Impacts of Climate Change on Broad Acre Cropping and Adaptation Options

In New Zealand, broad acre cropping covers a range of land uses, and arable crops such as wheat, barley, maize and oats cover around 165,000 ha. Vegetables, such as potatoes, onions, peas, carrots and seed crops, cover some 55,000 ha, while forage crops like maize, along with cereal silage and brassicas for grazing, occupy more than 350,000 ha.

Impacts of climate change

Assuming adequate water and soil nutrient supply, potential yields of temperate cereal crops could increase by as much as 20% under future temperature increases and CO_2 concentrations.

Climate change is likely to affect both the yield and quality of broad acre crops in New Zealand. Increases in atmospheric CO_2 stimulate canopy photosynthesis, especially in temperate C3 crop species, and reduce water requirements for leaf transpiration. Warmer temperatures may also stimulate crop yields, making for faster emergence, canopy development and growth rates during winter, spring and autumn, when most crops are inhibited by cold temperatures.

Similar potential yield increases are projected for forage crops, like winter cereals and brassicas, which are harvested in a vegetative state and have longer periods to grow, thanks to the shortening of cycles of preceding annual crops.

However, such accelerated crop development also shortens crop cycles. This may be important for crops such as maize, peas and potatoes, reducing the time available for sunlight interception and photosynthesis. Changes in rainfall affect the risk of drought and floods and these can have severe impact on crop yields and, sometimes, quality.

Climate change also alters the incidence and activity of plant pathogens, insects and weeds, which could reduce yields and compromise crop quality.

Simulation modelling can explore the complex interactions between climate change effects and their consequences for crop yields. Without adaptation, yields of forage crops, such as silage maize, along with more temperature-sensitive crops like potatoes and peas, are reduced under some climate change scenarios. In these cases, higher temperatures shortened growth cycles and this was not off-set by the CO_2 fertilisation effect on photosynthesis, which is less pronounced in C4 crops such as maize. Adaptive measures that shift the growth period to cooler times of the year are required to maintain production.

www.climatecloud.co.nz

Ministry for Primary Industries
Manatū Ahu Matua

A resource developed through the Climate Change Technology Transfer Programme

This can be achieved either by changing sowing dates, using varieties with different maturity, or shifting to alternative crop species (see Table 1).

Table 1. Adaptation options for broad acre cropping

Tactical	*Strategic*	*Transformational*
• Change in crop calendars • Change in crop varieties • Use of conservation agriculture • Improvement in soil water and irrigation management • Improvement in soil nutrient management • Improvement in pest management	• Change in crop species • Develop new 'climate-resilient' genotypes • Use of precision agriculture • Monitoring and forecasting programmes • Irrigation development and expansion	• Develop new cropping systems • Development and adoption of innovative technologies • Change to alternative land uses

Adaptive capacity

When climate change favours crop growth the adaptive processes must ensure that any potential gains are fully realised through provision of adequate water, nutrients and differential crop management. Most tactical adaptation options, and some strategic ones such as the development and expansion of irrigation, enable this.

In a warmer future, catchment hydrologies could well alter, as may water allocation policies. This could see irrigation allowances constrained. To explore these impacts and the effectiveness of adaptive options, crop models were used to evaluate yield response under restricted water availability.

A crop rotation of wheat, barley, kale and greenfeed crops in Canterbury during 2030-2050, under the high climate scenario, assumed decreasing irrigation water allowances and two irrigator types with contrasting efficiencies (roto-rainer and centre-pivot), Figure 2.

