# The Economic Implications of Climate-Induced Changes in Agricultural Production

**Report to NIWA**

**Prepared by Infometrics Ltd**

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# CONTENTS



## Authorship


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# 1. SUMMARY

Two previous papers, Tait et al (2005) and Infometrics (2008)[1], looked at the effects of climate on agricultural production by econometrically estimating the effect of climate variability (in particular, drought) on the production of milksolids and meat with a panel dataset, and then incorporating the production effects into a general equilibrium model in order to assess the economy-wide implications of changes in agricultural production.

The results showed negative economic effects. A reduction in sheep and beef output of 5% together with a reduction in dairy output of about 10% (based on the estimated effects of the 1998/99 drought) led to a reduction in private consumption of around 0.7% and a reduction in gross domestic product of over 1%. Greenhouse gas emissions declined by more than 5%.

In this paper we again analyse the effects of climate-induced changes in agricultural production, and include forestry as well. We pursue a different methodology to estimate the effects of future climate change on agricultural and forestry output. Instead of looking at adverse climatic events, notably droughts, this study is focussed on the longer term impacts of projected climate change based on a number of models and scenarios. There is also explicit modelling of the relationship between temperature, water availability and plant growth. As before the results are then fed into a general equilibrium model of the New Zealand economy.

Some of the climate change scenarios indicate more drought-like conditions, mainly for eastern regions, while others indicate little change. In addition, other regions such as Southland experience wetter and warmer conditions.

Under some scenarios the wider economic effects are negative, but most results show a positive effect. Changes in real gross national disposable income range from -0.2% to 1.8% and changes in gross domestic product vary between -0.4% and 3.9% – all relative to a situation of no climate change. Changes in agricultural and forestry output are an order of magnitude larger, with Horticultural output showing the most sensitivity to climate change.

The difference in direction between the earlier results and those obtained in this paper are largely because plants, animals and farm management are adversely affected by short term departures from 'normal' climatic conditions, whereas progressive climate change over many decades allows more time for adaptation – albeit not unlimited.

[1] Stroombergen (2008): *The Economic Implications of Climate-Induced Variations in Agricultural Production.* Infometrics report to NIWA, May.

Tait A.B.; Renwick, J.A. and Stroombergen, A.H. (2005): The economic implications of climate-induced variations in milk production. *NZ Journal of Agricultural Research*, 48, 213–225.

# 2. CLIMATE SCENARIOS

The effects of climate change on agriculture were estimated by NIWA by calculating each region's net photosynthesis using a model of the relationship between water availability and growth, as well as the regulation of growth by temperature.

*<text on methodology to come from Anthony>*

Climate changes over three future periods were examined; 2020-39 (midpoint reference year 2030), 2050-69 (2060) and 2080-99 (2090), using information from three emissions scenarios and 19 global climate models. The period 1980-99 (1990) was chosen as the baseline climate. This produced a wide range of results for each time period, as summarised in Table 1 below by the changes in Net Primary Production (NPP) at the 10$^{th}$ percentile, median and 90$^{th}$ percentile. Figure 1 shows the geographical spread of these changes.

Industry aggregation is based on 2007 land use data derived from the agri-quality data set.

**Table 1: Projected Changes in Net Primary Production**

| | All | Arable | Dairy | Horticulture | Forestry | Sheep/beef |
|---|---|---|---|---|---|---|
| | | **Percentage change in NPP: 2030-49 from 1980-99** | | | | |
| **Low-10th Percentile** | -1.45 | -1.09 | -1.78 | -1.72 | -0.66 | -1.46 |
| **Median** | 9.17 | 7.78 | 9.24 | 9.53 | 9.29 | 9.04 |
| **High-90th Percentile** | 25.47 | 18.42 | 25.39 | 23.98 | 26.61 | 26.96 |
| | | **Percentage change in NPP: 2050-69 from 1980-99** | | | | |
| **Low-10th Percentile** | -4.93 | -1.21 | -5.36 | -5.52 | -3.13 | -4.19 |
| **Median** | 15.57 | 13.93 | 15.84 | 14.83 | 16.23 | 15.31 |
| **High-90th Percentile** | 46.39 | 38.93 | 45.50 | 44.35 | 49.17 | 49.65 |
| | | **Percentage change in NPP: 2080-99 from 1980-99** | | | | |
| **Low-10th Percentile** | -12.30 | -3.70 | -13.18 | -8.15 | -10.39 | -12.74 |
| **Median** | 20.21 | 18.66 | 20.82 | 19.40 | 20.75 | 19.43 |
| **High-90th Percentile** | 75.04 | 51.86 | 73.96 | 71.86 | 78.75 | 85.08 |

The results reveal an interesting picture:

1. The changes in NPP cover a range from modest decreases to large increases, and appear to become more pronounced with time at different ends of the range.

2. As expected there is not a great deal of difference between industries given the integrated land use in New Zealand (high within region elasticity).

3. However, the detailed results show more variability, manifested as extensions to the autumn and spring growing seasons and much deeper summer droughts. Thus the aggregated results used to estimate the economic effect of climate change do not necessarily reflect risk at any given farm gate.

4. In some regions the thermal environment for plant production remains largely within the optimal range, so large changes in terms of the pasture experiencing below wilting point conditions are infrequent. Other regions see changes beyond the wilting point threshold.

