The EcoClimate Report

Climate change and agricultural production

New Zealand's climate is likely to change over this century in response to increasing greenhouse gas emissions. We need to know how those changes will affect land managers and primary production systems. A report is now available that takes that first step in understanding the effect on agricultural production: Costs and Benefits of Climate Change and Adaptation to Climate Change in New Zealand: Agriculture: What do we know so far?

2007

Ministry of Agriculture and Forestry
Te Manatū Ahuwhenua, Ngāherehere

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Potential benefits and costs of a changing climate on New Zealand's future agricultural production

A consortium of national experts, EcoClimate, prepared the report using projections from global climate models as a starting point. The report uses down-scaled global models to make projections on future temperatures, rainfall and droughts across the regions of New Zealand. The economic effect of these projections was then estimated on dairy, sheep and beef farming production. The results provide useful information for New Zealand's land management sectors, including farmers, foresters, growers and regional councils, to use for risk assessment and future planning.

The EcoClimate report findings indicate that we can expect changes in the way the rural environment responds to a changing climate. For an average year in the future, the projected changes to pasture production are small when averaged across the country. Production is projected to increase in Southland and the West Coast of the South Island but production is also projected to decrease in some east coast areas and Northland. Pasture drying in spring is likely to begin earlier and there may be an earlier start to pasture growth in the late winter or spring. In response, farmers may adapt to the changes by having lambs ready for the works earlier than at present.

The report, however, paints a different picture for droughts in some regions in extreme years. The projected national decrease in pasture production due to drought is worse than the driest year in the 1972-2002 period (which includes the serious droughts of 1977/78 and 1997/98).

A literature review was also prepared on the past costs of droughts and floods affecting New Zealand agriculture. The review showed that the national costs of drought are related to the number of days of soil moisture deficit. The greater the deficit, the greater the cost is likely to be. The costs of floods depend on many factors including land use, assets at risk and vulnerability, as well as the severity of the weather event. This means that the costs of floods cannot be reliably estimated from a few simple indicators. However, the impacts and cost summaries provided in the report's appendix may be useful for risk assessment.

This report allows land managers and government to begin understanding what a changing climate may mean for land management and the best way to adapt to these changes. The government is developing a five year adaptation programme with primary sectors, Maori and local government, as part of the Sustainable Land Management and Climate Change Plan of Action.

The work within the report is an initial study, based on a limited set of climate model runs, and it contains some assumptions. The authors stress that the report should be viewed as part of a risk assessment of how production could change across the country, rather than a firm prediction for the future. The report is summarised on the following pages:

Final report [2.7M PDF]: Costs and Benefits of Climate Change and Adaptation to Climate Change in New Zealand Agriculture: What Do We Know so Far? Contract report by EcoClimate Consortium: Integrated Research on the Economics of Climate Change Impacts Adaptation and Mitigation. Wellington: Ministry of Agriculture and Forestry 112 pages.

Background to the climate study

Scientific research on global warming is well publicised and a consensus has emerged that the global climate is changing. In 2007, the Intergovernmental Panel on Climate Change (IPCC) published an impartial scientific assessment of climate change and concluded that warming of the climate system is unequivocal. It is virtually certain that warmer conditions will occur over most land areas as the century progresses, the frequency of heavy rainfall events is very likely to increase, and an increase in the area affected by droughts is likely. These findings are from the IPCC's Fourth Assessment Report and strengthen conclusions from the IPCC's previous Third Assessment Report in 2001.

Global models were run as part of the IPCC assessment processes to project how the climate could change by using a range of greenhouse gas emission scenarios. These models operate at a global scale and do not cover the effects of localised features well, like New Zealand's hills and mountains. The New Zealand EcoClimate consortium took results from model runs used in the 2001 IPCC assessment as a starting point for more localised research.

This initial New Zealand study drew mainly on results from a single global climate model, the UK Hadley Centre climate model version 2 (HadCM2), although it considered a range of possible future greenhouse gas emission scenarios. This model was selected as being one which reflects an enhancement in the west to east rainfall patterns across the country.

The consortium downscaled the model projections to this country's regions by using known relationships between broad climate patterns over the southwest Pacific region and local rainfall and temperature patterns across New Zealand. The consortium then used data from agricultural and economic research to derive relationships between climatic variations and pastoral production in New Zealand. By applying these relationships to the projected regional changes in climate, they estimated how the production of dairy, beef and sheep products could change in future. Towards the end of the study, the consortium recalculated some of the work building on the 2007 IPCC assessment work and updated some conclusions. The resulting New Zealand maps illustrate projected changes to regional climate under various scenarios.

The report is a valuable first step in understanding what a changing climate means for agricultural production but the results in this study should not be treated as firm predictions. The results should be considered sensitivity studies indicating how agricultural production could change with changing patterns of temperature and rainfall.

The report provides a starting point for further analysis. There are a number of factors that have not been assessed, including:

- the effects on production of increased carbon dioxide concentrations in the atmosphere. Plausible estimates on the effects ranged from no effect to an increased projection of 15% in pastoral production by mid-century, in areas not constrained by soil fertility
- feed or livestock transport between regions, irrigation, land use change or changes in production or demand from other countries.

Dealing with a Range of Possible Futures

How can the future be modelled when there is uncertainty in the behaviour of weather and biological systems, agricultural production, and economic outlooks? These areas are complex by themselves, and together the task becomes even more complicated.

The global rate of climate change depends on the levels of greenhouse gases emitted into the atmosphere. In turn, the amount of gases emitted depends on political decisions, as well as economic and social factors. Scenarios are used to consider a range of emission levels based on different economic and social assumptions. Models are then run using the scenarios to estimate the global temperature changes.

For this initial study the consortium drew on the scenarios used by the Intergovernmental Panel on Climate Change (IPCC) in the third and fourth assessment reports published in 2001 and 2007. To estimate the effects of climate change on future production, the EcoClimate report used downscaled climate change projections to estimate changes in the annual growing degree day values and changes in the soil moisture deficit.

The EcoClimate report uses the UK Hadley Centre model from the IPCC third assessment report and focuses on local changes corresponding to medium-low and medium-high emission scenarios. This enabled the consortium to examine how New Zealand pastoral production might change for the central 50% of the IPCC temperature projections.

For example, the global model over a certain period might indicate a temperature increase from 1 to 5 degrees centigrade (a range of 4 degrees). The basis for modelling is provided by using 25 and 75 percent of this range (2 to 4 degrees centigrade). These outcomes are referred to in the EcoClimate report as h25 and h75.

The report considers two main future 30-year periods from the third assessment report: 2020–2049, and 2070–2099. These periods are referred to by the central values, that is, as the "2030s" and "2080s", respectively. The report then analyses the differences between projections for these periods with values calculated in the 1972-2002 period. The results of these studies are presented for the entire country and by regions using the h25 (medium-low) and h75 (medium-high) values for both future periods.

National averages, regional differences

Using the downscaled models, the projected changes to growing degree days and soil moisture deficit in response to a changing climate have been estimated and plotted across New Zealand. In summary, the projections from the IPCC third assessment show that the west is likely to become wetter, the east drier and all of the country warmer. The increase in growing degree day values everywhere, and differences in soil moisture deficit across the land, will cause changes in plant growth patterns affecting agricultural productivity.

Figures 2 and 3 show the annual growing degree days and soil moisture deficit values using downscaled data from the Hadley Centre model, using the h25 and h75 values for each scenario. The annual growing degree day values are shown for 1972/73. The differences in the growing degrees days for each scenario are then shown compared with the 1972/73 base year.

