Climate change impacts on feed grain production and quality in New Zealand

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Introduction

Most recent publicity about climatic impacts on agriculture has focused on the El Nino event which has had drastic effects both here in New Zealand and around the world. However, El Nino and its opposite, La Nina, are short-term events which occur regularly and contribute to climatic fluctuations from year-to-year. We are all familiar with this short-term variability, and farmers are accustomed to coping with it.

In contrast, the global climate change that we will discuss is a more gradual shift which is occurring against the background of short-term variability. It is being caused by a steady increase in so-called greenhouse gases in the atmosphere resulting mainly from the utilisation of fossil fuels and deforestation. The possibility that these human activities could influence the earth's climate has been recognised by meteorologists for at least 30 years. However, there has been considerable uncertainty in predictions of what these effects would be, both globally and at regional and local levels. Often, the focus has been on potential negative impacts, such as sea level rise, and adverse impacts on ecosystems, catchments and existing farming systems. The focus has rarely been on opportunities which could result from climate change.

We will consider the likely effects of climate change on feed grain production and quality in New Zealand and whether these are likely to represent potential opportunities or threats to grain producers and feed industry end-users. We will describe a "most likely" climate change scenario and then we will discuss how it may affect cereal grain crops in terms of their production locations, yield potential and grain quality for feed production.

Climate Change Scenario

Carbon dioxide concentration

Atmospheric concentrations of greenhouse gases, mainly carbon dioxide, but also others such as methane and nitrous oxide, are increasing. The increase in carbon dioxide concentration has been exponential from about 250 ppm since the industrial revolution began, and is predicted to reach about 500 ppm by the year 2050 unless there are significant reductions in deforestation and the use of fossil fuels (Salinger and Hicks, 1990).

The increase in carbon dioxide concentration will have a direct effect on plant growth and, therefore, crop production. However, temperature and rainfall changes caused by the greenhouse effect of carbon dioxide in the atmosphere could have larger impacts. The nature and extent of these changes are controversial among meteorologists, but the following temperature and rainfall changes are a consensus of the most likely scenario for New Zealand.

Temperature

Mean temperature increase in New Zealand by 2050 is likely to be in the range from 1.5 to 3.0°C. Little local variation in the change is expected because New Zealand's climate is moderated by airflows from the surrounding oceans (Salinger and Hicks, 1990).

Rainfall

There is much uncertainty in predictions of rainfall changes that will be caused by climate change. Rainfall is very dependent on topography and the directions of arrival of rain laden airflows. Changes in the latter are uncertain. The most likely changes are that annual rainfall will be at least 10% higher in the north and west of both islands, and drier in the south and east. The distribution of rainfall could be more even throughout the year (Salinger and Hicks, 1990).

Other predicted changes

Changes in sea levels and snow levels though important, will have negligible direct effects on arable farming.

Sea level. Sea level will rise due to expansion of sea water and melting from the arctic and antarctic ice caps caused by the higher temperature. Predictions of sea level rise by 2050 vary from 0.2 to 1.4 m, but it is unlikely to exceed 0.5 m (Salinger and Hicks, 1990).

Snow level. Snow level may rise by between 300 and 450 m. Like rainfall, it will be very dependent on the type and direction of incoming storms.

Impacts On Crops

In general, the implications for crop production are positive. Higher carbon dioxide concentration and temperature will tend to increase biological productivity and, therefore, have the potential to increase crop yields. However, these effects will be countered by the faster rate of development and, therefore, shorter crop growth duration caused by higher temperature. Substantial impacts, either positive or negative, could result from changed rainfall patterns and changed incidence of weeds, pests and diseases.

Carbon dioxide concentration

Increased growth of C3 (temperate) crops such as wheat, barley and oats is likely because their growth rate is limited by carbon dioxide availability (Salinger, 1991; Wilson and Jamieson, 1991). However, the growth of plants such as maize with the C4 photosynthetic system is unlikely to change.

Temperature

The main effect of increased temperature will be to increase the development rate of plants. The thermal time (°C days) required by most crop species or cultivars to reach maturity is generally constant. More thermal time will be available (for example, a 1.5°C increase in the mean temperature will add 400-600 °C days to the growing season, depending on the crop duration) so crops will mature earlier. As a result, their opportunity to grow and accumulate yield will be reduced. Two examples of the consequences for wheat are that 1) the growth duration will be reduced by 1-3 days for each 1°C rise in temperature above 10°C (Slafer and Rawson, 1994) and 2) grain yield will be reduced by 3% per 1°C of temperature above 15°C during grain filling (Wardlaw, 1994). Barley is less sensitive to temperature than wheat; its kernel weight will decline by about 1% per 1°C of temperature above 15°C during grain filling (Savin *et al.*, 1997).

An advantage of elevated temperature is that the frost-free season will increase, reducing the risk of frost damage to cereals. This benefit may be offset by the fact that if temperatures over 30°C become more common there will be an increased risk of floral infertility in many of the cereals. This would be caused mainly by a reduction in pollen viability and germ tube development.