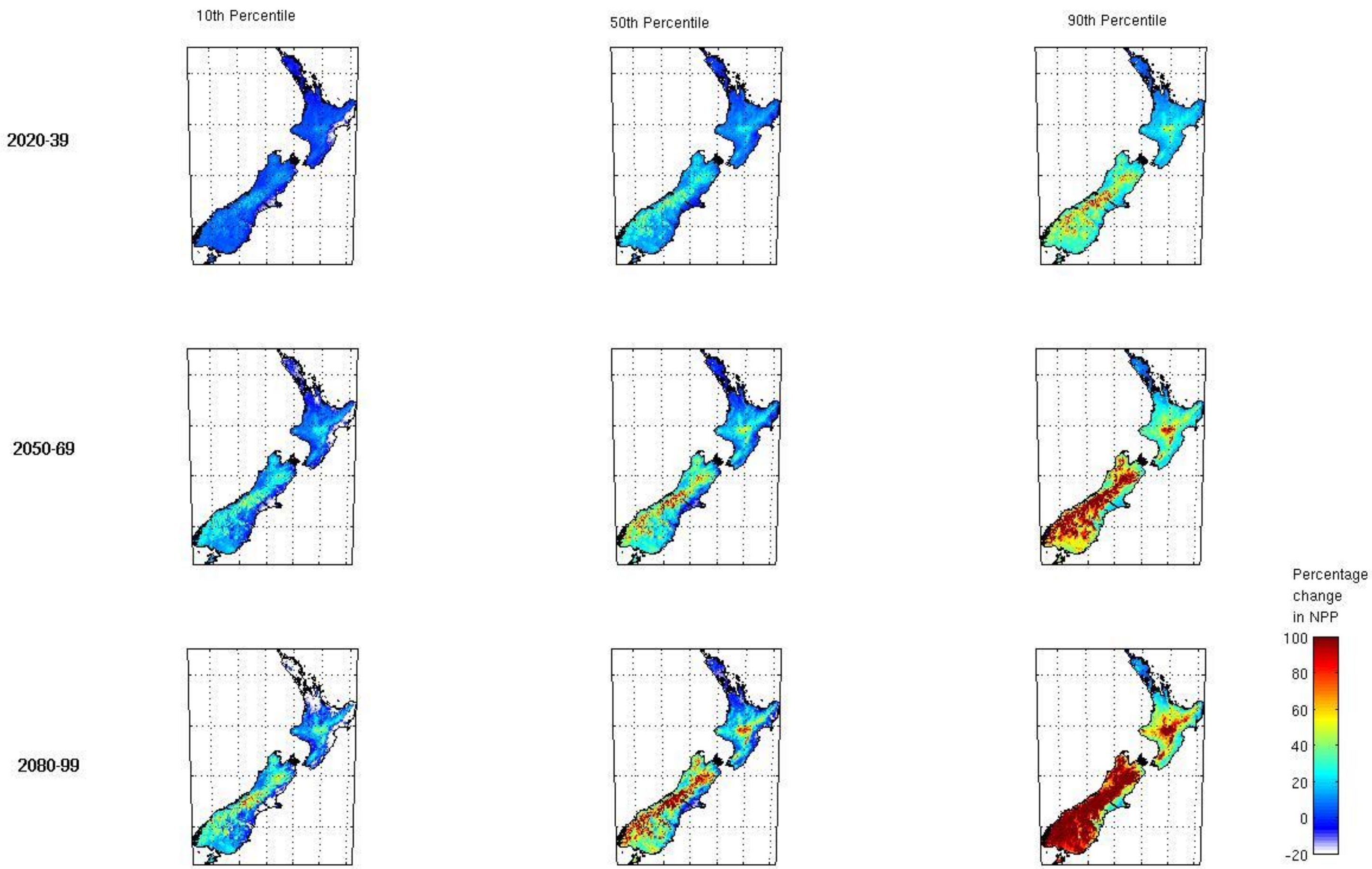
5. The usual east coast/Northland drying effect is evident, even as early as 2030 for the low scenario. There is a large range in responses across the North Island driven by inter-model rainfall variability. We also see conditions becoming too hot for growth later on in the century to the north, but enhancing it in the south.

6. Adaptation is not modelled. For example dairying might shift out of Northland, kiwifruit might move from the Bay of Plenty to Nelson, high sugar c4 grasses might be developed for the northern Waikato, and of course irrigation could be expanded in some eastern regions, although this may not always be cost-effective

7. The dominant signal if we look at the median results, is for an overall increase in New Zealand NPP over time, which stems from large increases in NPP in West Coast, Southland, Otago and central North Island regions, offset somewhat by smaller decreases or no change in Canterbury, and eastern and northern North Island.

8. The message from the range of results is that while reduced or no change in NPP for much of New Zealand is possible, there is also a significant probability of little change to substantial increases in NPP for much of the country.

**Figure 1: Projected Changes in Net Primary Production**



# 3. ECONOMIC MODELLING

## BAU Scenario

Business as Usual (BAU) scenarios are developed which represent pictures of the economy at three snapshot points in the future, in this case 2030/31, 2060/61 and 2090/91, as representative of the periods 2020-39, 2050-69 and 2080-99 respectively.

The BAUs are not necessarily the most likely forecasts of what the economy might look like. Indeed it is impossible to predict how the economy might evolve over such distant horizons. Rather the BAUs are intended to be plausible projections of the economy that can constitute a frame of reference against which other scenarios may be compared. The BAUs do not take into account any effects of climate change – not domestically nor internationally, although they do include carbon prices.

It also assumed that over time New Zealand takes on progressively tighter obligations of responsibility for emissions. Any excess needs to be covered by purchasing emission permits on the international market. Carbon prices are assumed to increase over time and New Zealand's Emissions Trading Scheme (ETS) is integrated into the world market.

**Table 2: BAU Emission Obligations and Prices**

| | 2030/31 | 2060/61 | 2090/91 |
|---|---|---|---|
| Responsibility target as % of 1990 emissions | 85% | 50% | 20% |
| Carbon price (real $NZ/tonne $CO_2$e) | $100 | $150 | $200 |

For 2030/31 it is assumed that the free allocation of New Zealand emission units will be as currently legislated under the ETS. However, for 2060/61 and 2090/91 we assume no free allocation. For all years no explicit allowance is made for net forestry emissions, as these are as likely to be positive as negative. In any case any credit or debit in this regard does not significantly alter the relative effects of climate change.

Further detail on the BAUs is given in Appendix B.

Given the BAUs the model is then 'shocked' with a number of scenarios, described in the following section.

## Climate Scenarios

The following nine climate change scenarios are examined, treating the changes in NPP in Table 1 as changes in productivity relative to BAU. That is, gross output in the four agricultural industries and in the forestry industry can change by the amounts in Table 1 without any changes in inputs of land, labour or capital. In no scenario is the model forced to increase or reduce output. The output response is endogenous, depending on the specified productivity shock, the price and scarcity of resources, the ability to sell more output in local and foreign markets, and so on.