The maps show that the growing degree day values increase using the medium low scenario in 2030s and again in 2080s. A greater increase is shown using the medium high scenario in 2030s and 2080s. As expected, the biggest differences are in the medium high scenario but by the 2080s in the medium low scenario in the north east of the North Islands differences are more marked.

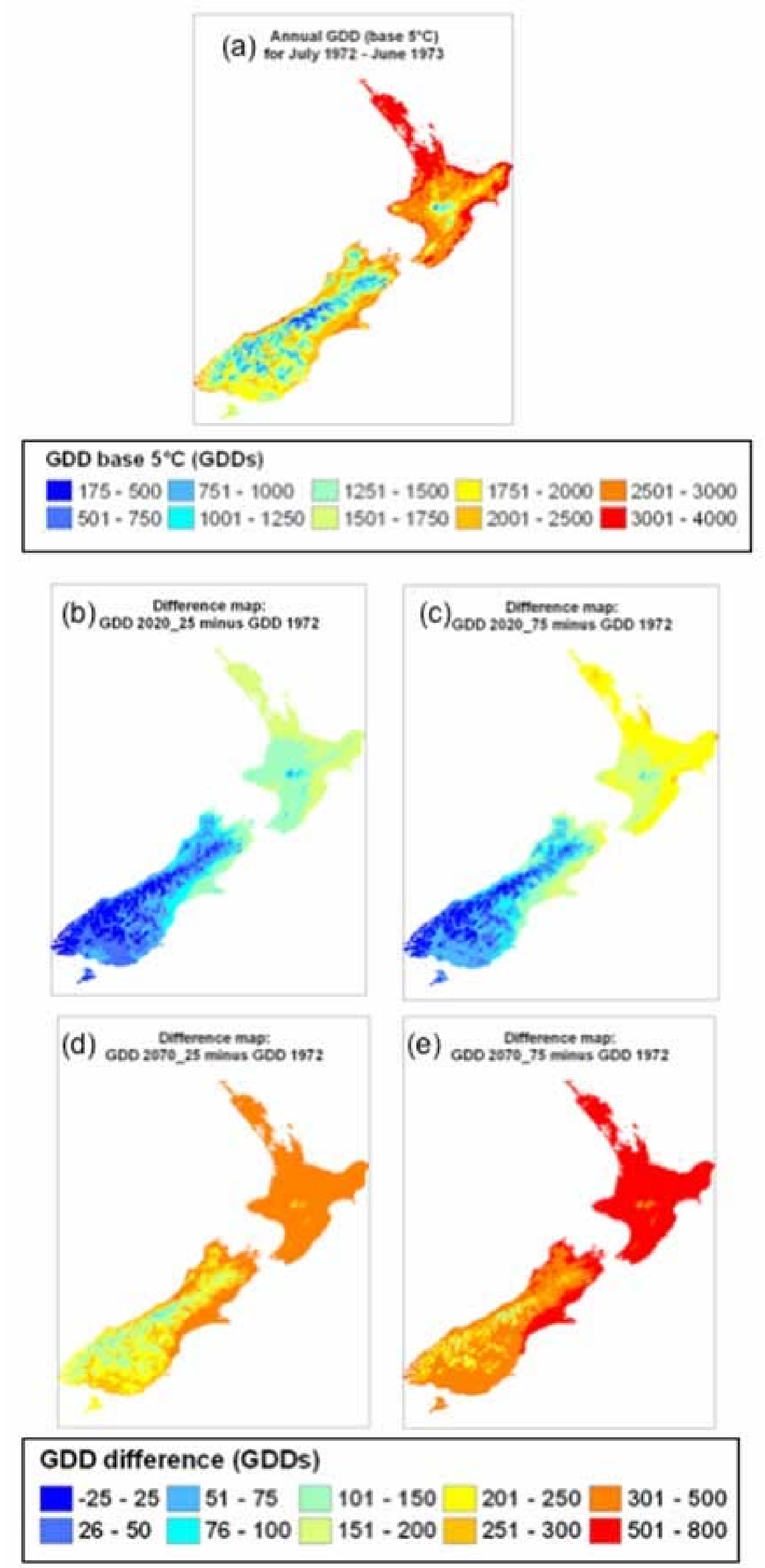

Figure 2. Examples of annual growing degree day values (GDD, base 5°C):

(a) For the agricultural year July 1972 – June 1973
(b) Increases to 2020/21, for the low-medium scenario (h25)
(c) Increases to 2020/21, for the medium high (h75)
(d) Increases to 2070/71, for the low-medium scenario (h25)
(e) Increases to 2070/71, for the medium high (h75)

Under these examples, the eastern Coromandel peninsula under the low medium scenario 2020/21 shows an increase of between 151-200 in growing degree days and by the 2070/71 this becomes an increase of between 251-300, compared with the 1972/73 year. In contrast, under a medium high scenario by 2020/21, the eastern Coromandel peninsula shows an increase of between 251-300 in growing degree days and by the 2070/71 this becomes an increase of between 500-800.

