Changes in drought risk with climate change

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Executive Summary

As human activity adds more greenhouse gas to the atmosphere, most climate change scenarios predict rising temperatures and decreased rainfall in the east of New Zealand. This means eastern parts of the country are expected to experience more droughts as the 21st century goes on. Our report seeks for the first time to define the possible range of changes in future drought risk.

This report was commissioned because of the importance of drought for agriculture and water resources. The report aims to give central and local government and the agriculture sector an indication of how big future drought changes could be in the various regions. This information can be relevant in managing long-term water resources and land use, including planning for irrigation schemes.

Methods Used

Nobody can predict exactly how much New Zealand's climate will change. Future greenhouse gas concentrations depend on global social and economic development, climate projections differ between models, and natural climate variability adds a further complication. But that is not to say that 'anything goes'. Rather, it means that there is a range of plausible scenarios in response to the question 'How will climate change affect future drought risk?'

In this report we investigate four scenarios, by combining two different global-average temperature projections with two different regional patterns as produced by two climate models. The two global temperature projections span the central portion but not the full range of possible global temperature changes developed by the Intergovernmental Panel on Climate Change for their 2001 Climate Change Assessment. For the models used, the global temperature increase by the 2080s ranges from 1.8°C to 2.9°C. The global models predict trends in broad climate patterns across the Pacific. These are "downscaled" to produce more locally-detailed New Zealand projections, using a statistical technique that accounts for the effect on climate of New Zealand's topography. One model predicts there would be even more rain falling in the west of New Zealand and less in the east than at present. The other model predicts only a small change in the west/east rainfall compared to the present day. Both models predict a general warming of New Zealand, but at a lesser rate than the global average.

In this Summary we highlight just two of these scenarios: a "low-medium" scenario coupling the lower global temperature projection with the downscaled climate model having the small west/east rainfall change, and a "medium-high" scenario which couples the higher global temperature projection with the downscaled model in which the west/east rainfall ratio changes significantly. The low-medium scenario and the medium-high scenario bracket many of the most plausible projections for future New Zealand climate change (including our other two scenarios that are discussed in the main report) and hence provide useful guidance for decision-makers.

Drought is caused by a number of climatic factors, including how much rain falls, how high temperatures are, and how much wind the country experiences. We have used the 'potential evapotranspiration deficit' (*PED*), accumulated over a July to June 'growing year' as our measure of drought. This measure incorporates all three of the above climatic factors. Accumulated *PED* is the amount of water that would need to be added to a crop over a year to prevent loss of production due to water shortage. For pastures not receiving irrigation, an increase in accumulated *PED* of 30 mm corresponds to approximately one week more of pasture moisture deficit (reduced grass growth). In this study, drought *risk* is defined as the probability that a given level of dryness, expressed as accumulated *PED,* is exceeded in any given year.

Key Findings

1. Drought risk is expected to increase during this century in all areas that are currently already drought-prone, under both the 'low-medium' and the 'medium-high' scenarios.

2. Under the 'low-medium' scenario, by the 2080s severe droughts (defined in this report as the *current* one-in-twenty year drought) are projected to occur at least twice as often as currently in the following areas: inland and northern parts of Otago; eastern parts of Canterbury and Marlborough; parts of the Wairarapa; parts of Hawkes Bay; parts of the Bay of Plenty; and parts of Northland (see Figure ES1).

3. Under the 'medium-high' scenario, our results suggest that the frequency of severe drought in these areas could increase even more. By the 2080s, severe droughts are projected to occur more than four times as often in the following regions: eastern parts of North Otago, Canterbury and Marlborough; much of the Wairarapa, Bay of Plenty and Coromandel; most of Gisborne; much of Northland. For many of the other eastern regions, the frequency of severe drought is projected to at least double by the 2080s under this scenario (see Figure ES2).

4. Water deficits in an average year are projected to increase by between about 50 mm and 250 mm *PED* in the driest regions by the 2080s, depending on the climate scenario and location. Annual averages are currently about 300-500 mm *PED* in these areas. In some dry areas, a 200 mm increase in average annual *PED* would mean that a drought of medium severity (such as the 1991/92 drought in Canterbury) could become the yearly norm in those areas by the 2080s.

5. The projected increased *PED* accumulation over the year would probably produce an expansion of droughts into the spring and autumn months. For the 'medium-high' scenario, the drying of pasture in spring is advanced by about a month in the 2080s in dry eastern regions, relative to the present climate.

6. The table below summarises changes in severe drought risk for characteristic locations in some currently drought-prone locations.