**Table 3 Scenario Specification**

| | 2030/31 | 2060/61 | 2090/91 |
|---|---|---|---|
| Low-10th Percentile | 31L | 61L | 90L |
| Median | 31M | 61M | 91M |
| High-90th Percentile | 31H | 61H | 91H |

For all scenarios a number of macroeconomic closure rules are adopted.

1. Capital market closure: Rates of return on capital are held constant at BAU levels, with capital formation being the equilibrating variable.

2. Labour market closure: Total employment is held constant at the BAU level, with wage rates being the endogenous equilibrating mechanism. While employment may be more variable than wage rates in the short run, in the medium term the nature of the labour market in New Zealand means that how the economy adjusts to climate change is more likely to affect wage rates than employment.

3. External closure: The balance of payments is a fixed proportion of nominal GDP, with the real exchange rate being endogenous. This means that any adverse shocks are not met simply by borrowing more from offshore, which is not sustainable in the long term.

4. Fiscal closure: The fiscal surplus is held constant at the BAU level, with personal income tax rates being endogenous.

# 4. MODEL RESULTS

## BAU Scenario

Although we do not wish to place any emphasis on the BAU scenarios, especially the more distant ones, it may be useful to sketch a rough picture of what the economy might look like at least for 2030/31. Table 4 summarises the results.

**Table 4: Business as Usual Scenario to 2030/31**

| | % pa 2006-2031 | % pa 2001-2011 |
|---|---|---|
| Private Consumption | 2.1 | 2.9 |
| Investment | 2.0 | 3.9 |
| Exports | 2.8 | 2.6 |
| Imports | 2.2 | 4.3 |
| GDP | 2.2 | 2.6 |
| RGNDI | 2.3 | 2.9 |
| | | |
| Population | 0.8 | 1.3 |
| RGNDI/capita | 1.5 | 1.6 |
| | | |
| $CO_2e$ | 0.5 | 0.8 |
| $CO_2e$/capita | -0.3 | -0.5 |
| | | |
| Excess emissions (Mt) | 31.5 | NA |

* December years 2001 and 2010

In spite of the global financial crisis from 2007, the decade to 2001-2011 saw reasonable economic growth with Gross Domestic Product (GDP) rising at an average annual rate of 2.6% and Real Gross National Disposable Income (RGNDI) at 2.9% pa.[2] Population expansion meant that RGNDI per capita rose rather less quickly at 1.6% pa, but this is still marginally stronger than what is envisaged over the period to 2030/31. Projected growth is slower for a number of reasons:

- Lingering effects of the global financial crisis, both in New Zealand and overseas, the latter having a direct effect on New Zealand's exports.
- An aging labour force.
- An obligation to purchase emission permits on world markets to cover excess emissions (see previous section).
- Higher oil prices, and New Zealand still a net importer of oil based fuels.

The projected increase in $CO_2$ emissions is only 0.5% pa compared to 0.8% pa over the last decade. Slower population and economic growth contribute to this result. On a per capita basis the negative growth is attributable to emissions pricing and increases in energy efficiency, whereas the historical decline in per

[2] RGNDI is equivalent to GDP with adjustments for changes in the terms of trade and net remittances overseas.

capita emission is largely attributable to more electricity generation from renewables.

## Climate Scenarios

Table 6 summarises the macroeconomic results and the changes in gross output in the agricultural and forestry industries for each of the future scenarios.

With the magnitude of the climate shocks rising over time, positively and negatively, it is not surprising to see that the changes in GDP also increase over time, reaching a maximum of 3.9% in Scenario 91H.

The component of final demand that shows the largest increase is exports. In fact the changes in exports are about twice as large, proportionately, as the changes in GDP. Given the weight of agricultural products in New Zealand's exports, and the magnitude of the exogenous changes in NPP, this is not surprising.

However, not all of the changes in NPP are translated into more exports. Exports are not an end in themselves – they are the means to buy imports which are essential to raising economic welfare. A more favourable growing climate (or analogously a productivity enhancing technological development) means that fewer resources such as labour and capital are required to maintain a given level of agricultural exports. In fact agricultural output expands and uses fewer resources, allowing them to be allocated to the production of other consumer goods and services.

Hence private consumption also rises, with household demand being met by both more domestic production and more imports, the latter paid for by the lift in export receipts.

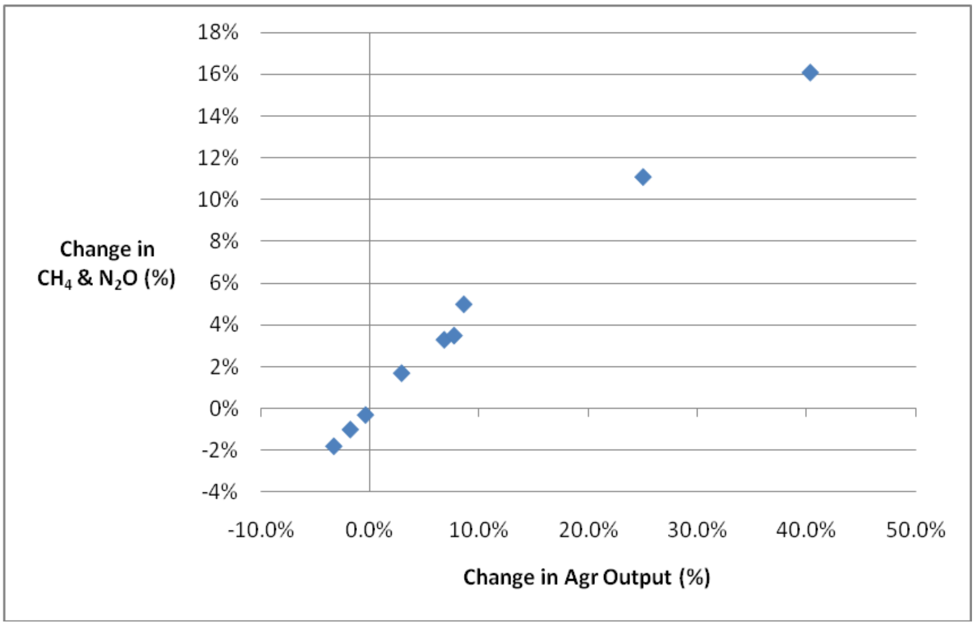
The changes in RGNDI are always less (absolutely) than the changes in GDP. This occurs for two main reasons:

1. Whenever agricultural productivity rises, output from those industries expands, leading to higher GHG emissions. As shown in Figure 2 the relationship between the change in agricultural output and the change in $CH_4$ and $N_2O$ emissions is almost linear. The extra emissions have to be offset by purchasing emissions permits on the world market, meaning that some of the increase in national income goes offshore.