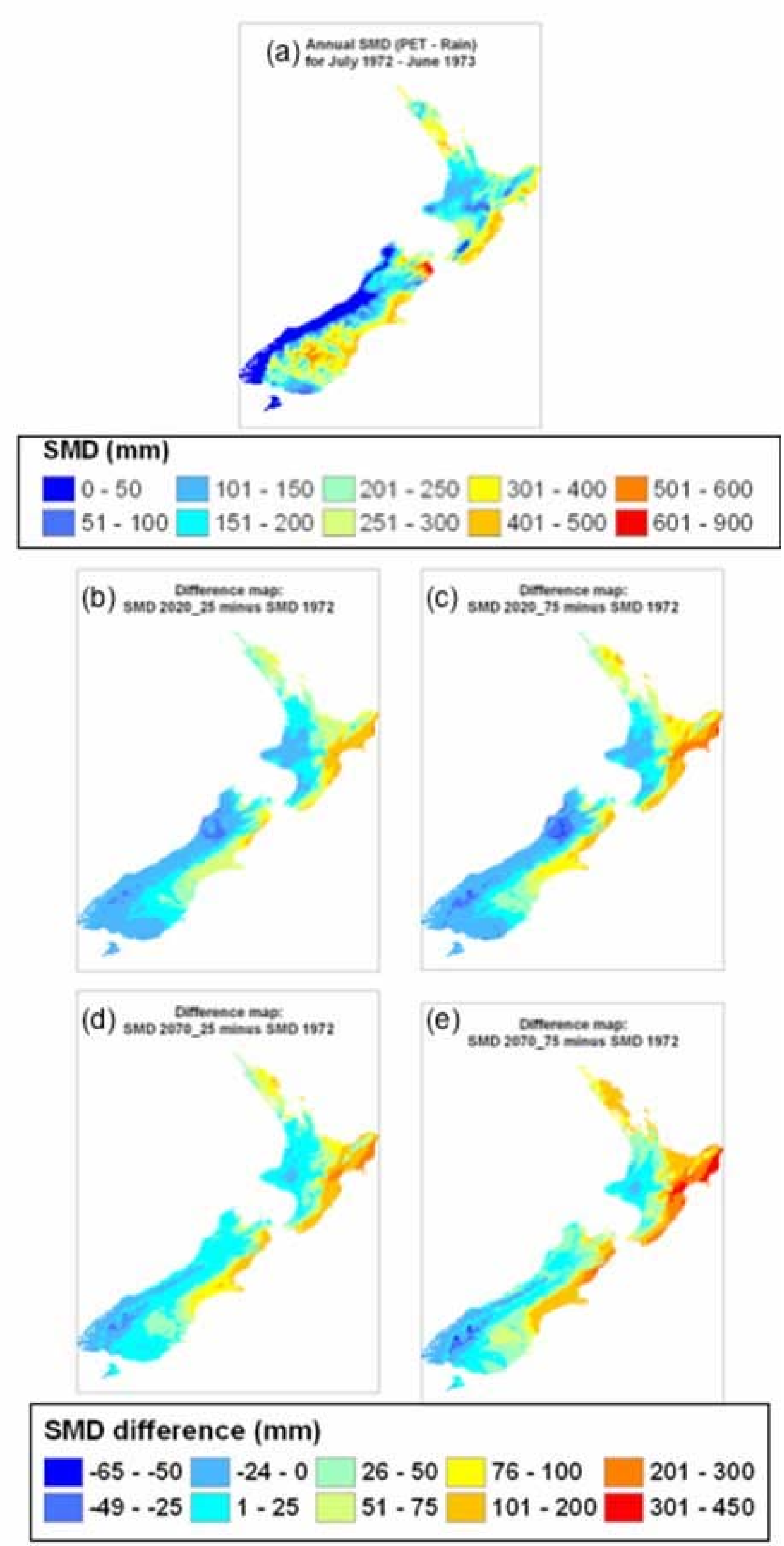

Figure 3. Examples of soil moisture deficit (SMD, mm):
(a) For the agricultural year July 1972 – June 1973
(b) Increases to 2020/21, for the low-medium scenario (h25)
(c) Increases to 2020/21, for the medium high (h75)
(d) Increases to 2070/71, for the low-medium scenario (h25)
(e) Increases to 2070/71, for the medium high (h75)

In parts of Taranaki, under the low medium scenario, soil moisture deficit decreases by 65-50 mm by 2020/21 but increases by 1-25mm by 2070/71 when compared with the 1972/73 year. This shows the effects of more westerlies bringing rain and the projected temperatures rising into the future, in turn increasing evapotranspiration.

At the time of writing the report, NIWA began downscaling the output of models from the IPCC's fourth assessment report that was released in 2007. The fourth assessment report analysed the impacts of climate change based on 12 new global climate models for the future years 2040 and 2090.

The consortium took results from downscaling the fourth assessment to do preliminary analysis on the impacts of climate change at a regional level. The later analysis is largely consistent with the earlier work based on the third assessment report and provides more information on the sensitivity of those projected changes.

For comparison's sake, work based on the fourth assessment uses one emissions scenario and the output averaged from the 12 climate models for the future years 2040 and 2090. In contrast, work on the third assessment report used one model, the Hadley model, and two emission scenarios.

One of the key differences in the new projections is the seasonality of the projected changes. There is a strong consensus between the 12 models that future temperature increases in spring will be smaller than those for the other three seasons. For scenarios of future rainfall, the 12-model average shows an important difference between the winter/spring and the summer/autumn seasons.

The winter/spring pattern, which also dominates the annual-average pattern, is for more persistent westerly winds across New Zealand. This winter/spring pattern leads to increased rainfall in western districts and reduced rainfall in the east and north of the country. In the other two seasons, especially summer, the 12-model average is for reduced westerlies over the North Island and increases in summer rainfall in the east of the North Island. However, it should be noted that there is a considerable spread across the 12 models in the projected summer rainfall changes, and some (such as the updated Hadley Centre model) still indicate decreases in the east of the North Island.

Preliminary analysis on the IPCC fourth assessment report also recalculated the annual growing degree days and soil moisture deficit and these values are shown in Figures 5 and 6.

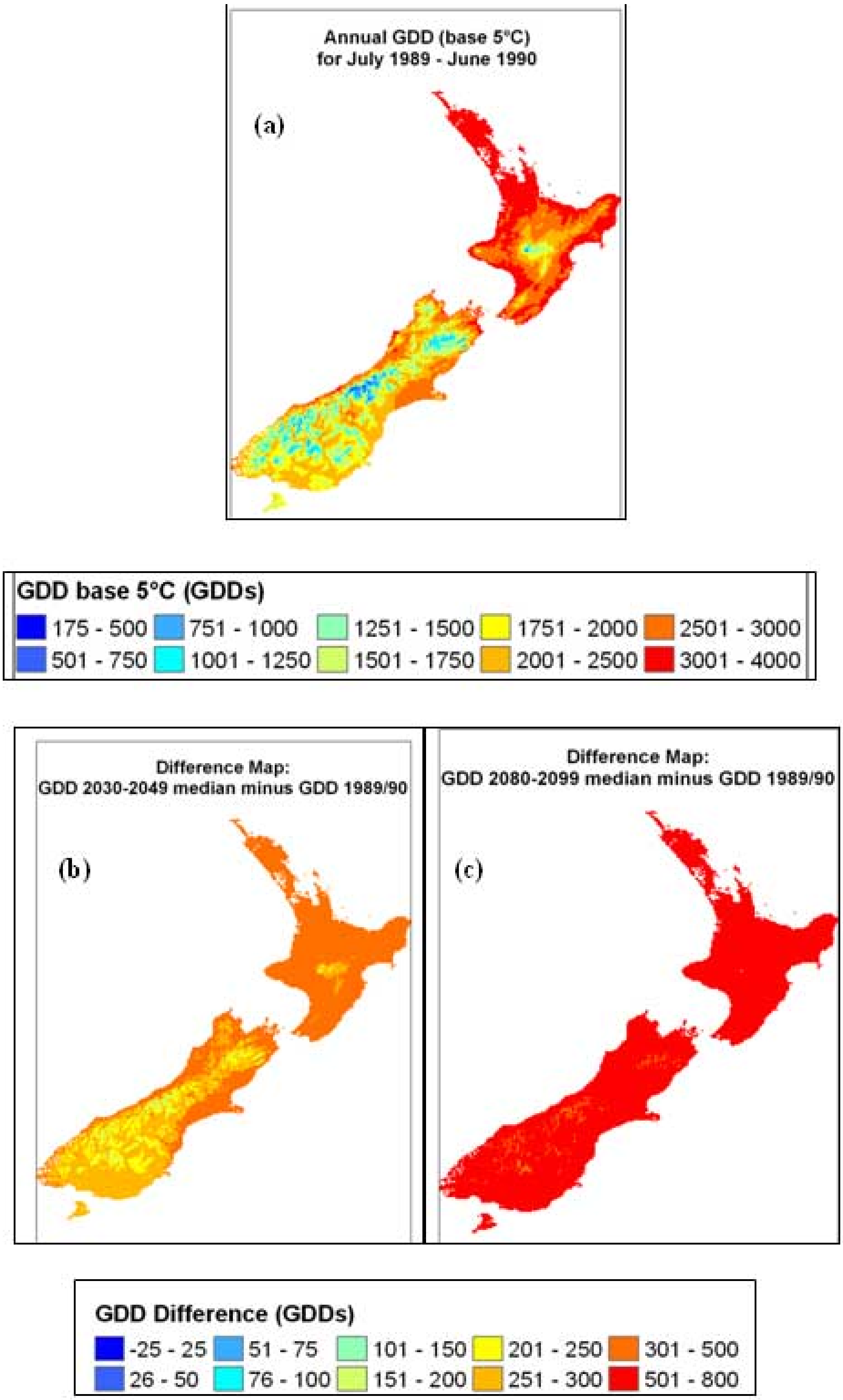

Figure 5: Examples of annual growing degree day values (GDD, base 5°C) data, downscaled from the IPCC fourth assessment report:
(a)GDD for the agricultural year July 1989 – June 1990;
(b) Increases to the 2030–2049 median GDD; and
(c) Increases to the 2080–2099 median GDD.
Under these examples, the eastern Coromandel peninsula in the 2040s shows an increase of between 301-500 in growing degree days and by the 2090s this becomes an increase of between 501-800, compared with the 1989/90 year.

