CLIMATE CHANGE AND FORAGE PRODUCTION

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ABSTRACT

Historical records show that average annual temperatures are increasing in most parts of the world along with changes in precipitation patterns. These changes are affecting the production of alfalfa and other forage crops in many regions. Climate changes are primarily driven by increasing carbon dioxide concentrations in the atmosphere due to the burning of fossil fuels. Models that predict future climate trends indicate that ambient temperatures will continue to increase. Precipitation may also change with the general trend of wetter regions getting more rain and dry regions getting less. Increased carbon dioxide levels in the atmosphere can stimulate the growth of many crops including alfalfa. This increase along with other climate changes are predicted to increase alfalfa yields from 10 to 30% in most regions if adequate water is available to maintain that production. Management changes such as earlier harvests and additional cuttings will be needed to adapt to the changing climate. The greatest threat to long-term sustainability of alfalfa production is the availability of water, particularly in dry regions where production is dependent upon irrigation. Other challenges of changing climate may include increased weed and insect pressure. Although the future offers challenges, with proper adaptation, alfalfa can remain and perhaps improve as a sustainable crop for current and future generations.

Key Words: Alfalfa, climate, greenhouse gas

INTRODUCTION

Climate change has become a sensitive political issue. The media has contributed to the polarization on this issue by sensationalizing both sides of the issue. We know much about the science surrounding climate change, but real science is often ignored by both those promoting and denying the issue. Let's set aside preconceived opinions and look at the scientific evidence and potential effects on forage production. We will look at historical changes that have occurred in the recent and distant past. We will also look at what is likely to occur in the future and how that may affect forage production. By preparing for the future, steps can be taken to adapt to the change providing a productive and sustainable future for alfalfa and other forage crops.

HOW IS OUR CLIMATE CHANGING?

Climate changes are slow and difficult to observe over time. Weather varies considerably from day to day and year to year, masking the change that is occurring. Only through long-term measurements can we quantify changes in temperature and precipitation. Temperature measurements across the United States (U.S.) since 1991 have documented a 1-2ºF increase in average annual temperature in the west with little change in the southeast (Melillo et al., 2014). Measures of global temperature have shown about a 1ºF increase over this 30-year period and

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In: Proceedings, 2022 World Alfalfa Congress, San Diego, CA, 14-17 November, 2022. UC Cooperative Extension, Plant Sciences Department, University of California, Davis, CA 95616. (see http://alfalfa.ucdavis.edu for this and other alfalfa conference proceedings.)

almost a 2°F increase since 1900. This may not seem like much change, but this is a substantial change over this relatively short period.

Precipitation patterns are also changing, but the magnitude and direction of change varies greatly among locations within the U.S. and throughout the world. In general, drier regions are getting drier and wetter regions are getting wetter. Within the western U.S., there has been little change in annual precipitation since 1991 (Melillo et al., 2014). Some local regions have seen 10-15% increases while others have seen 10-15% decreases. The driest region is Arizona where much of the state has seen 10-20% decreases in long-term annual precipitation. Much of the Midwest and Northeast have experienced 10-20% increases in precipitation. This change has occurred primarily through more intense storms. Extreme rainfall events have increased by about 40% in the Northern U.S. with little change in the southwestern states (Melillo et al., 2014).

One of the challenges in the western states is a decrease in winter snowpack in the mountains. With increasing temperature and changes in precipitation, less snow is accumulating and thus less is available through summer snowmelt (Melillo et al., 2014). This is of particular concern for those that rely on this water source for irrigation of crops.

These changes are well documented, but the cause is often questioned. Scientific evidence strongly supports that the cause is increasing carbon dioxide (CO_2) concentrations in the atmosphere. Measurements have documented about a 30% increase in this concentration since 1960 (Melillo et al., 2014). Measurements made through ice bores in the Antarctic indicate that current levels far exceed anything that has occurred throughout human history and beyond. There is a high correlation between global temperature and atmospheric CO_2 concentration.