   Taking Scenario 31H as an example, the increase in emissions relative to BAU of 3.3% is about 2800 MT. At a carbon price of $100/tonne the cost of emission permits is about 0.1% of GDP. This effect increases over time in line with the rising carbon price, reaching 0.5% of GDP in Scenario 91H when the much higher NPP causes total GHG emissions to rise by almost 11%, and $CH_4$ and $N_2O$ emissions by over 16%.

2. The larger effect though is from changes in the terms of trade. As agricultural production expands producers are forced down the demand curve in order to sell the extra output. Again taking Scenario 31H as an example, if there was no change in the terms of trade the change in RGNDI would be 1.2%, only just under the change in GDP. Effectively some of the benefits of higher agricultural (and forestry) productivity are transferred to foreign customers.

**Figure 2: Changes Agricultural Output and non-$CO_2$ Emissions**




Primary exporters, especially co-operatives, tend to be production-driven. Any new technology or favourable change in the climate that lowers the cost of production may generate some short-term super-normal profits, but supply rises eventually as existing farmers increase production and new entrants move into the industry. Unless the co-operative is a very small player in the market into which it sells, that increase in supply will force the co-operative to look at offering price reductions or to search for lower value markets.

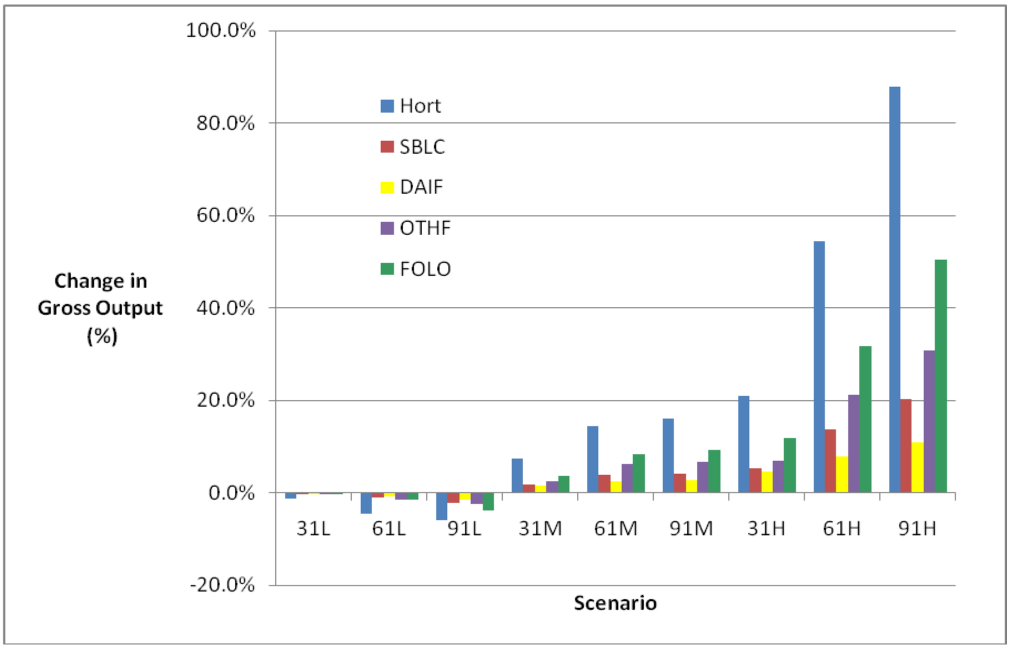
In Scenario 91H, the most optimistic of the nine examined, the increase in the volume of exports of dairy, meat, wool, horticultural products and logs is about 47%, so a reduction in the terms of trade of just under 5% is not implausible.

A new equilibrium is established, characterised by greater output and lower prices than existed before the climate-induced productivity boost. The rate of return will be as it was before, with the positive productivity effect offset by some combination of higher input costs, such as for land, and lower product prices. The relative sizes of these two effects are determined by the price elasticities of demand for output and factor substitution possibilities.

The reduction in product prices is of course beneficial to consumers, but that converts into a gain in national economic welfare (RGNDI) only if those consumers live in New Zealand. As most of New Zealand's agricultural output is exported, it is foreign consumers who capture a large part of the benefit of on-farm NPP improvements. This is manifested as a decline in the terms of trade, which is evident in Table 6. Of course foreign consumers also share in the losses when NPP declines.