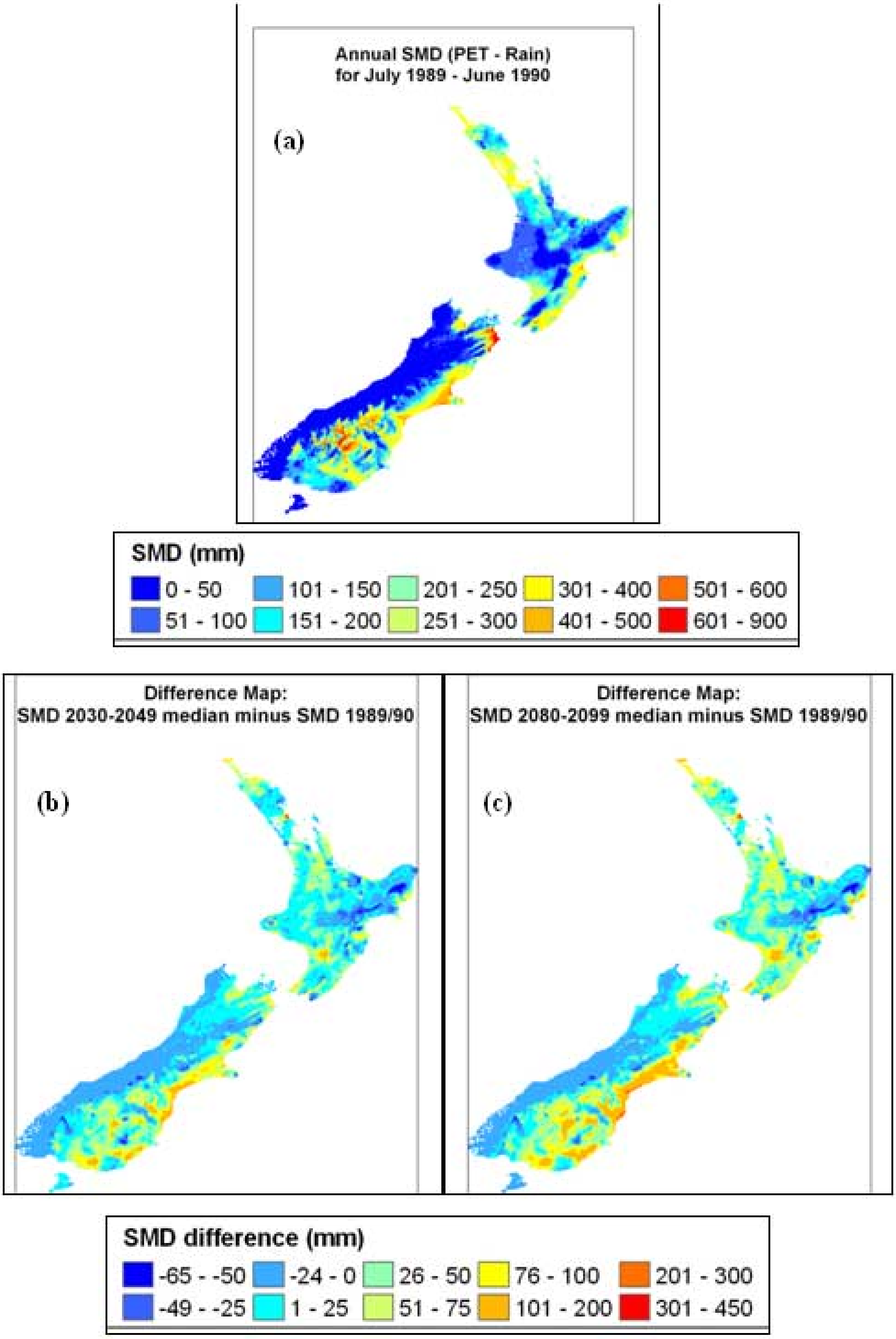

Figure 6: Examples of annual moisture deficit index (SMD, mm) data, downscaled from the IPCC fourth assessment report:

(a) SMD for the agricultural year July 1989 – June 1990;
(b) Changes to the 2030–2049 median SMD; and
(c) Changes to the 2080–2099 median SMD.

In Canterbury, the increasing soil moisture deficit is shown by the increasing amount of orange in the region in (b) and (c), when compared with the 1989/90 year.

Projected changes in production

Not all the projected effects of climate change on New Zealand agriculture are bad. Indeed on average there may be relatively little change this century across the country. But extremes, such as drought, may become worse and there are differences in how individual regions are affected.

For an *average* year later in the century, production is projected to decrease in some dry east coast locations and Northland, and to increase in Southland and the South Island West Coast, although the projected changes averaged over the whole country are small. However, the projected national decrease in production for the driest years during the two future periods considered (2030s and 2080s) is worse than for the driest year in the 1972 – 2002 period.

The EcoClimate report presents projected changes based on the Intergovernmental Panel on Climate Change (IPCC) third and fourth assessment reports. More analysis was completed on the production impacts using the third assessment scenarios due to the earlier timing of the original work and availability of the fourth assessment's downscaled data.

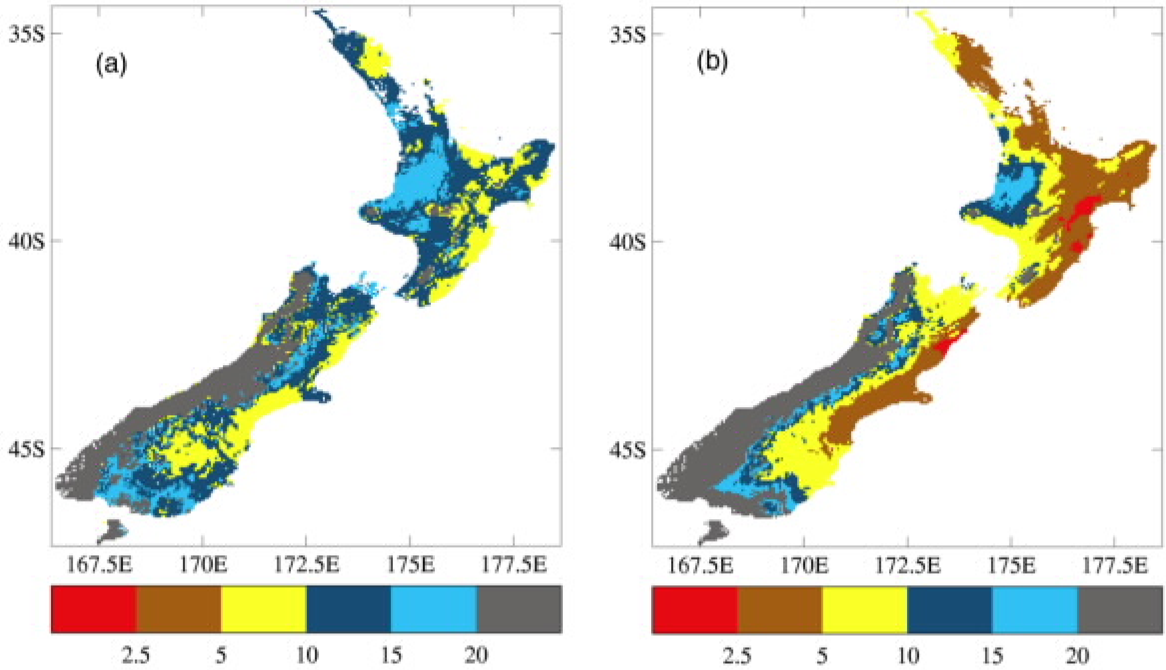

Figure 7: Projected changes to the frequency of droughts.

