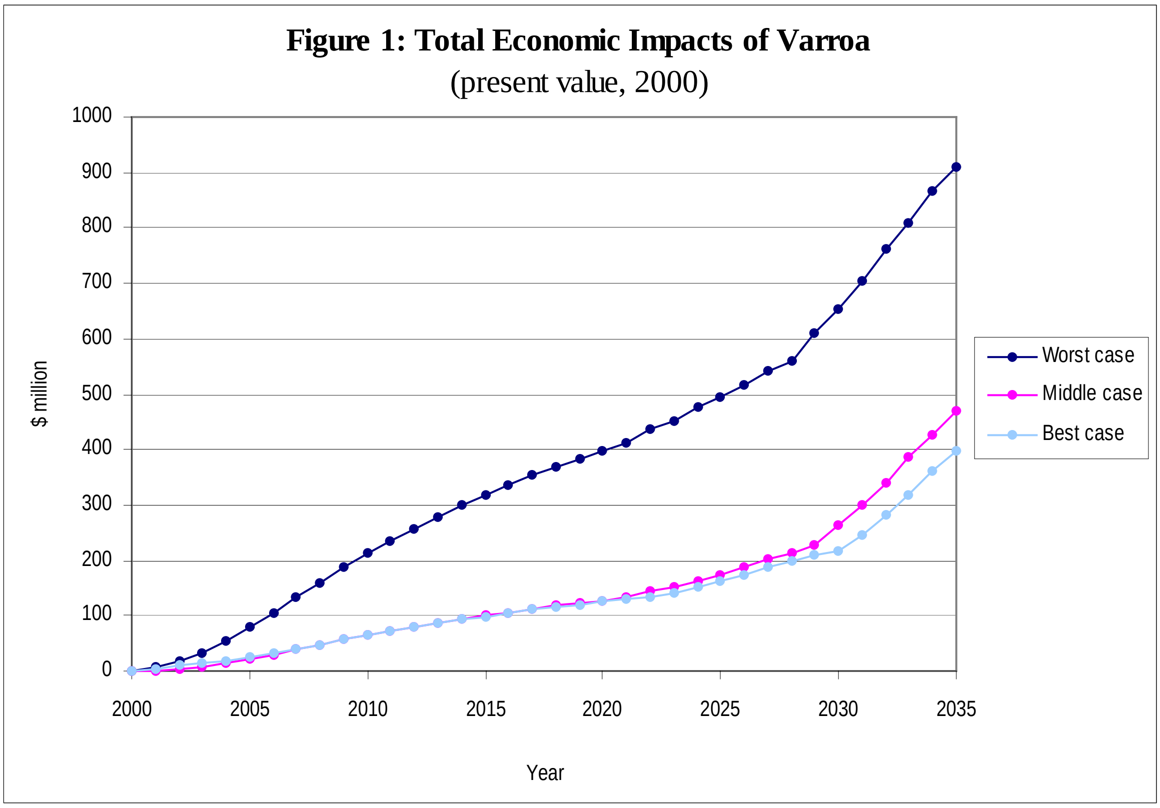
Figure 1: Total Economic Impacts of Varroa
(present value, 2000)
$ million
1000
900
800
700
600
500
400
300
200
100
0
2000
2005
2010
2015
2020
2025
2030
2035
Year
Worst case
Middle case
Best case