Carbon dioxide and some other gases in the atmosphere, including methane, trap heat radiated from the sun. This is a good thing, because without this heat-trapping blanket around our planet, temperatures would be too cold for us to survive. The problem is that these increasing gas concentrations are thickening the blanket and causing temperature rise. The primary cause is the release of CO_2 through the burning of fossil fuels. For each gallon of fuel consumed, about 20 pounds of CO_2 are created and emitted to the atmosphere. This is taking carbon that has been stored in the earth for many years and adding new CO_2 to the atmosphere much more rapidly than it can be absorbed in vegetation, soil, and ocean water.

Methane from cattle also receives blame for global warming. Cattle produce a lot of methane (with more warming potential than CO_2), but this is part of a natural cycle. Methane from cattle oxidizes in the atmosphere transforming that carbon back to CO_2. Since that carbon originally came from CO_2 in the atmosphere through fixation by feed crops, this completes a natural cycle. Methane emission from cattle has a short-term impact but does not create a long-term accumulation in the atmosphere such as we are experiencing from the CO_2 created through fossil fuel combustion.

HOW WILL CLIMATE CHANGE AFFECT FORAGE PRODUCERS?

To look into the future, we must rely on models. Many global climate models have been developed throughout the world. These models use mathematics to represent the complex physical, biological, and chemical relationships and interactions between the land, ocean and atmospheric processes that drive our weather and climate. As these models develop, they become more sophisticated and accurate in their predictions.

We have selected nine of these models to study future climate and daily weather patterns for regions of the U.S. throughout the rest of this century (Rotz et al., 2016). Similar climate data were not available for locations for other countries, but these U.S. data can illustrate the anticipated effects for other parts of the world. A worst-case scenario was modeled, where the international consumption of fossil fuels continues at its current rate. Predicted weather data were summarized for recent (1996-2015), mid-century (2040-2059) and late-century (2081-2100) periods. The mean and variation among models were considered.

Figure 1 shows predicted seasonal temperatures for dry regions in the western U.S. to more humid regions in the east. Similar increases in temperature are predicted throughout the year. Based upon the current rate of greenhouse gas emissions, average annual temperatures are predicted to increase by 3 to 4ºF by mid-century and 8 to 10ºF by the end of the century. In general, temperature increases are a little greater in more northern locations relative to southern locations. The 'error bars' on the graph show the variation in prediction among the climate models. As would be expected, the uncertainty in model predictions increases as we get further into the future. All models are consistent though in predicting increases in temperature.