The projected driest annual conditions in 2080s under (a) low medium and (b) medium high scenarios for conditions that currently occur on average once every 20 years. For example: In the left hand map Timaru is yellow, meaning that rather than a drought occurring (on average) once every 20 years, the drought could occur between once every 5 years and once every 10 years i.e. 2 to 4 times more frequently than at present.

The report's key findings are:

For average years, the projections show no strong increase or decrease during the coming century in production when averaged over the whole country. Projected national dairy production ranges from 96 to 101%, and projected sheep/beef production from 91 to 96% of the 1972–2002 average. See Figures 8, 9, 10 and 11 for projections derived from the Hadley Centre (HadCM2) model. Projections from the fourth assessment downscaling work are shown in Figures 12, 13 and 14.

- Flows in the rivers fed from the Southern Alps in Canterbury and Otago are expected to increase (on average) under most climate change scenarios. Water supply reliability from irrigation systems fed from this source may increase. But it is yet unclear whether the increased water supply will compensate for an increase in demand.
- Agricultural areas in eastern New Zealand outside Canterbury and Otago are likely to face greater shortages of water in future. This includes Northland, Hawke's Bay and parts of the Tasman and Marlborough regions.
- Compared to 1990, the number of Growing Degree Days (base 5°C) in the 2080s may increase by as much as 500–800 growing degree days for most of the North Island, and for some northern and eastern parts of the South Island (from South Canterbury north). For comparison, currently the average growing degree days exceed 3000 in warmer parts of the North Island.
- Improvements in production are projected for both dairy and sheep/beef in the West Coast and Southland. These regions are likely to remain wetter with a warming climate.
- As the century progresses, the drying of pasture in spring is likely to begin earlier; the projected increase in temperatures and growing degree days may give rise to an earlier start to pasture growth in the late winter or spring. Farmers might choose to bring forward some of their operations in response to the changes, for instance, lambs may be ready for the works earlier than at present.
- Using the Hadley Centre (HadCM2) model, the projected driest years in the 2030s and 2080s are worse for national average production than the worst climatic year between 1971 and 2002. In that worst year, estimated production was 64% of the long-term average for dairy, and 67% of the long-term average for sheep/beef. Under the climate change scenarios, the projected worst years reach only 52% and 50% of the long-term average production for dairy and sheep/beef respectively.
- There is little change between the national average production figures derived from the third and fourth assessment reports. Table 1 below shows national pasture production from areas under high producing pasture in 2002, relative to the median year during the recent period (1989/90).

Period	Median	Worst
Recent	Reference	70.9%
2030–2049	100.2%	51.9%
2080–2099	103.1%	51.7%

- A decline is projected for dairy and sheep/beef production in an average-year and worst-year production in the east coast (Bay of Plenty, Gisborne, Hawke's Bay, Wellington, Canterbury), and also for Northland. These projections use the data derived from the Hadley Centre model downscaled from the IPCC third assessment report. Tables 2, 3, 4 and 5 provide a breakdown by region for average and worst years.
- Analysis of the IPCC third assessment report suggests that Hawke's Bay and Gisborne are particularly vulnerable to increased frequency of successive dry years in the future. However, subsequent modelling based on the IPCC Fourth Assessment Report suggests that Gisborne may not be as badly affected. Changes in El Niño conditions in the future may also influence the impact of climate change.
- The projected impacts on dairy production and sheep/beef production, using the Hadley Centre model from the third assessment report are shown in Figures 8, 9, 10 and 11. The average-year and average worst years are shown for the 2030s and the 2080s for both the low-medium and medium-high scenarios. For comparison, relative production projections derived from the fourth assessment report are shown in Figures 12, 13 and 14.

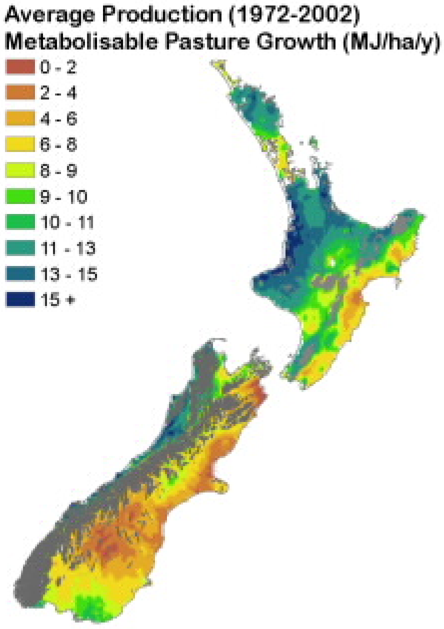

Figure 8: Estimates of average pasture production for the period July 1972–June 2002. This combines estimated above ground dry matter production with digestibility of herbage for ruminant animals. Areas shown in grey are Land Use Capability Class 8 (Mountain Land) unsuitable for any pastoral use.

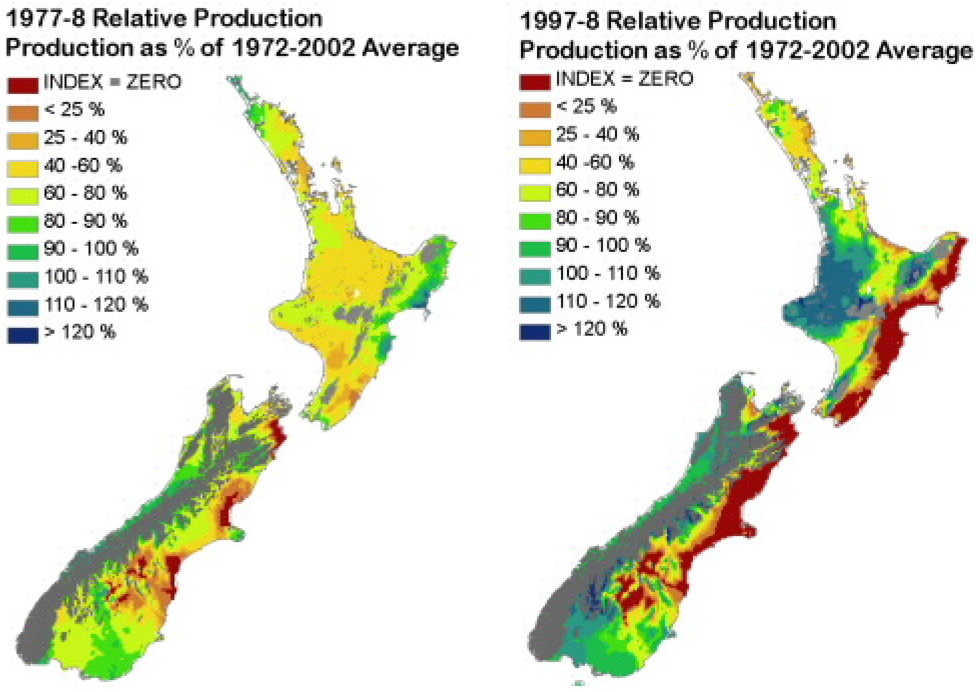

Figure 9: Relative production estimates (compared to the 1972–2002 average) based on metabolisable pasture growth estimates, for two agricultural years with unusually dry conditions over parts of New Zealand (1977/78 and 1997/98). Areas shown in grey are Land Use Capability Class 8 (Mountain Land) unsuitable for any pastoral use.