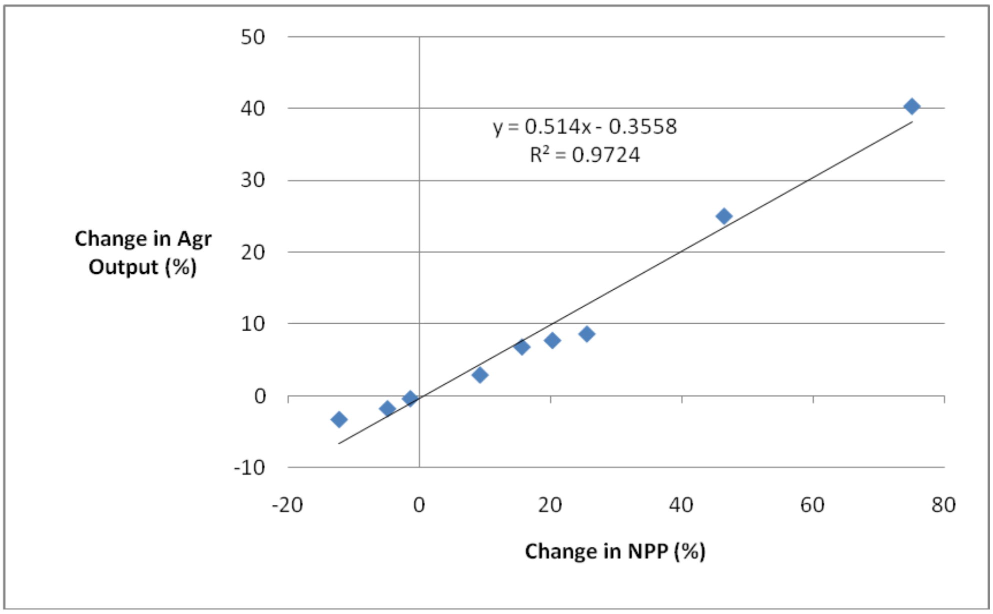
At the industry level, the agricultural sub-industry that is most sensitive to the NPP shocks is Horticulture. See Figure 3. It probably has less scope to adapt to adverse climatic shocks compared to other types of farming. Equally, under favourable climate changes production can increase without requiring much in the way of other inputs.

**Figure 3: Changes in NPP and Agricultural Output**




As shown in Figure 4 the change in agricultural production tends to be about half of the change in NPP, suggesting a combination of offsets due to higher input prices and some transfer of the positive income effects of increases in productivity spilling over to other industries. That is, because the price elasticity of demand for food is less than one, a given percentage reduction in its price is not met with a corresponding increase in demand. Some of the gain that consumers receive is instead used to buy more goods and services that have a higher income elasticity of demand. This mechanism is just the demand side of the reallocation of resources on the supply side from exporting to consumption, discussed above.

**Figure 4: Changes in NPP and Agricultural Output**




After Horticulture, Forestry shows the next largest changes in output (Figure 3), though it does also experience some of the largest NPP shocks. Log exports are more of a 'commodity' than most agricultural exports and New Zealand is a small player in the world market compared to its position in the market for goods such as milk powder, coarse wools and gold kiwifruit. Hence an increase in New Zealand production would have an imperceptible effect on world prices. Nevertheless as forestry pushes into more marginal land (even in the presence of favourable climate shocks) we might expect to see lower value logs being produced. So even if the price of any particular grade of log does not fall as supply from New Zealand rises, the average price received for a basket of New Zealand logs may decline somewhat.

### Sensitivity Test

In this scenario we re-run Scenario 91H with doubled export relative price elasticities of demand for the four agricultural commodities and logs, from the default values shown in Table 5. This is labelled Scenario 91Ha in Table 6.

**Table 5: Export Relative Price Elasticities of Demand**

| Commodity | PED |
|---|---|
| Dairy and Meat | 1.2 |
| Horticulture | 3.5 |
| Logs | 4.0 |

The higher elasticities are not intended to be of equal merit to the standard elasticities. Those for horticulture and logs are already quite high and so doubling them could lead to some unrealistic changes in output. In the case of horticulture for example the doubled elasticity means that a 10% increase in the price of horticultural products from New Zealand relative to the price of horticultural products from other countries would lead to a 70% drop in the quantity demanded.

As we are interested in knowing how the effects of a climate shock differ if some behavioural parameters (in this case export elasticities) are different, the BAU also has to be re-run with the doubled elasticities. If this is not done a comparison of Scenario 91Ha with the original BAU would confound the effects of climate change with the effects of changing the elasticities. It would be as if climate change caused the elasticities to be different.

The increase in GDP in Scenario 9Ha is 6.2% compared to 3.9% in Scenario 9H, and the corresponding figures for RGNDI are 3.8% and 1.8%. Total emissions rise by 18.0% in Scenario 9Ha compared to 10.8% in Scenario 9H, with figures for agricultural non-$CO_2$ emissions of 28.7% and 16.1% respectively.

As expected there are some dramatic increases in primary output with the Forestry harvest nearly doubling and Horticulture output surging by over 200%. Although 2090 is a distant horizon, a change of 200% still implies an extra 1.4% per annum growth over BAU in every year. Whether these sorts of increases can occur without ever more marginal land having to be used at escalating unit cost (and perhaps with undesirable environmental effects as well) is a moot point, but the implication is that the results in Scenario 9Ha are probably over-optimistic.

Perhaps the key message to take from these results is that the more price sensitive foreign consumers are, the greater the potential gain to New Zealand from favourable climate change that lowers agricultural production costs, provided the increase in foreign demand can be met without generating higher domestic costs (including environmental costs) that offset the favourable effect of the productivity enhancement. The alternative scenario is that our export mix is focused less on commodities implying less reliance on a pure quantity response as the means by which the country benefits from favourable climate change. It would also mean greater resilience to adverse climate change, which is within the probability distributions for net primary production estimated by NIWA.

## Comparison with Other Research

Tait et al (2005) and Infometrics (2008)[3], looked at the effects of climate change on agricultural production by econometrically estimating the effect of climate variability on the production of milksolids and meat, using a combined cross-section (by region) time series approach. The production effects were then incorporated into a general equilibrium model in order to assess the economy-wide implications of changes in agricultural productivity induced by climate change.

In terms of the size of effects, a change of one standard deviation in Days of Soil Moisture Deficit (DSMD) was estimated to lead to a 3-4% change in milksolids production per cow. With respect to meat, an increase of one standard deviation in DSMD was estimated to reduce the average slaughter weight of cattle by 2-3% and the average slaughter weight of sheep by about 4-7%. While these effects are statistically significant, in the case of beef they are generally smaller than the differences between regions, and in the case of sheep meat they correspond to about four years worth of ongoing productivity improvement at historical rates.