For maize, maximum seedling growth occurs at 26°C, which is considerably higher than the temperature at sowing time in most of New Zealand. Increased temperature is therefore likely to permit earlier sowing of maize and greater flexibility in choice of hybrid and location.

The outlook for the quality of New Zealand's cereals is good. For wheat, any yield losses are likely to be more than compensated for by an increase in grain protein percentage. Yield declines with temperature mainly because starch production drops, but protein accumulation is less sensitive to temperature (Stone and Nicolas, 1998). Consequently, protein content tends to increase as temperature rises. Only if the temperature during grain filling rises above about 30°C are prized characters such as dough strength and elasticity likely to suffer from high temperature damage (Stone *et al.*, 1997).

As with yield, the quality of barley is less sensitive to temperature than that of wheat. Raising the daytime temperature during grain filling by as much as 9°C has no significant effect on grain or malt ß-glucan levels, although diastatic power tends to increase with temperature (Savin *et al.*, 1997). Malt extract is not very sensitive to changes in daily temperature maxima in the 21-30°C range.

In maize, kernel weight and density will decline with increased temperature, and starch granule size and amylose content may decline, although this varies from hybrid to hybrid (Lu *et al.*, 1996).

The effects of increased temperature on wheat growth and development can be summarised as follows:

Increased temperature
⇓
Increased development rate
⇓
Decreased time at each growth stage
↙ ⇓ ↘
Reduced tillering ⇐ Reduced photosynthesis ⇒ Reduced grain fill
⇓ ⇓
Reduced grain number   Reduced grain size
↘ ↙
Reduced yield and quality

Pests, diseases and weeds

Most weeds, pests and diseases that currently affect arable farming will probably remain as problems under the climate change scenario, although their distribution and severity may alter. The predicted changes to temperature and rainfall are most likely to reduce the impact of these species. The main risk is that higher temperature may allow more successful, inadvertent introductions of new problem species. Another factor is that climate change may affect the use of agrichemicals which are sensitive to temperature or moisture in their mode of action.

Many cereal diseases in New Zealand are favoured by warm, moist conditions which could be more prevalent. Pathogens may be more likely to survive over winter, and new and more rapid development of epidemics and more rapid secondary spread of diseases may occur. It is possible that a number of diseases not currently causing problems in New Zealand, such as leaf blights of maize, could become serious.

Storage and handling

Little change should be required in the storage and handling practices to maintain high grain quality. The need to dry grain may be reduced as it will mature earlier and be able to dry further in the field. However, higher temperature and humidity will mean grain storage facilities or practices may need to be modified, because the conditions will favour storage problems caused by moisture, storage fungi and higher temperature. Higher grain storage temperature may also favour the development of aflatoxin producing fungi. If new crops are grown, or crops are grown outside the regions where they are currently produced, then storage and handling infrastructures will need to evolve to accommodate these changes.

Consequences for Arable Cropping

Despite its small size, New Zealand has a wide variety of climatic conditions which allow production of several grain crops with contrasting environmental requirements. These range from milling oats in Southland to maize in areas of the North Island. Spring barley and wheat are grown throughout the country. For wheat, in particular, specific cultivar types are better adapted to different climates with, for example, cultivars from the UK and Europe predominantly grown in southern regions. Changes in arable cropping that are likely to occur as a result of climate change include:

- a significant geographical shift in crop production patterns because the range of adaptation of each crop will be changed. In some cases, the shift will be necessary to avoid high temperature events that could reduce grain yield and quality. In most cases the change will represent an opportunity rather than a limitation; for example, the viable range for maize production could move south (Wilson *et al.*, 1994).
- a breeding focus on selecting cultivars with adaption to the conditions resulting from climate change.
- production of newly viable arable crops such as soybeans, rice or sorghum in some areas
- increased emphasis on the efficient use of water in crop production, especially in traditional eastern grain production areas. This will require better irrigation management or improved water conservation practices in dryland crop production.
- changes in plant protection strategies to account for new problems or changes in existing problems. There is likely to be a higher risk of inadvertent, successful new introductions of weeds, pests and diseases, so improved biosecurity may be needed with associated higher penalties for infringements.
- improved grain quality due to higher protein content, especially in wheat, and more favourable drying conditions at harvest time.
- a need for gradual infrastructure changes to cope with production, transport and storage of grain in new regions, and with production of new crops.

Conclusions

Reasonably good predictions are available for the likely implications of climate change on the production of grain crops. This supports the value of research to define the climatic requirements of crop species and cultivars and to develop models relating growth and development to climatic factors. The accuracy of the predictions depends mainly on the accuracy of the climate change forecasts. The latter are more uncertain than the crop response forecasts. It is clear, however, that crop production is sensitive to small temperature changes: even an increase of 1 or 2°C could have significant implications. Changed rainfall patterns would also be very important.

It is important to recognise and take seriously the fact that a gradual, long-term climate change is occurring, that its general nature and likely impacts on crop production are known, and to allow for it in long-term decision making. The predictions and time scale mean that there is no need for panic and no good reason for lack of preparation.

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