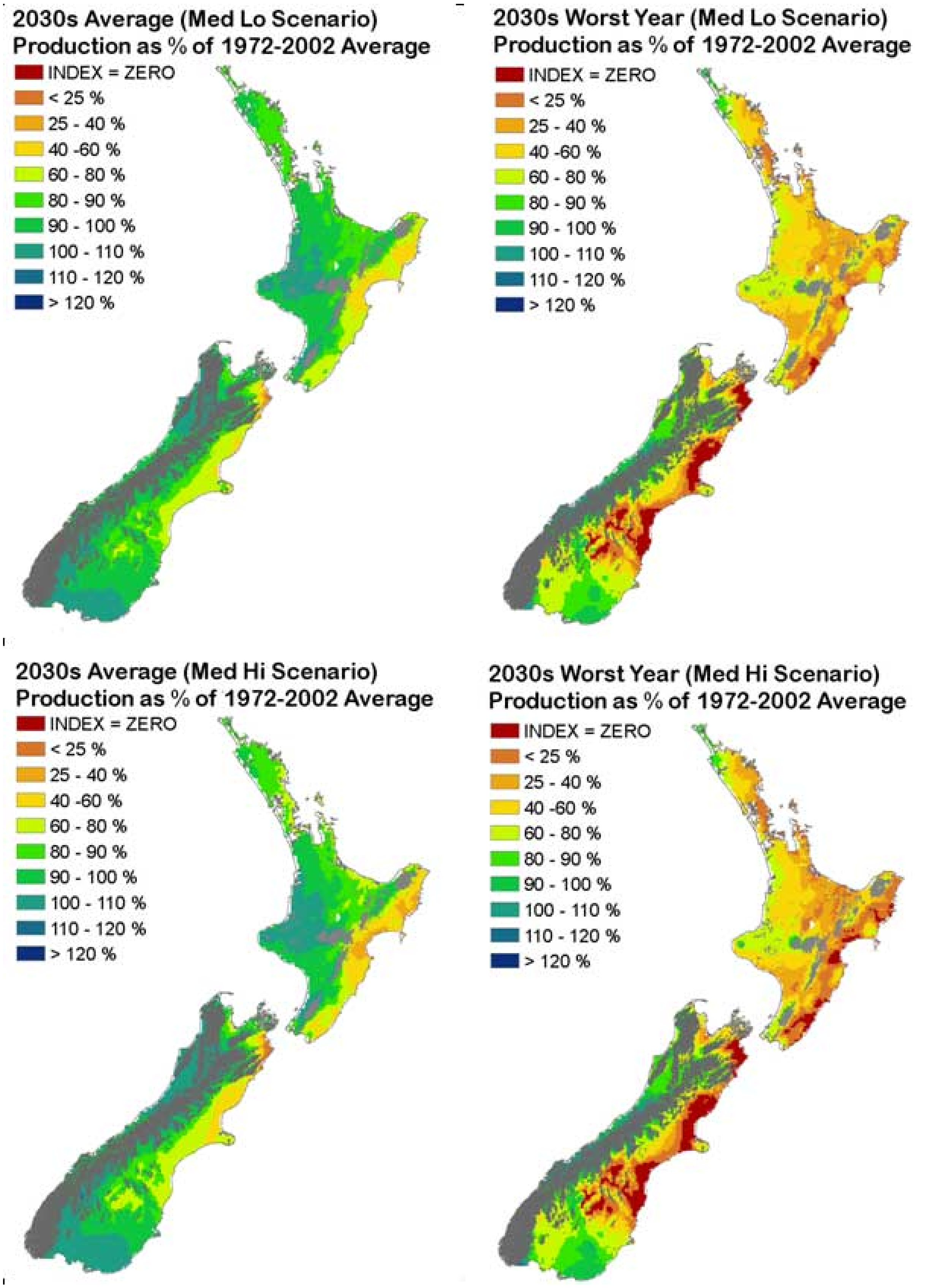

Figure 10: Relative production projections for the 2030s, based on the Hadley model and metabolisable pasture growth estimates. Areas shown in grey are Land Use Capability Class 8 (Mountain Land) unsuitable for any pastoral use.

