IMPLICATIONS OF CLIMATE PREDICTIONS ON FORAGE PRODUCTION IN WESTERN STATES

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ABSTRACT

Historical records show that average annual temperatures are increasing in the western states with relatively minor changes in precipitation. 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 in this region with small increases in precipitation, primarily in the winter months. These changes are predicted to increase alfalfa yields from 10 to 30% across the western states as long as adequate water is available to maintain this production. Management changes such as earlier harvests and additional cuttings will be needed to adjust to the changing climate. The greatest threat to long-term sustainability of alfalfa production in the region is availability of water for irrigation. Other environmental impacts of producing alfalfa in this region are small, but steps can still be taken to reduce the impact for current and future generations.

Key Words: Alfalfa, climate, greenhouse gas

INTRODUCTION

Climate change has become a sensitive political issue. The media has contributed greatly 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 those 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 in the western U.S. Finally, we will look at the greenhouse gas emissions from forage production and discuss ways of reducing these emissions.

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 western states have documented a 1-2^{o}F increase in average annual temperature since 1991 (Melillo et al., 2014). At the same time, annual temperatures have not shown much change in the Southeast. Measures of global temperature have shown about a 1^{o}F increase over this period and almost a 2^{o}F increase since 1900. This may not seem like much change, but this is a substantial change in this relatively short period.

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Precipitation patterns are also changing, but the magnitude and direction of change varies greatly among locations within our country and throughout the world. In general, drier regions are getting drier and wetter regions are getting wetter. Within the western states, 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 70% in the Northeast with relatively small increases in some western states (Melillo et al., 2014).

One of the greatest challenges in the western states is a decrease in winter snow pack 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 is thickening the blanket and causing temperature rise. The primary cause is the increase in CO_2 due to 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 for millions of years and adding new CO_2 to the earth's atmosphere much more rapidly than it can be absorbed in vegetation, soil and ocean water.

Methane from cattle has also received much 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 just completes a natural cycle. Methane emission from cattle 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 WESTERN 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 (Rotz et al., 2016) to study future climate for the western states. We used these models to predict future daily weather patterns for the rest of this century. A worst-case scenario was assumed, 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 was considered.

Figure 1 shows predicted seasonal temperatures for central California and southern Idaho. Similar increases in temperature are predicted throughout the year at these locations. In California, the average annual increase is 3.6^{o}F by mid-century and 8.3^{o}F by late-century. In the more northern location of Idaho, the increase is a little greater at 4.6^{o}F by mid-century and 10.7^{o}F by late-century. For a location around Billings, Montana, the increase was 4.8^{o}F by mid-century and 11.2^{o}C by late-century (data not shown). This supports that greater temperature increases are being experienced in more northern locations. The ‘error bars’ on the graphs show the variation among model predictions. 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.

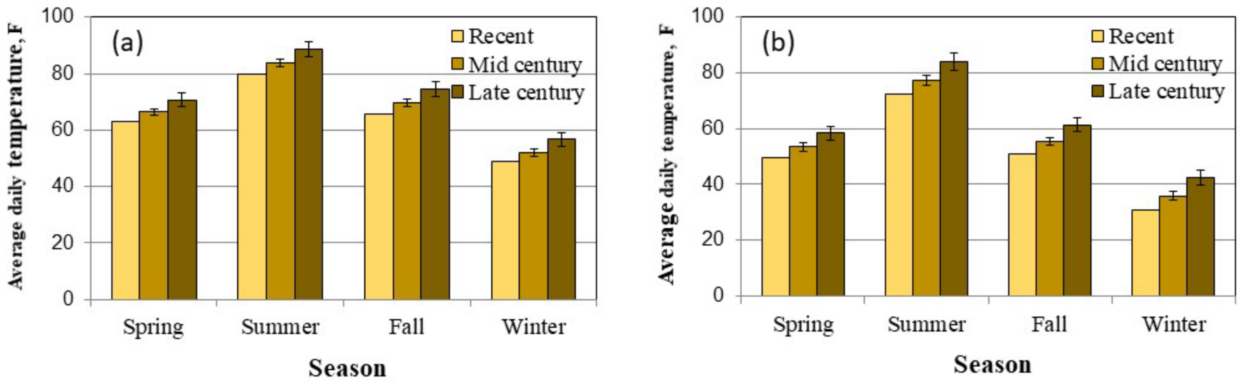

Figure 1. Recent and predicted future average temperatures for (a) central California and (b) southern Idaho.