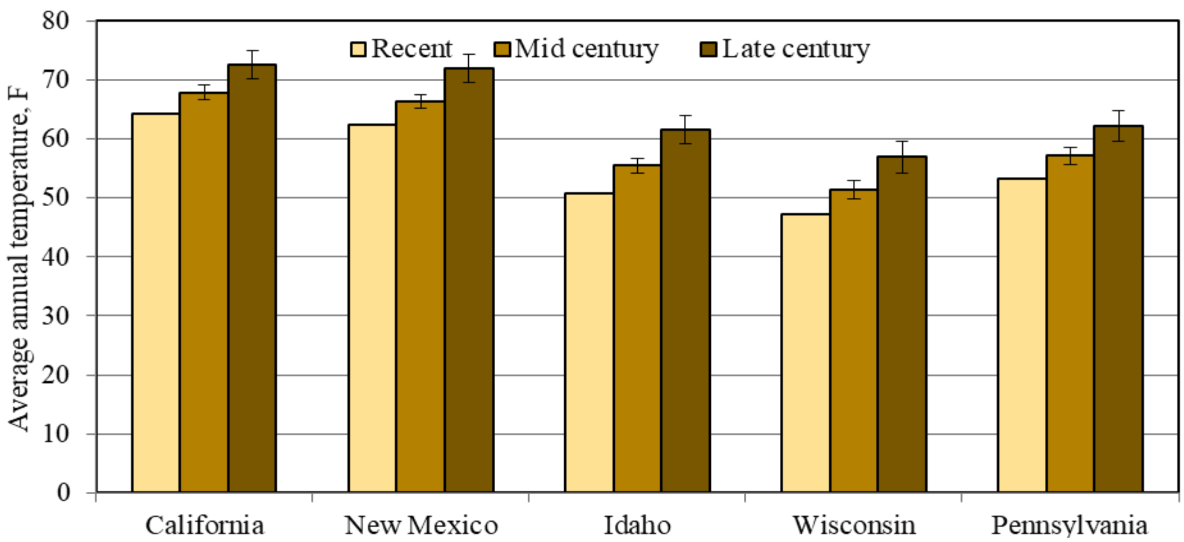

Figure 1. Recent and predicted future average annual temperatures for selected locations of the United States.

As stated above, these predictions are for a worst-case scenario where little is done to reduce our current CO_2 emission rates. Steps are being taken though to reduce fossil fuel consumption and related emissions. Therefore, temperature increases may begin to slow by mid-century with a smaller increase by late century.

Figure 2 indicates that annual precipitation is projected to have little change in the dry western regions while increases are anticipated in the wetter eastern regions. Precipitation patterns will also vary throughout the year. Predicted changes in precipitation for California show a substantial (up to 25%) increase during the winter season with little change during the rest of the year. In Wisconsin, most of the increase comes in the spring with little change in the summer. In Idaho and Pennsylvania, most of the increase comes in the winter with smaller increases throughout the remainder of the year. Compared to temperature, there is more variability among models in predicting future precipitation, but the trends tend to be consistent.

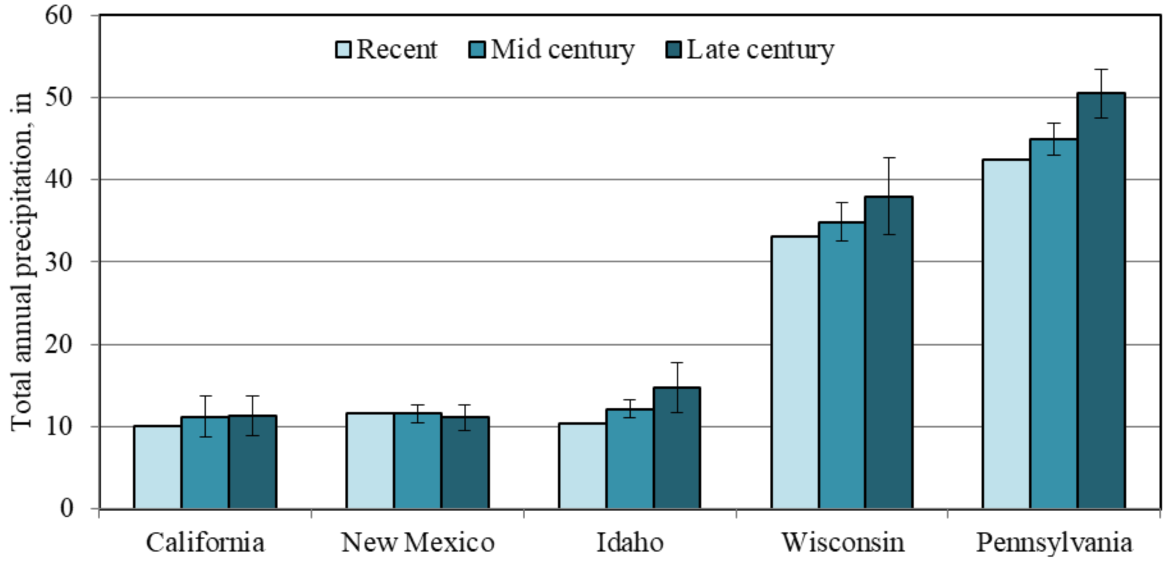

Figure 2. Recent and predicted future total annual precipitation for selected locations.