Modelling results showed that a reduction in sheep and beef output of 5% together with a reduction in dairy output of about 10% (based on the estimated effects of the 1998/99 drought) leads to a reduction in private consumption of around 0.7% and a reduction in GDP of over 1%. Greenhouse gas emissions decline by more than 5%.

While the new results confirm that the effects of climate change can be negative, positive effects predominate over the next century or so.

The main reason for this apparent inconsistency is that fundamentally different things are being examined. The earlier work captured the effects of temporary departures from normal climatic conditions – short term variability such as drought – while in this report we look at effects of persistent longer term climate change. Presumably plants and animals are better able to adapt to the latter. Of course departures from normal climatic conditions will still occur in a future where 'normal' could be climatically more favourable than in the past.

The previous econometric work dealt directly with changes in the physical amount of agricultural output – notably milksolids and meat, not with changes in Net Primary Production. While over the longer term we would expect changes in NPP to be a reasonable proxy for changes in any kind of farming output, adaption to seasonal variation with regard to water availability for example, or changes in animal physiology, could lead to divergences between NPP and animal output over the next few decades. This might mean that the NPP-based results are over-optimistic.

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[3] Op cit

Finally, a forthcoming paper by Reisinger and Stroombergen[4] uses two global models to look at the effects of climate change mitigation on world agricultural output and world agricultural commodity prices (albeit that the focus of the paper is on alternative GHG exchange rate metrics). An important finding is that worldwide the effects of climate change mitigation are expected to lead to higher agricultural prices, thus providing a counteracting force to the downward pressure in New Zealand caused by favourable climate change. If this is correct the implication is that New Zealand will enjoy even larger economic benefits from longer term climate change than those estimated above.

The final piece in the jigsaw is to understand the direct effect of climate change on world agricultural production, along the lines of exploratory research in Stroombergen (2009).[5] To further progress that research means addressing possible differences between the effects of climate change on New Zealand's agricultural output estimated by global models versus those estimated by NIWA – as above. The latter should be more accurate as in global models New Zealand is typically combined with other countries in the Asia Pacific region. Regardless of which projections are better, however, an inconsistency could arise with regard to world agricultural commodity prices as for some commodity prices the actions of New Zealand are not totally irrelevant.

[4] Reisinger, A and Stroombergen, A. (2011): *Implications of alternative metrics to account for non-$CO_2$ GHG emissions*. Report prepared for Ministry of Agriculture and Forestry.

[5] Stroombergen (2009): *The International Effects of Climate Change on Agricultural Commodity Prices, and the Wider Effects on New Zealand*. Infometrics report to Motu.

## Table 6: Summary of Results of Climate Change Scenarios

| Scenario | 31L | 31M | 31H | 61L | 61M | 61H | 91L | 91M | 91H | 91Ha |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **2030/31** | | | **2060/61** | | | **2090/91** | | |
| | Low | Median | High | Low | Median | High | Low | Median | High | High |
| AAU (MT) | 52.2 | 52.2 | 52.2 | 30.7 | 30.7 | 30.7 | 12.3 | 12.3 | 12.3 | 12.3 |
| $CO_2$ price ($/tonne) | $100 | $100 | $100 | $150 | $150 | $150 | $200 | $200 | $200 | $200 |
| | | | | | % Δ on BAU | | | | | |
| Private Consumption | 0.0 | 0.3 | 0.9 | -0.1 | 0.5 | 1.6 | -0.2 | 0.5 | 2.1 | 4.7 |
| Exports | -0.1 | 1.0 | 2.9 | -0.4 | 1.6 | 5.8 | -0.9 | 1.9 | 10.0 | 16.1 |
| Imports | 0.0 | 0.3 | 1.0 | -0.2 | 0.6 | 2.3 | -0.3 | 0.7 | 3.5 | 8.7 |
| GDP | -0.1 | 0.5 | 1.3 | -0.2 | 0.7 | 2.4 | -0.4 | 0.8 | 3.9 | 6.2 |
| RGNDI | 0.0 | 0.3 | 0.7 | -0.1 | 0.4 | 1.3 | -0.2 | 0.4 | 1.8 | 3.8 |
| Terms of Trade | 0.1 | -0.6 | -1.6 | 0.2 | -0.8 | -2.9 | 0.5 | -1.0 | -4.9 | -4.9 |
| $CO_2e$ | -0.2 | 1.1 | 3.3 | -0.6 | 2.1 | 7.1 | -1.2 | 2.3 | 10.8 | 18.0 |
| $CH_4$ & $N_2O$ | -0.3 | 1.7 | 5.0 | -1.0 | 3.3 | 11.1 | -1.8 | 3.5 | 16.1 | 28.7 |
| Gross Output | | | | | | | | | | |
| Horticulture | -1.2 | 7.3 | 20.8 | -4.5 | 14.3 | 54.4 | -6.0 | 16.0 | 87.9 | 219.1 |
| Livestock and cropping | -0.3 | 1.8 | 5.2 | -1.1 | 4.0 | 13.8 | -2.1 | 4.1 | 20.2 | 35.4 |
| Dairy cattle farming | -0.3 | 1.6 | 4.5 | -0.8 | 2.5 | 7.8 | -1.5 | 2.6 | 10.9 | 17.2 |
| Other farming | -0.4 | 2.4 | 6.8 | -1.4 | 6.1 | 21.3 | -2.5 | 6.6 | 30.9 | 62.1 |
| Forestry | -0.3 | 3.7 | 11.9 | -1.4 | 8.3 | 31.7 | -3.9 | 9.2 | 50.5 | 94.2 |

# APPENDIX A: THE ESSAM MODEL

The ESSAM (Energy Substitution, Social Accounting Matrix) model is a general equilibrium model of the New Zealand economy. It takes into account the main inter-dependencies in the economy, such as flows of goods from one industry to another, plus the passing on of higher costs in one industry into prices and thence the costs of other industries.