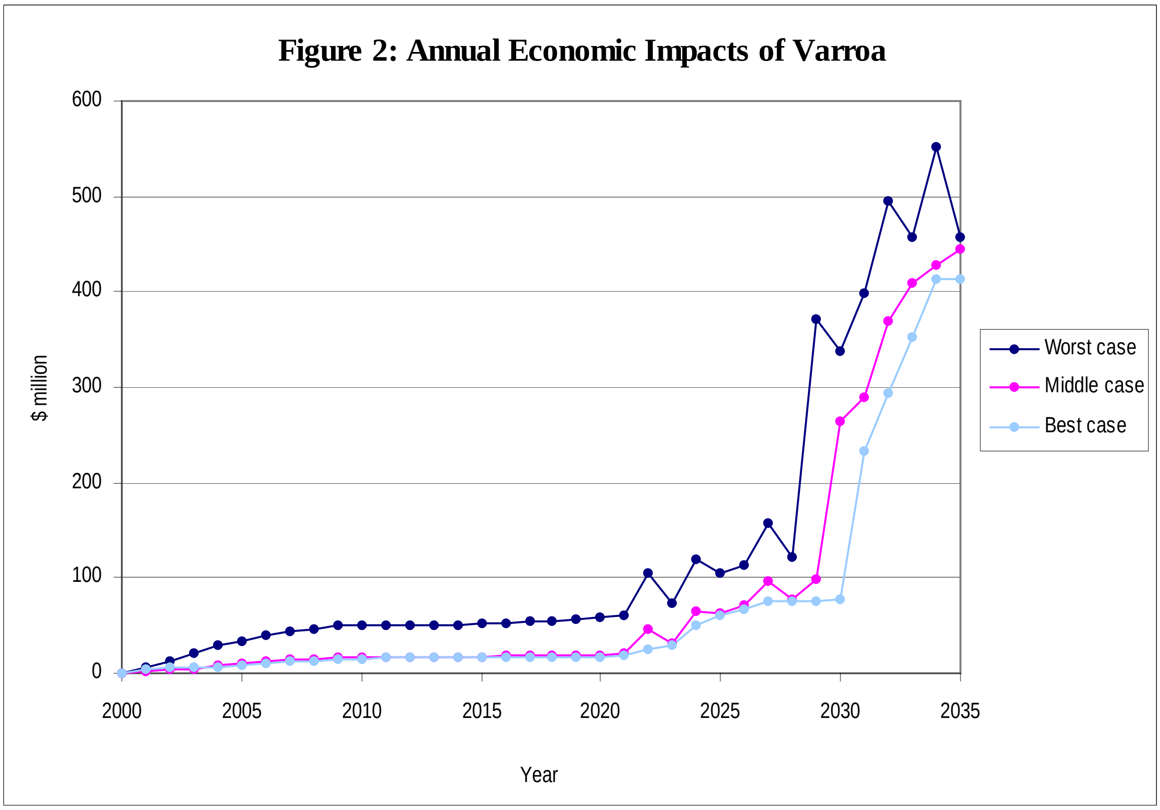
Figure 2: Annual Economic Impacts of Varroa
$ million
600
500
400
300
200
100
0
2000
2005
2010
2015
2020
2025
2030
2035
Year
Worst case
Middle case
Best case

Figure 3: Total Economic Impacts to 2035 by Sector
(present value, 2000)

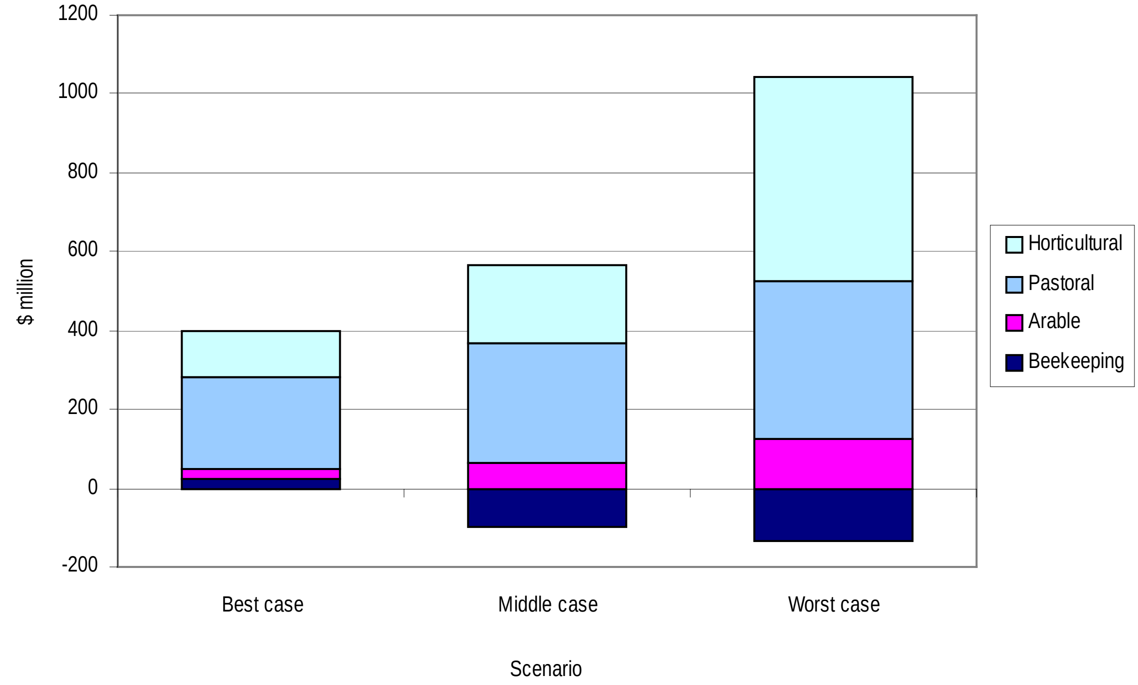

Figure 4: Total Economic Impacts to 2035 by Region
(present value, 2000)