Location	Present *PED* (mm) 1 in 20 yr drought	2080s, low-med scenario. *PED*(mm), 1 in 20 yr drought	2080s, med-high scenario. *PED*(mm), 1 in 20 yr drought	2080s, low-med scenario. Average return interval (yrs) for current 1 in 20 yr drought	2080s, med-high scenario. Average return interval (yrs) for current 1 in 20 yr drought
Ranfurly (N. Otago)	645	700	725	8.5	6.5
Darfield (E.Canterbury)	465	515	650	10.5	3.5
Blenheim (E. Marlborough)	895	955	1035	12.0	7.0
Napier (Hawkes Bay)	740	820	1010	9.5	2.5
Whangarei (Northland)	415	465	580	8.0	3.0

We use the 1-in-20 year drought (i.e., a drought that on average occurs only once in 20 years) as the measure for a 'severe' drought. The first three columns of the table provide information on how dry the current and future 1-in-20 year droughts could be. The last two columns indicate how often a drought that *currently* occurs once in 20 years, on average, could occur in future.

Points to bear in mind when reading this report

- Projections of future climate and resulting drought risk, particularly at the regional level, are subject to considerable uncertainty. This report should be taken as a guide to what may happen, rather than a categorical set of predictions. In particular:
  - The New Zealand climate change scenarios used in this report span the central portion but not the full range of IPCC projections of possible global temperature changes (1.4 to 5.8°C by 2100). Thus changes in drought risk which are smaller than those projected under our "low-medium" scenario are possible, particularly if substantial international action is taken to reduce greenhouse gas emissions. Similarly, changes greater than our "medium-high" scenario are also possible.
  - The study utilises projected future daily time-series of rainfall to produce the future *PED* scenarios. These are obtained by adjusting observed daily rainfalls by monthly factors obtained from the downscaled global climate model predictions. This approach assumes there is no change in the number of wet days each month compared to the present climate – just a proportional change in the amount of rain each wet day.
  - Results presented in this report assume that the increase in leaf stomatal resistance to evaporation due to rising carbon dioxide levels is roughly offset by an increase in leaf area. 'Increase in stomatal resistance' refers to the idea that less moisture passes through the minute pores (stomata) in a plant's leaves and stem when there is more CO_2 in the atmosphere. But increased CO_2 concentration will also stimulate leaf growth because CO_2 acts as a fertiliser, so the number of stomata through which moisture can pass increases. We assumed in this report that the two effects cancel each other out. The technical appendix to this report discusses the possible implications of changes in stomatal resistance on the projected changes in drought risk.
- The projected changes are relative to a 1972-2003 baseline, a period probably already somewhat drier in the east than for the 20th century overall because of long-term (20-30 year) natural variation in the climate. This long-period natural variation will continue to influence drought risk from decade to decade, in addition to the changes expected from increased greenhouse gases.
- Our *PED* calculations, and comments on drought frequency, are for unirrigated pasture. Irrigation can in principle offset increases in drought risk where sufficient water for irrigation is available. This report does not address how actual irrigation demand for river or ground water may change in future, or how current water resources might be affected by lower annual rainfall and increased drought frequency. This is a subject on which further research is recommended.
- A 'one-in-twenty-year' or 'twenty year average recurrence interval' event will not normally occur precisely once every twenty years. Over a very long period of time such an event is expected to occur in one twentieth of all years, but any separate individual events may occur closer or further apart in time.
- This report focuses on drought risk, and does not explore possible implications of climate change for heavy rainfall and flooding. The report indicates that many parts of New Zealand are likely to become drier on average, but this is in terms of the moisture availability for pasture growth. It does not necessarily mean the frequency of very heavy rainfall and floods will decrease. Previous research suggests the frequency of very heavy rainfall may in fact increase in many parts of New Zealand, even in those areas where the annual rainfall decreases on average.