The ESSAM model has previously been used to analyse the economy-wide and industry specific effects of a wide range of issues. For example:

- Energy pricing scenarios
- Changes in import tariffs
- Faster technological progress
- Policies to reduce carbon dioxide emissions
- Funding regimes for roading

Some of the model's features are:

- 53 industry groups, as detailed in the table below.
- Substitution between inputs into production - labour, capital, materials, energy.
- for energy types: coal, oil, gas and electricity, between which substitution is also allowed.
- Substitution between goods and services used by households.
- Social accounting matrix (SAM) for complete tracking of financial flows between households, government, business and the rest of the world.

The model's output is extremely comprehensive, covering the standard collection of macroeconomic and industry variables:

- GDP, private consumption, exports and imports, employment, etc.
- Demand for goods and services by industry, government, households and the rest of the world.
- Industry data on output, employment, exports etc.
- Import-domestic shares.
- Fiscal effects.

### Production Functions

These equations determine how much output can be produced with given amounts inputs. A two-level standard translog specification is used which distinguishes four factors of production – capital, labour, and materials and energy; with energy split into coal, oil, natural gas and electricity. Land is also included for agriculture and forestry

### Intermediate Demand

A composite commodity is defined which is made up of imperfectly substitutable domestic and imported components - where relevant. The share of each of these components is determined by the elasticity of substitution between them and by relative prices.

### Price Determination

The price of industry output is determined by the cost of factor inputs (labour and capital), domestic and imported intermediate inputs, and indirect tax payments. World prices are not affected by New Zealand purchases or sales abroad.

### Consumption Expenditure

This is divided into Government Consumption and Private Consumption. For the latter eight household commodity categories are identified, and spending on these is modelled using price and income elasticities in an AIDS framework. An industry by commodity conversion matrix translates the demand for commodities into industry output requirements and also allows import-domestic substitution.

Government Consumption is usually either a fixed proportion of GDP or is set exogenously. Where the budget balance is exogenous, either tax rates or transfer payments are assumed to be endogenous.

### Stocks

Owing to a lack of information on stock change, this is exogenously set as a proportion of GDP, domestic absorption or some similar macroeconomic aggregate. The industry composition of stock change is set at the base year mix, although variation is permitted in the import-domestic composition.

### Investment

Industry investment is related to the rate of capital accumulation over the model's projection period as revealed by demand for capital in the horizon year. Allowance is made for depreciation. Rental rates or the service price of capital (analogous to wage rates for labour) also affect capital formation. Investment by industry of demand is converted into investment by industry of supply using a capital input- output table. Again, import-domestic substitution is possible between sources of supply.

### Exports

Exports are determined from overseas export demand functions in relation to world prices and domestic prices inclusive of possible export subsidies, adjusted by the exchange rate. Export quantities can also be set exogenously.

### Supply-Demand Identities

Supply-demand balances are required to clear all product markets. Domestic output must equate to the demand stemming from consumption, investment, stocks, exports and intermediate requirements.

### Balance of Payments

Receipts from exports plus net capital inflows (or borrowing) must be equal to payments for imports; each item being measured in domestic currency net of subsidies or tariffs.

## Factor Market Balance

In cases where total employment of a factor is exogenous, factor price relativities (for wages and rental rates) are usually fixed so that all factor prices adjust equi-proportionally to achieve the set target.

## Income-Expenditure Identity

Total expenditure on domestically consumed final demand must be equal to the income generated by labour, capital, taxation, tariffs, and net capital inflows. Similarly, income and expenditure flows must balance between the five sectors identified in the model – business, household, government, foreign and capital.

## Industry Classification

The 53 industries identified in the ESSAM model are defined below. Industries definitions are according to Australian and New Zealand Standard Industrial Classification (ANZSIC). For the five agricultural industries in the model the finer definitions are as follows.

| | | |
|---|---|---|
| A011100 | Plant Nurseries | 1 |
| A011200 | Cut Flower and Flower Seed Growing | 1 |
| A011300 | Vegetable Growing | 1 |
| A011400 | Grape Growing | 1 |
| A011500 | Apple and Pear Growing | 1 |
| A011600 | Stone Fruit Growing | 1 |
| A011700 | Kiwi Fruit Growing | 1 |
| A011910 | Citrus Growing | 1 |
| A011920 | Berry Fruit Growing | 1 |
| A011990 | Other Fruit Growing nec | 1 |
| A012100 | Grain Growing | 2 |
| A012200 | Grain-Sheep and Grain-Beef Cattle Farming | 2 |
| A012300 | Sheep-Beef Cattle Farming | 2 |
| A012400 | Sheep Farming | 2 |
| A012500 | Beef Cattle Farming | 2 |
| A013000 | Dairy Cattle Farming | 3 |
| A014100 | Poultry Farming (Meat) | 4 |
| A014200 | Poultry Farming (Eggs) | 4 |
| A015100 | Pig Farming | 4 |
| A015200 | Horse Farming | 4 |
| A015300 | Deer Farming | 4 |
| A015910 | Mixed Livestock | 2 |
| A015930 | Beekeeping | 4 |
| A015990 | Livestock Farming nec | 4 |
| A016910 | Tobacco and Hops Growing | 4 |
| A016920 | Cultivated Mushroom Growing | 4 |
| A016990 | Crop and Plant Growing nec | 4 |
| A021200 | Shearing Services | 5 |
| A021300 | Aerial Agricultural Services | 5 |
| A021900 | Services to Agriculture nec | 5 |
| A022000 | Hunting and Trapping | 5 |