Precipitation patterns and amounts don't tell the complete story. With increasing temperature, evapotranspiration from the crop will also increase. Figure 3 shows the difference between the projected increase in precipitation and the increase in evapotranspiration. In the dry regions, there is a projected annual deficit of 2 to 4 inches by mid-century. In the wetter eastern regions, there is a small increase in water available. Since most of the increase in precipitation occurs in the winter and spring periods and most of the evapotranspiration occurs in the summer, summers will get drier.

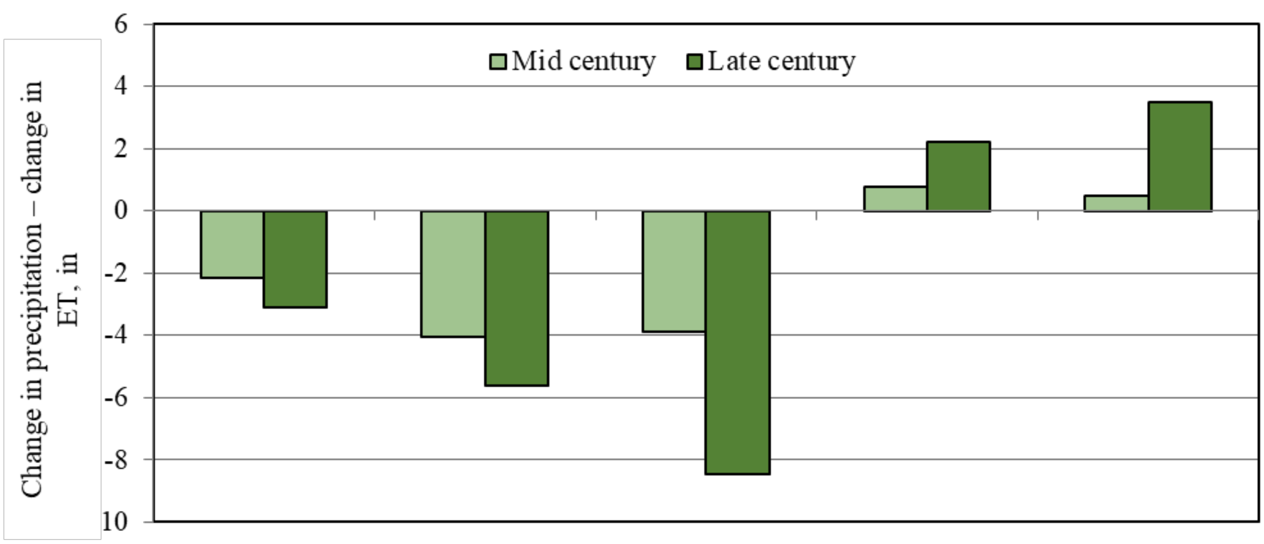

Figure 3. Difference between predicted future precipitation and predicted evapotranspiration for alfalfa crops at selected locations.

Atmospheric and climate changes will have varying effects on forage production. An important benefit comes from the increasing CO_2 levels in the atmosphere. More available CO_2 stimulates growth of most forage crops including alfalfa. Increasing temperatures also increase the growing season, particularly in northern locations, which can lead to more harvests per year. Changes in precipitation patterns will affect field curing and harvest of forage crops in some parts of the country, but this is not anticipated to have much effect since most of the increase in precipitation occurs outside the harvest season.

By linking crop and global climate models, we can study predicted impacts on crop production (Rotz et al., 2016). The Integrated Farm System Model was used to simulate alfalfa growth and harvest under weather patterns predicted by each of the nine climate models. Harvested alfalfa yields were predicted to increase at each of the locations by mid-century with less change during the remainder of the century (Figure 4). This increase primarily came from “carbon fertilization” through the increase in atmospheric CO_2. For the northern locations, the longer growing season allowed an extra cutting of the alfalfa, further increasing yield.