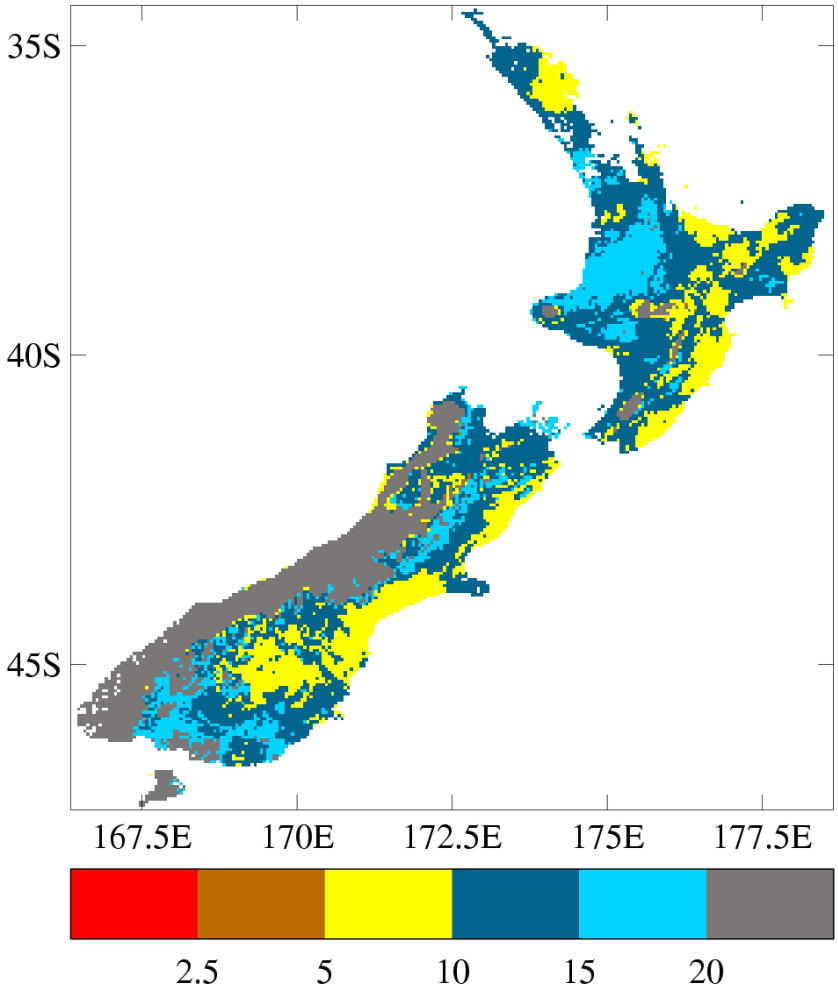

Figure ES1: Predicted average recurrence interval (years) in the 2080s under the 'low-medium' climate scenario, for the driest annual conditions that currently occur on average once every 20 years. The measure used is the *PED* (Potential Evapotranspiration Deficit) accumulated over a growing year (July to June). Example: Timaru is in a yellow region on the map. This means the current one-in-twenty year drought could occur (on average) between once every 5 years, and once every 10 years, in the 2080s under the 'low-medium' scenario (ie, 2 to 4 times more frequently than at present).

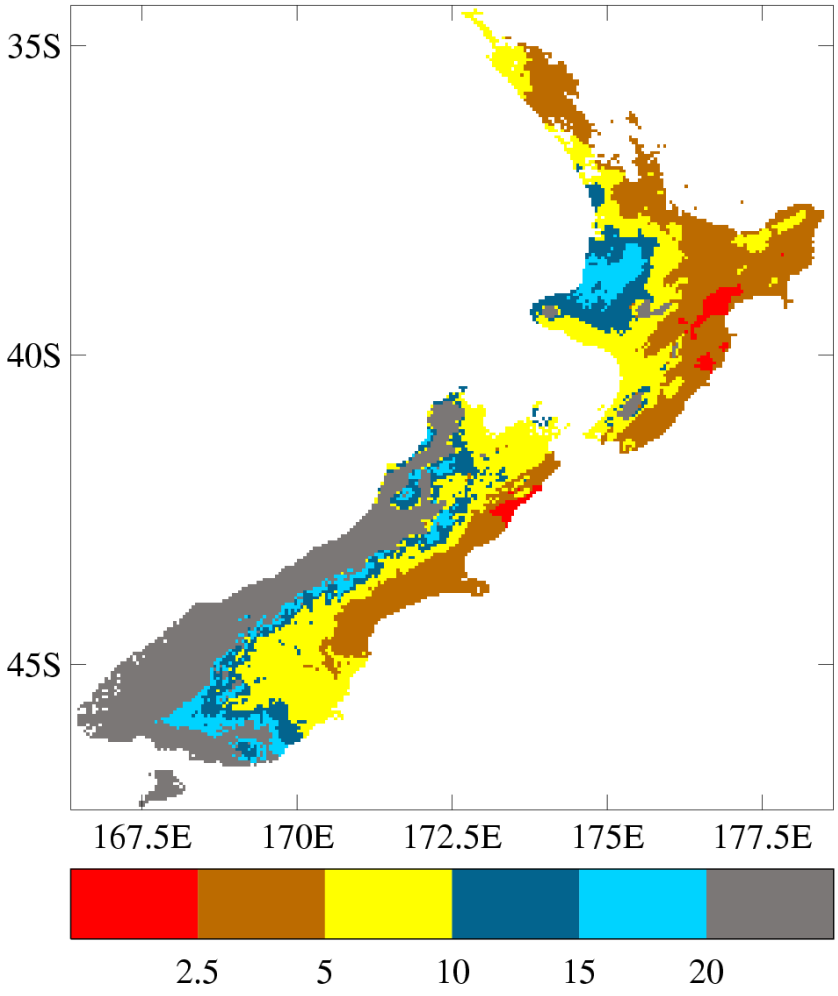

Figure ES2: Predicted average recurrence interval (years) in the 2080s under the 'medium-high' climate scenario, for the driest annual conditions that currently occur on average once every 20 years. The measure used is the *PED* (Potential Evapotranspiration Deficit) accumulated over a growing year (July to June). Example: Timaru is in a brown region on the map. This means the current one-in-twenty year drought is predicted to occur (on average) between once every 2.5 years, and once every 5 years, in the 2080s under the 'medium-high' scenario (ie, 4 to 8 times more frequently than at present).

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