As stated above, these predictions are for a worst-case scenario where little is done to reduce our CO_2 emissions. In reality, steps are being taken 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.

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 (Figure 2a). Data for Idaho show about a 12% increase in annual precipitation with little change during the summer season (Figure 2b). Montana data (not shown) indicate a 25% increase in annual precipitation with the increase occurring in the winter and spring seasons. Compared to temperature, there is more variability among models in predicting precipitation, but the trends tend to be consistent.

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 and grasses. Increasing temperatures increase the growing season, particularly in northern locations, which can lead to more harvests per year. Higher temperatures also increase evapotranspiration, and thus increase water requirements. Increases in precipitation are of some benefit; however, the minor changes found in the western states will not provide much help. Increases in evapotranspiration are expected to exceed increases in precipitation. Changes in precipitation patterns will affect field curing and harvest of forage crops in some parts of the country, but this will not have much effect in the relatively dry region of the western states.

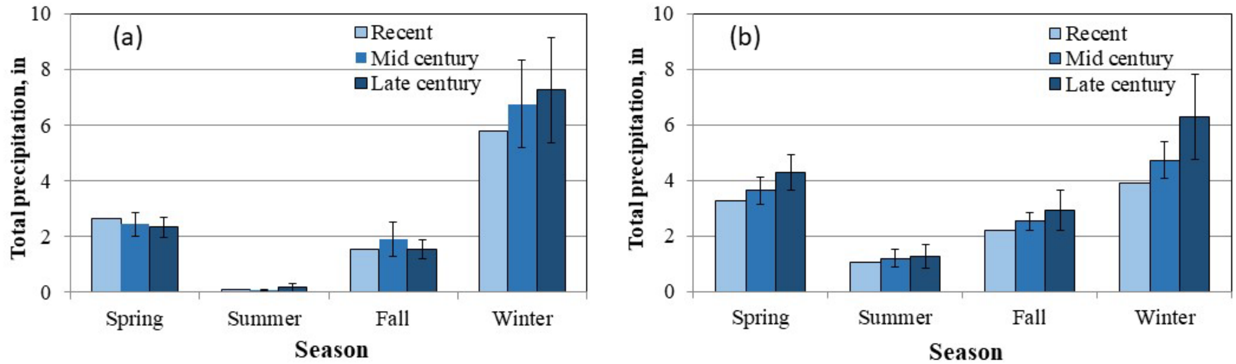

Figure 2. Recent and predicted future precipitation for (a) central California and (b) southern Idaho.

By linking crop models to global climate predictions, 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. Simulations were done for alfalfa operations in central California, southern Idaho, and central Montana. Harvested alfalfa yields were predicted to increase at each of the locations by mid-century with little change during the remainder of the century (Figure 3a). This increase primarily comes 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.

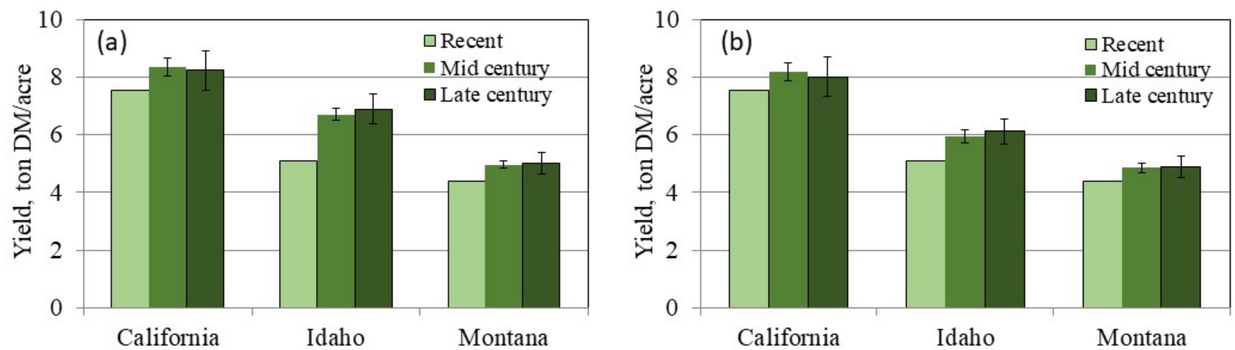

Figure 3. Predicted future alfalfa yields with (a) unlimited irrigation water and (b) irrigation limited to current use.