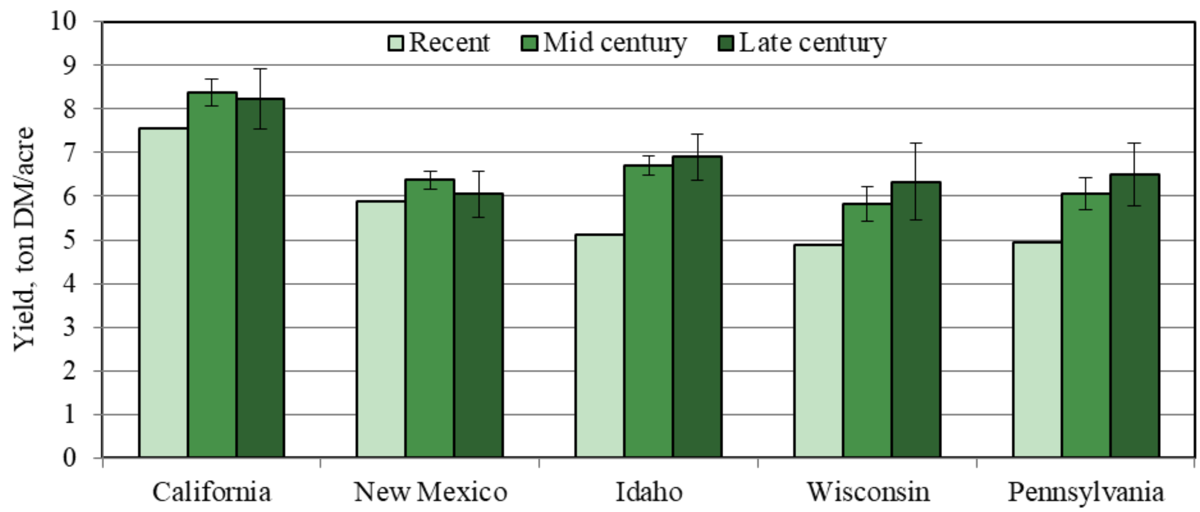

Figure 4. Recent and predicted future alfalfa yields as influenced by increased atmospheric carbon dioxide concentration and climate change at selected locations.

These projections were based upon the assumption that increased irrigation water would be available to support the increased growth in the dry western regions. With increasing limitations on water availability and use in crop irrigation, this may be an optimistic projection for the dry regions. In general, alfalfa yield is about proportional to the amount of water applied to the crop (Lindenmayer et al., 2010). If irrigation water becomes more restricted, the loss of production may be substantial.

Changes in temperature and rainfall can also affect nutrient losses from farms, but for forage producers this impact should be minimal. Our model predicts a 20 to 60% increase in phosphorus runoff across these five locations due primarily to more intense storms. The prediction for recent weather is less than 1 lb of phosphorus per acre, which is very little compared to other crops and particularly those grown in the eastern states. Therefore, the increased loss from alfalfa fields is still little loss. A similar prediction was found for nitrogen losses with most of the loss coming in the form of nitrate leaching to groundwater.

Other concerns that were not addressed in our simulated production systems are that of weed (Jugulam et. al., 2019), insect and disease (Trebicki and Finlay, 2019) control. Milder winters, longer growing seasons and increased atmospheric CO_2 will likely promote weed growth as well as crop growth. More and different insect infestations and diseases may also develop. These can also affect future yields and management practices that were not considered in this analysis.

CONCLUSIONS

Increases in atmospheric CO_2 and related changes in climate may increase alfalfa yields as long as adequate water is available to maintain production.

Gradual changes in management (planting dates, harvest dates, number of harvests, crop genetics and pest control) will be needed to adapt and perhaps take advantage of future climate.

The greatest challenge for sustainable forage production in dry climates will be access to adequate water for irrigation.

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