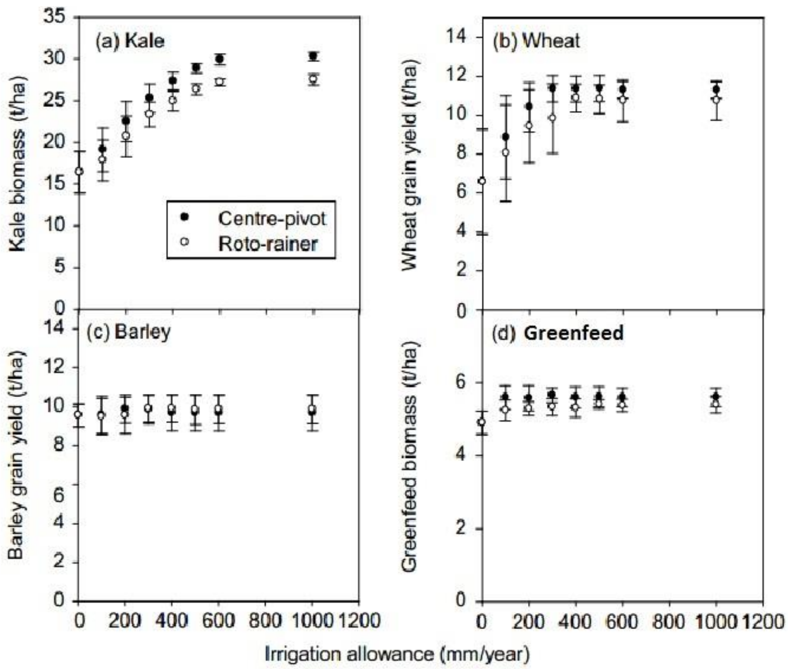

Figure 2. Simulated yields of four crops grown in a rotation in Canterbury assuming contrasting maximum annual irrigation allowances from 0 to 1000 mm, two irrigation systems (centre-pivot and roto-rainer) for the A2 emissions scenario from 2030–2049.

Errors bars delimit the 25th and 75th percentiles of 20-year simulations. Crops are (a) Kale, (b) Wheat, (c) Barley, and (d) Greenfeed.

The analysis showed that summer crops, represented by forage kale, were the most sensitive to restricted water allocation, producing only half their attainable yield when grown under dry-land conditions (Figure 2). In contrast, crops such as wheat, barley and greenfeed, grown during cooler periods when water demand is lower, would suffer less from irrigation constraints.

Use of more efficient irrigators, such as centre-pivots instead of roto-rainers, consistently improved yields of all crops, particularly in light soils with low water storage capacity. Growing crops in soils with higher water holding capacity also ensured greater resilience to the effects of limited water allocation. Careful selection of crop location based on accurate understanding of soil properties is an example of adaptation to limited water supply.

Stronger climatic changes might require more expensive strategic adaptation options. For example, developing and expanding irrigation infrastructure might increase the resilience of arable systems to high uncertainties in rainfall. Such uncertainties are what most dramatically impact on crop yields in free-draining soils. Similarly, plant breeding and selection programmes could target new crop varieties better suited to drier, warmer conditions, perhaps with deeper root systems and/or different maturity.

Extreme climate change might demand long-term investment in transformational adaptive options. That could mean, for instance, establishing new broad acre cropping industries in New Zealand, such as rice or soybean, or, investing in research and development of crop species with radically improved physiological characteristics. It may be possible in the future to breed crops which have more efficient photosynthesis and better drought resilience. In some circumstances, it may be most expedient to adopt alternative land uses, like dry-land livestock or agro-forestry.

Knowledge gaps

More studies are needed to improve the accuracy of climate change impacts and adaptation assessments for broad acre cropping systems. Knowledge gaps include:

- data on experimental results from comparison of adaptive options
- uncertainties in rainfall projections (both amount and seasonality) that largely impact crop yield
- climate projections and crop responses to extreme events such as heat waves, severe droughts and floods, which are not well represented in current models:
    - The magnitude of CO_2 fertilisation under farm conditions
    - The unknown impact of climate change on yields through factors such as insects, diseases and weeds.

Historically, advances in agricultural technologies have had profound effects on global and regional crop production. It is still uncertain whether future technological advances will have similar effects in a warming climate, either by reducing yield gaps,the difference between actual and potential yields, and/or by increasing potential yields.

The fortunes of New Zealand broad acre crops will not be determined by local impacts alone. The impact of climate change on other key producing countries, the balance in global supply and demand for food, changes in commodity prices, trade policies and the viability of alternative land uses will all play their part.

All these factors will influence New Zealand's broad acre sector, and our choices, as we adapt to a warmer world.

Further Information

The full technical report is *Impacts of Climate Change on Land-based Sectors and Adaptation Options, Stakeholder Report, Chapter 5. Broad acre Cropping*. This is freely available at: www.climatecloud.co.nz/CloudLibrary/2012-33-CC-Impacts-Adaptation_SLMACC-Chapter5.pdf

The following industry organisations have information on adaptation options and climate impact assessments:

- Horticulture new Zealand www.hortnz.co.nz
- Foundation for Arable Research www.far.org.nz

Climate change fact sheets and case studies are available from the Ministry for Primary Industries www.mpi.govt.nz

Glossary

C3 crop species – these are the most common plants and include cereals such as wheat, barley, rice, rye, oat, soybean, beets and most of our pasture species

C4 crop species – examples of these species are maize and sweet corn, sugar cane, sorghum and millet, and kikyu pasture

Acknowledgements

Photos kindly provided by LandWISE and Anna Rhodes