The first set of simulations was done assuming that adequate irrigation water was available to meet the needs of the crop. This created up to a 25% increase in water consumption per unit of hay produced. Another set of simulations for future weather was done with available irrigation water limited to that currently used for optimal alfalfa production. Under these conditions, future yields were similar to current yields in California and Montana with some increase in Idaho (Figure 3b). If irrigation water becomes even more restricted, the loss of production may be considerable. In general, alfalfa yield is about proportional to the amount of water applied to the crop (Lindenmayer et al., 2010).

Changes in temperature and rainfall can also affect nutrient losses from farms, but for forage producers in the western states this impact should be minimal. Our model predicts over a 100% increase in phosphorus runoff due primarily to more intense storms. The prediction for recent weather is less than 2 ounces per acre, which is very little compared to other crops and particularly those grown in the eastern states. Therefore, a doubling of little loss 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. The operation in California had substantially greater loss than those in the other locations, so this may become a greater concern for the future in this region.

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 species and diseases may also develop. These can also affect future yields and production costs.

DOES FORAGE PRODUCTION HAVE A CARBON FOOTPRINT?

Forage production, like any other production process, releases greenhouse gases to the atmosphere. The common measure for this impact has become known as the carbon footprint. This is a measure of all sources of greenhouse gas emissions during the life cycle of the product. Our analysis of alfalfa production in the western states gives a carbon footprint on the order of 350 lb CO_2 equivalent per ton dry matter of hay produced. To put this in perspective, this is similar to the emission from driving a pickup truck about 200 miles. Totaled over all alfalfa in the U.S., alfalfa production contributes a little over 0.1% of the estimated total emissions in the country and about 1.5% of the estimated emissions from all of agriculture. The carbon footprint for grass forage production is a little greater due to the need for nitrogen fertilizer. If we include grass hay production, the contribution toward national emissions would be 3 to 4 times that for alfalfa alone, but still small compared to other major emission sources.

Most of this emission occurs through the production and use of fuel, fertilizer and lime. Really, forage producers are removing substantial amounts of CO_2 from the atmosphere through plant growth, i.e. atmospheric CO_2 is fixed as carbohydrates in plants. Since this forage is ultimately fed to animals that convert the carbohydrates back to CO_2, we cannot take credit for this assimilation of carbon as a reduction in greenhouse gas emissions.

Although forage production is a relatively small contributor to greenhouse gas emissions, we all need to do our part to reduce emissions. For forage producers, this comes through more efficient use of fuel, fertilizer and lime. Reducing trips across the field, perhaps by combining swaths or windrows, will save fuel. Soil testing and using optimum applications of lime and fertilizer can reduce these inputs. Proper use of manure nutrients, when available, can further reduce fertilizer requirements. These savings can often be economically as well as environmentally beneficial.

IS CLIMATE CHANGE A CONCERN?

This all sounds positive for forage producers in the western states as long as adequate water is available for crop irrigation. So is there reason for concern?

As stated above, changes in climate are affecting various regions differently. Global analyses indicate that crop production in the northern U.S., Canada, Europe and northern Asia may benefit by projected changes in atmospheric CO_2, temperature and rainfall, but crop production in the rest of the world may suffer (Cline, 2007). This creates political issues surrounding future food production and security. There is also an ethical issue in that the countries contributing the least to increasing atmospheric CO_2, may suffer the most (Hayhoe and Farley, 2009).

For forage producers in the western states, the issue of future availability of irrigation water cannot be ignored. This resource will likely decrease in many areas of the west. For those that rely on surface water for irrigation, water availability is becoming more limited. Ground water sources should be more stable as long as the aquifers are being rapidly replenished.

CONCLUSIONS

Increases in atmospheric CO_2 and related changes in climate may increase alfalfa yields in western states 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 adjust to projected climate.

Southern regions of the U.S. and many other areas of the world have greater challenges ahead to adapt to changes in climate.

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