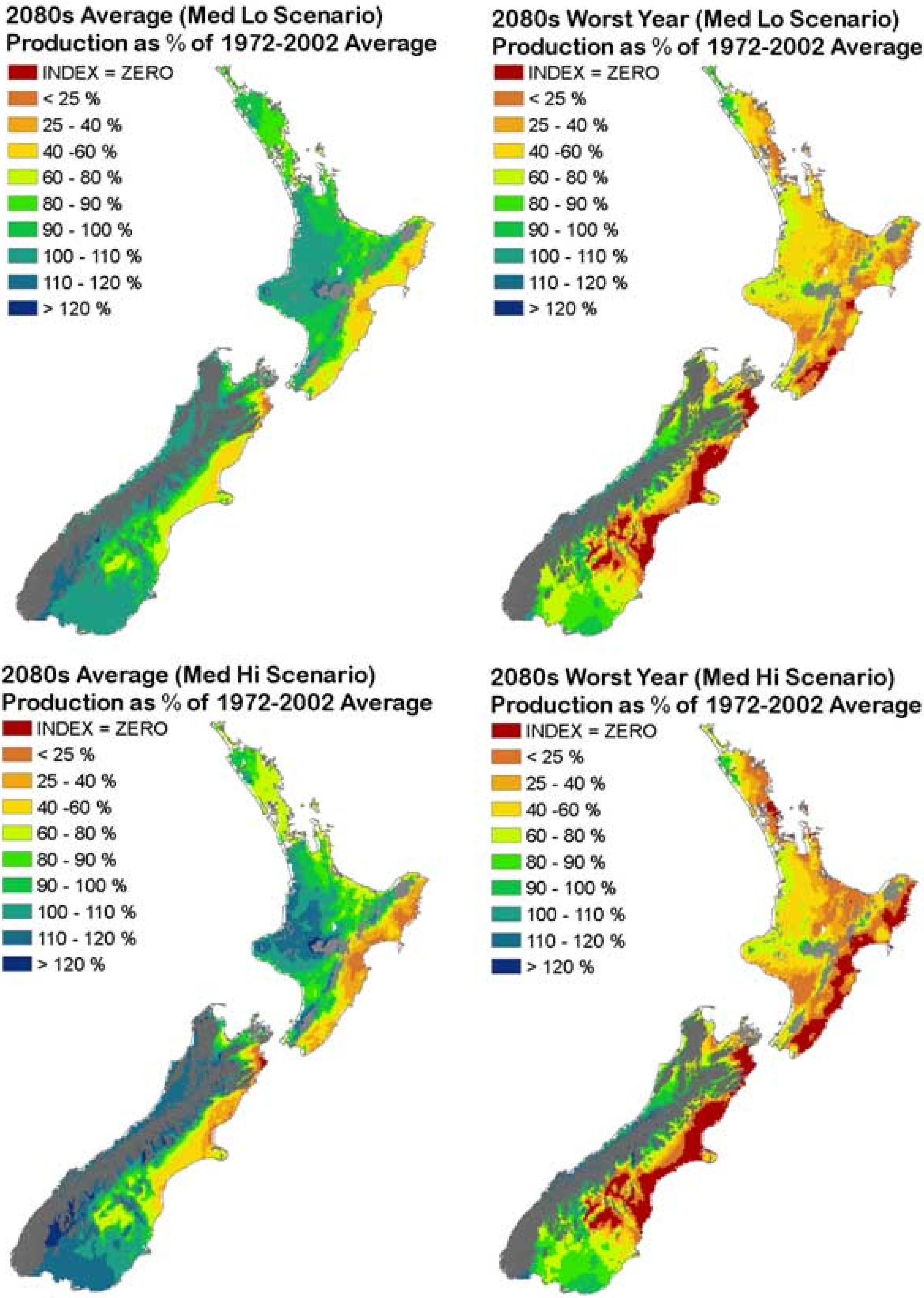

Figure 11: Relative production projections for the 2080s, based on the Hadley model and metabolisable pasture growth estimates. Areas shown in grey are Land Use Capability Class 8 (Mountain Land) unsuitable for any pastoral use.

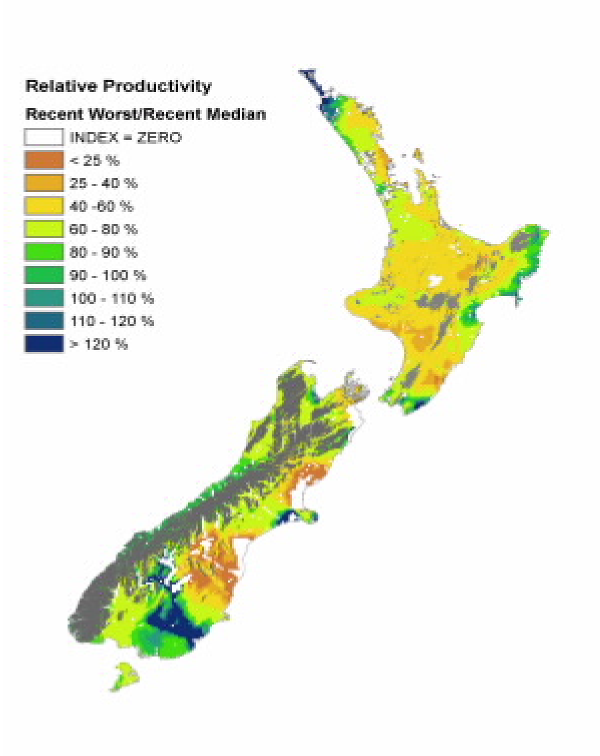

Figure 12: Relative production estimate (compared to 1989/90; the 1972–2001 median year) based on metabolisable pasture growth estimates for 1977/78. This agricultural year had unusually dry conditions over parts of New Zealand. Areas shown in grey are Land Use Capability Class 8 (Mountain Land) unsuitable for any pastoral use. Note, the index=zero areas on these maps are now coloured white, where previously they were coloured red).

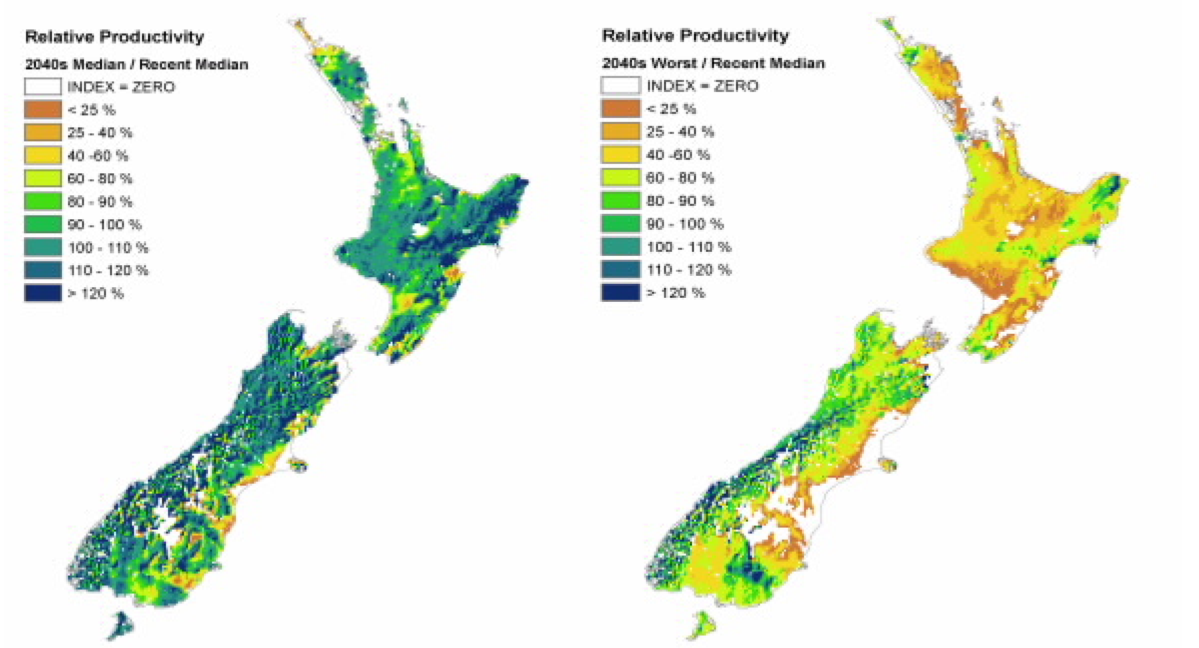

Figure 13: Relative production projections for the period 2030–2049, based on the later IPCC models and metabolisable pasture growth estimates. Note, the index=zero areas on the AR4 maps are now coloured white, where previously they were coloured red).

