End-of-the-century climate and Pacific Northwest wheat production

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In order to sustain long-term profitable wheat production in the Pacific Northwest, scientists, agribusiness, and producers need to understand climate change trends into the future. Integrated climate and cropping system models enable us to predict regional precipitation and temperature to the end of the century. What we know about the potential impact of climate change on Pacific Northwest wheat production points toward a future that, assuming appropriate management and adaptation, might bring an increase in productivity for the region, along with somewhat limited concern for dramatic adverse effects.

By the end of the century, precipitation in the Pacific Northwest is projected to change by -1.8 to 12.5%, with a higher winter concentration and a trend to some decrease in the summer, compared to today's precipitation patterns. In terms of temperature, there is a clear trend toward warming, with mean annual temperatures in the region increasing 3.1 to 11.7°F. Concurrently, atmospheric carbon dioxide (CO_2) concentration will increase from today's average of about 400 ppm to somewhere between 538 and 936 ppm, depending on future emissions of greenhouse gases.

The productivity of the region's wheat-based dryland agriculture depends directly on the amount and distribution of precipitation. Annual precipitation ranges widely across the region, from about 7 to 24 inches, thus influencing cropping intensity and use of fallow years. Although concurrent warming will produce alterations to the hydrological cycle (for example, less snow accumulation), these changes are unlikely to have a significant impact for dryland wheat production, with crops continuing to utilize all soil-available water for growth and yield.

The impact of warming could be of more consequence. Assuming that vernalization and day length requirements of cultivars are well adapted to environmental conditions, the progression of wheat development is directly dependent on the accumulation of degree days (the sum of daily mean temperature above a base temperature). Thus, warming will tend to shorten the number of days between emergence and maturity. A shorter growing season

IMPACT

Toward the end of the century, predicted hydrological cycle changes are unlikely to have a significant impact for dryland wheat production. What we don't know with certainty is the rate and magnitude of future climate change as influenced by societal decisions and technological innovation. The effects of future warming trends can be mitigated with informed cultivar selection and management. Increases in CO_2 concentration may increase biomass produced per unit of water use, benefiting Pacific Northwest farmers. In the near future, REACCH will study the little-understood impact of climate change on pests, diseases, and weeds that could increasingly affect wheat production and cost.

Photo by Brad Stokes.

implies that the amount of solar radiation capture will be reduced, thus reducing the accumulation of biomass and grain yield.

Fortunately, adaptation to this condition is possible by selecting winter wheat cultivars with a slower rate of development that can better utilize the longer available growing season resulting from warming. In the case of spring wheat, earlier planting is a way to adapt to an accelerated growing season. Another impact of warming, which can be extremely damaging, is excess heat during pre-flowering and flowering. Grain numbers can be substantially reduced by a few days of early daylight hours with temperatures above 88°F during this sensitive period. This is an impact of great concern in southern latitudes of wheat production in the United States, but it is unlikely to be a significant factor in the Pacific Northwest unless the most extreme warming projections become reality. In the end, with informed cultivar selection and management, wheat production in the region likely will continue to be more affected by water limitation than by other factors.

What about the increase of atmospheric CO_2 concentration? This greenhouse gas is the most important contributor to climate change. Nonetheless, many crops, especially those with the so-called C_3 biochemical photosynthetic pathway, will benefit from increased atmospheric CO_2 concentration. The majority of crops, including wheat, fall into this group.

Photosynthetic rate depends on CO_2 concentration within the leaves, with the rate increasing linearly at first, and then non-linearly (at decreasing rates) in response to increasing internal CO_2 concentration. Eventually, the internal CO_2 concentration reaches a maximum saturation value at which no further photosynthetic rate increase occurs. At current atmospheric CO_2 concentration, wheat photosynthesis operates at an internal CO_2 concentration of about 280 ppm, while saturation is reached at about 580 ppm. Another beneficial effect of increasing CO_2 concentration is that stomata reduce their aperture, which results in less water loss (partially counteracted by slightly larger crop canopies). The combination of these effects increases the units of biomass produced per unit of water use, a fact that can be beneficial for Pacific Northwest dryland wheat production. These types of responses have been well documented in the scientific literature.

Altogether, what we know about the potential impact of climate change on Pacific Northwest wheat production seems to point toward a future that, assuming appropriate management and adaptation, might bring an increase in productivity for the region and somewhat limited concern for dramatic adverse effects. Now, what about what we do not know?

There is a large degree of uncertainty in the projection of future climate, particularly regarding rate and magnitude of future climate change. Although the long-term warming trend is a point of agreement among more than 20 climate models, there are large discrepancies among them regarding the rate of increase. This variation is compounded by different possible future CO_2 emission scenarios and pathways for atmospheric CO_2 concentration increase as conditioned by societal decisions. We do not know which of these projections will materialize, and thus we cannot be certain about the extent of negative or positive impacts on wheat production.

More troubling is the lack of clarity about the extent to which climate change will lead to more extreme events, with these extremes damaging crop canopies due to cold weather or reducing grain set due to extreme heat events. Also, there is little understanding of the impact of climate change on pests, diseases, and weeds that could increasingly affect wheat yield and production cost.

Photo by Brad Stokes.

Regarding the beneficial impact on biomass production of increasing atmospheric CO_2 concentration, the rate of gain eventually decreases, becoming flat at about 880 ppm, a concentration that could be reached by the end of the century. Finally, there is also uncertainty about the speed of technological innovation and adoption that would allow Pacific Northwest wheat producers to adapt to changing conditions and perhaps reap the benefits of farming in a potentially less affected region compared to others in the United States.