| | | |
|---|---|---|
| **1** | **HFRG** | Horticulture and fruit growing |
| **2** | **SBLC** | Livestock and cropping farming |
| **3** | **DAIF** | Dairy and cattle farming |
| **4** | **OTHF** | Other farming |
| **5** | **SAHF** | Services to agriculture, hunting and trapping |
| **6** | **FOLO** | Forestry and logging |
| **7** | **FISH** | Fishing |
| **8** | **COAL** | Coal mining |
| **9** | **OIGA** | Oil and gas extraction, production & distribution |
| **10** | **OMIN** | Other Mining and quarrying |
| **11** | **MEAT** | Meat manufacturing |
| **12** | **DAIR** | Dairy manufacturing |
| **13** | **OFOD** | Other food manufacturing |
| **14** | **BEVT** | Beverage, malt and tobacco manufacturing |
| **15** | **TCFL** | Textiles and apparel manufacturing |
| **16** | **WOOD** | Wood product manufacturing |
| **17** | **PAPR** | Paper and paper product manufacturing |
| **18** | **PPRM** | Printing, publishing and recorded media |
| **19** | **PETR** | Petroleum refining, product manufacturing |
| **20** | **CHEM** | Fertiliser and other industrial chemical manufacturing |
| **21** | **RBPL** | Rubber, plastic and other chemical product manufacturing |
| **22** | **NMMP** | Non-metallic mineral product manufacturing |
| **23** | **BASM** | Basic metal manufacturing |
| **24** | **FABM** | Structural, sheet and fabricated metal product manufacturing |
| **25** | **MAEQ** | Machinery and other equipment manufacturing |
| **26** | **OMFG** | Furniture and other manufacturing |
| **27** | **EGEN** | Electricity generation |
| **28** | **EDIS** | Electricity transmission and distribution |
| **29** | **WATS** | Water supply |
| **30** | **WAST** | Sewerage, drainage and waste disposal services |
| **31** | **CONS** | Construction |
| **32** | **TRDE** | Wholesale and retail trade |
| **33** | **ACCR** | Accommodation, restaurants and bars |
| **34** | **RDFR** | Road freight transport |
| **35** | **RDPS** | Road passenger transport |
| **36** | **RAIL** | Rail transport |
| **37** | **WATR** | Water transport |
| **38** | **AIRS** | Air transport and transport services |
| **39** | **COMM** | Communication services |
| **40** | **FIIN** | Finance and insurance |
| **41** | **REES** | Real estate |
| **42** | **EHOP** | Equipment hire and investors in other property |
| **43** | **OWND** | Ownership of owner-occupied dwellings |
| **44** | **SRCS** | Scientific research and computer services |
| **45** | **OBUS** | Other business services |
| **46** | **GOVC** | Central government administration and defence |
| **47** | **GOVL** | Local government administration |
| **48** | **SCHL** | Pre-school, primary and secondary education |
| **49** | **OEDU** | Other education |
| **50** | **HOSP** | Hospitals and nursing homes |
| **51** | **OHCS** | Other health and community services |
| **52** | **CULT** | Cultural and recreational services |
| **53** | **PERS** | Personal and other community services |

# APPENDIX B: THE BAU SCENARIOS

## 2030/31

The main input assumptions for the BAU to 2030/31 are discussed below.

### Population

Population is projected using Statistics New Zealand's (SNZ) Series 5. It is based on a middle path with respect to fertility, mortality and migration; namely medium fertility, medium mortality and net immigration of an average 10,000 people per annum. This yields a projected population in 2030/31 of 5,149,000, implying an average growth rate from the model's 2005/06 base year of 0.8% per annum.

### Labour Force

The projected labour force is 2,650,000, again based on SNZ Series 5, with medium (as opposed to low or high) labour force participation rates. Implied growth from 2005/06 is 0.7% pa.

The model requires either total employment or the average wage rate to be set exogenously. Our preferred approach for the BAU is to make an assumption about the rate of unemployment and let the model produce whatever profile of wage rates is consistent with this, rather than the other way around.

In a modern economy the rate of unemployment in the long run is driven primarily by demographic factors and labour market regulations, whereas wage rates are ultimately a function of the growth of the economy. Thus it is more plausible to assume some rate of unemployment that society is prepared to tolerate, which is likely to cover a fairly narrow range, than to assume some set growth path for wages – which could easily produce totally unrealistic projections of unemployment.

We assume a long run structural unemployment rate of 3.5%; on the low side of historical rates, but recognising the projected aging of the population and the associated slow growth in labour force.

### Energy Efficiency

The model requires projections of rates of improvement in energy efficiency, often referred to in energy models as the AEEI; the Autonomous Energy Efficient Improvement parameter. This is fuel specific and hence is required for coal, natural gas, oil products and electricity.

Typically in our medium to long term modelling we have used 1% pa for all fuels except for electricity use by households where a lower rate of 0.5% pa has been used. This is not because the efficiency of household appliances is assumed to improve at a slower rate than for industrial machinery. Rather it is a crude way to capture the increasing use of electrical appliances (such as computers and television decoders) that were previously less prevalent and that are frequently left on, even if only in stand-by mode, for extended periods of time. To this one might add the increasing use of clothes driers associated with the move to apartment living, and heat pumps which, while very energy efficient, are often used for air conditioning in homes which had no air conditioning prior to installation of a heat pump.

### Oil Price

The oil price is immensely difficult to forecast. We defer to the comprehensive discussion and analysis in NZTA (2008)[6] which shows a number of projections for the price of oil in 2028 ranging between US65/bbl and US$230/bbl, with an average of about US$115/bbl (all in 2008 prices). We assume a price of US$150/bbl for 2030/31, rising thereafter as shown in the table below.

### Balance of Payments

New Zealand has a long record of persistent and pronounced balance of payments deficits. The current economic recession has led to some improvement in the current account, and we expect that in the medium to long term further improvements will occur. With other countries improving their economic management and providing profitable opportunities for investment, New Zealand will find it more difficult to attract foreign investment to cover sizeable balance of payments deficits. For 2030/31 we assume a balance of payments deficit of 3.5% of nominal GDP, improving marginally to 3% for 2060/61 and 2090/91.

## 2060/61 and 2090/91

For the BAUs to 2060/61 and 2090/91, apart from simple extrapolations of growth in productivity, energy efficiency, population and labour force, the only significant changes are as follows:

| | 2030/31 | 2060/61 | 2090/91 |
|---|---|---|---|
| Responsibility target as % of 1990 emissions | 85% | 50% | 20% |
| Carbon price (real $NZ/tonne $CO_2$e) | $100 | $150 | $200 |
| Oil price (real US$/bbl) | $150 | $200 | $250 |

[6] New Zealand Transport Agency, 2008: *Managing transport challenges when oil prices rise,* Research Report 04/08, Wellington.