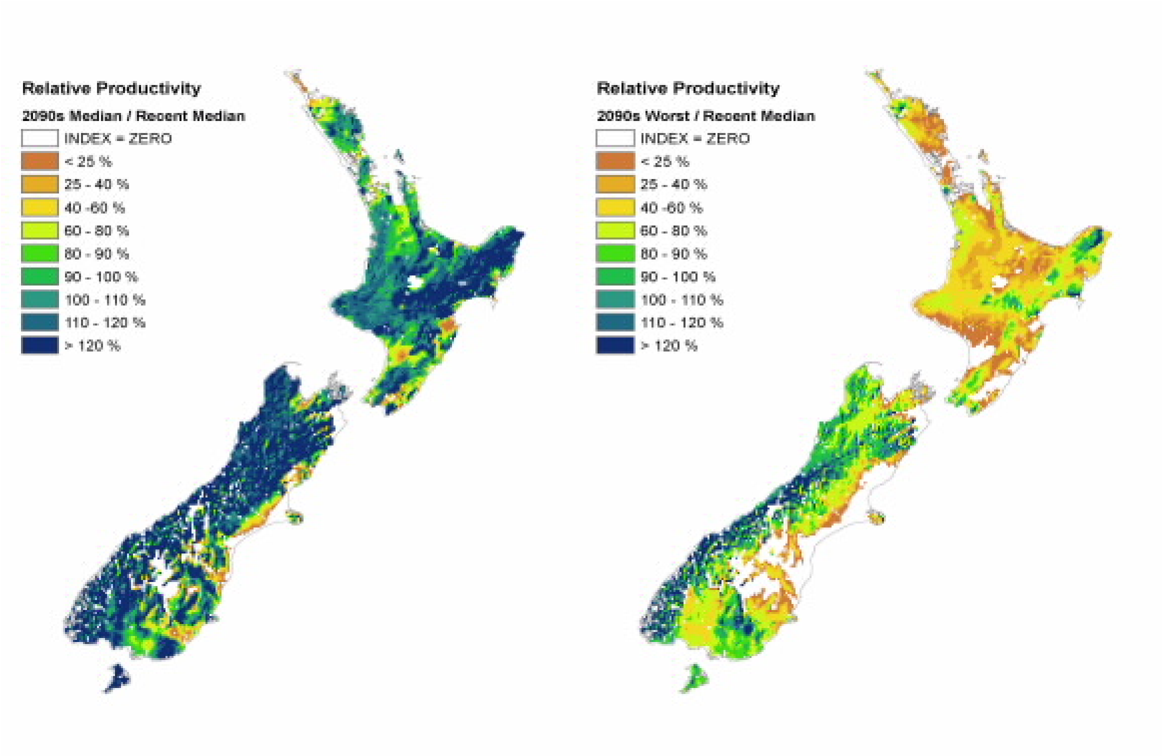

Figure 14: Relative production projections for the period 2080–2099, based on later IPCC models and metabolisable pasture growth estimates. Note, the index=zero areas on the AR4 maps are now coloured white, where previously they were coloured red).

Table 2: Average projected effect on national export revenue of dairy in an average year.

	2030s		2080s	
Region	Low-Medium (h25)	Medium High (h75)	Low-Medium (h25)	Medium High (h75)
Northland	92%	88%	91%	81%
Auckland	94%	90%	94%	86%
Waikato	98%	97%	102%	101%
Bay of Plenty	90%	85%	93%	83%
Gisborne	72%	61%	68%	48%
Hawke's Bay	68%	57%	63%	44%
Taranaki	104%	105%	108%	113%
Manawatu-Wanganui	100%	100%	102%	101%
Wellington	86%	80%	81%	69%
Tasman	98%	97%	103%	104%
Nelson	121%	120%	103%	126%
Marlborough	93%	90%	98%	94%
West Coast	104%	105%	111%	116%
Canterbury	93%	90%	98%	96%
Otago	101%	102%	105%	108%
Southland	104%	105%	111%	118%
Total	98%	96%	101%	100%

Table 3: Average projected effect on national export revenue of dairy in a worst year.

Region	2030s Low-Medium (h25)	2030s Medium High (h75)	2080s Low-Medium (h25)	2080s Medium High (h75)
Northland	54%	48%	53%	39%
Auckland	39%	34%	39%	29%
Waikato	52%	49%	54%	49%
Bay of Plenty	37%	29%	39%	21%
Gisborne	41%	27%	41%	16%
Hawke's Bay	47%	32%	44%	19%
Taranaki	63%	63%	61%	57%
Manawatu-Wanganui	47%	45%	41%	34%
Wellington	40%	33%	32%	22%
Tasman	60%	58%	61%	58%
Nelson	76%	74%	76%	66%
Marlborough	64%	60%	67%	61%
West Coast	93%	95%	95%	98%
Canterbury	62%	58%	64%	61%
Otago	75%	75%	72%	72%
Southland	86%	88%	88%	90%
Total	57%	54%	57%	52%

Table 4: Average projected effect on national export revenue for sheep and beef in an average year.

Region	2030s Low-Medium (h25)	2030s Medium High (h75)	2080s Low-Medium (h25)	2080s Medium High (h75)
Northland	93%	88%	92%	82%
Auckland	95%	91%	94%	87%
Waikato	100%	99%	105%	105%
Bay of Plenty	89%	83%	91%	81%
Gisborne	70%	58%	66%	46%
Hawke's Bay	67%	55%	61%	41%
Taranaki	104%	104%	108%	111%
Manawatu-Wanganui	98%	97%	101%	99%
Wellington	81%	72%	74%	57%
Tasman	98%	97%	103%	104%
Nelson	97%	94%	97%	97%
Marlborough	91%	87%	97%	93%
West Coast	104%	105%	111%	116%
Canterbury	87%	82%	88%	79%
Otago	101%	101%	106%	109%
Southland	104%	106%	112%	119%
Total	94%	91%	96%	93%

Table 5: Average projected effect on national export revenue for sheep and beef in a worst year.

	2030s		2080s	
Region	Low-Medium (h25)	Medium High (h75)	Low-Medium (h25)	Medium High (h75)
Northland	55%	50%	55%	41%
Auckland	46%	41%	46%	38%
Waikato	54%	52%	55%	52%
Bay of Plenty	38%	31%	38%	19%
Gisborne	42%	27%	41%	20%
Hawke's Bay	40%	25%	36%	15%
Taranaki	63%	63%	61%	57%
Manawatu-Wanganui	47%	45%	43%	38%
Wellington	26%	18%	18%	10%
Tasman	61%	60%	62%	59%
Nelson	61%	57%	64%	58%
Marlborough	65%	61%	68%	63%
West Coast	93%	95%	95%	98%
Canterbury	43%	38%	41%	35%
Otago	75%	75%	73%	72%
Southland	83%	85%	84%	88%
Total	57%	54%	56%	50%

Key definitions and concepts

Key concepts in the research, the resulting maps and their interpretation are Soil Moisture Deficit (SMD), Growing Degree Days (GDD), and drought.

Growing Degree Days, base 5°C: Growing degree days, base 5°C is a temperature-based parameter for assessing field crop growing requirements. If the average air temperature on a particular day exceeds 5°C, the daily growing degree day value is calculated as the mean daily air temperature minus 5. If the daily mean air temperature does not exceed 5°C, the daily GDD value is set to zero. Growing degree days are added over a set period, in this case July to the following June. As an example, the average annual growing degree day can exceed 3000 in warmer parts of the North Island and can be less than 1000 in cooler higher parts of the South Island. All these values are predicted to change in response to a changing climate.

Soil Moisture Deficit: Soil moisture deficit is a measure of how dry the soil is for plant growth and is also known as the "wilting point deficit" or "potential evapotranspiration deficit" (PED). It is obtained by running a daily "budget" for the amount of moisture in the soil taking into account rainfall (which adds to the daily balance) and evaporation of moisture through a crop or a grass field (which subtracts from the daily balance).

SMD is also known as the "wilting point deficit or potential evapotranspiration deficit". Once the soil moisture level has reached the wilting point (half of the available water capacity (AWC) of the soil), any continuing period of dry weather is summed at the daily rate of the potential evapotranspiration to give the total deficit. The total deficit values have been estimated from a water balance model which uses inputs of rainfall and potential evapotranspiration, and assumes the AWC of the soil is 150mm.

Drought is a sustained period of high soil moisture deficit. The report defines a drought as having a soil moisture deficit of 200 mm. Severe droughts like those in 1977/78 and 1997/98 have major economic effects and have an estimated soil moisture deficit of 400mm.

While most of the economy recovers from a drought in the next growth year (usually taken from 1 July to 30 June), it is much more difficult to recover from two drought years in a row. The report also calculates the risk of droughts occurring more than once.

The **EcoClimate** Consortium consists of scientists and researchers from GNS, the New Zealand Centre for Ecological Economics, Motu, AgResearch, NIWA, Infometrics, and Landcare Research.

Figure 1: New Zealand Regional Council Boundaries. Source: Statistics New Zealand