CLIMATE CHANGE AND NUTRIENT MANAGEMENT

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ABSTRACT

Climate change models for the intermountain region of eastern Oregon and Washington project warmer and wetter winters with warmer and drier summers. Crop response to the projected climate change conditions were estimated using CropSyst. The anticipated climate changes and increasing CO_2 levels are projected to result in greater yields of winter wheat with relatively small changes in yields of spring wheat, potatoes and apples. Greater yields will require increased nutrient supply and increased N efficiency to minimize emissions of green-house gases. Increasing N fertilizer application increased dryland wheat yield but did not halt the decline in soil organic matter in a crop-fallow system.

INTRODUCTION

Agricultural production, including animal agriculture, is a relatively small emitter of greenhouse gases (GHG), accounting for about 7% of total US greenhouse gas emissions (USEPA). These figures do not include transportation, processing, or other off-farm sources of GHG. Crop production has two different but related roles to play in the changing climate of the future. First, agriculture must adapt to the changing climate through changes in variety and crop selection, crop management, and other management factors. Second, agriculture can play a role in mitigating climate change by reducing the emissions of greenhouse gases. Three most common GHGs are CO_2, CH_4, and N_2O. They vary dramatically in their impact on climate as expressed in terms of their global warming potential (GWP) where CO_2 is taken to be 1 (Table 1). While most public attention is focused on CO_2, the GWP of CH_4, and N_2O are much greater than CO_2. Sulfur hexafluoride is not related to crop production but is shown for contrast.

Table 1. Global warming potential of selected greenhouse gases.

Gas	Global warming potential (20 year)
CO_2	1
CH_4	72
N_2O	289
Sulfur hexaflouride	16,300

It is ironic that the most common GHGs are so intimately connected to crop production. Agriculture, including animal agriculture, is responsible for about 60% of the N_2O emissions and about half of the CH_4 emissions in the US. Methane is a far more potent gas than CO_2 but it is the feedstock for essentially all N fertilizers, although N fertilizer can be manufactured using other sources of reduced carbon (C) such as coal. Finally, the greenhouse gas potential of N_2O is markedly greater than either CO_2 or CH_4 and it is emitted after N fertilizers are applied, especially to waterlogged soils that have limited O_2 for microbes.

The objective of this paper is to discuss the potential impacts of climate change on crop yields in the intermountain Pacific Northwest and discuss the role of N fertilizer management in soil organic matter.

RESULTS AND DISCUSSION

GHG emissions are driving climate change which is projected to result in substantial changes in temperatures and precipitation (amount, timing, intensity) in the future. Climate change models are based on various greenhouse gas emission models which in turn are driven by assumptions about the level of economic activity, regulations, technological developments, and other factors. The predictions of temperature and precipitation that result from these models vary but there is almost universal agreement that the world will be warmer in the future and that precipitation patterns, amount, and intensity will change. For example, Figure 1 shows projected change in surface temperatures under two different emission models for two different time periods.

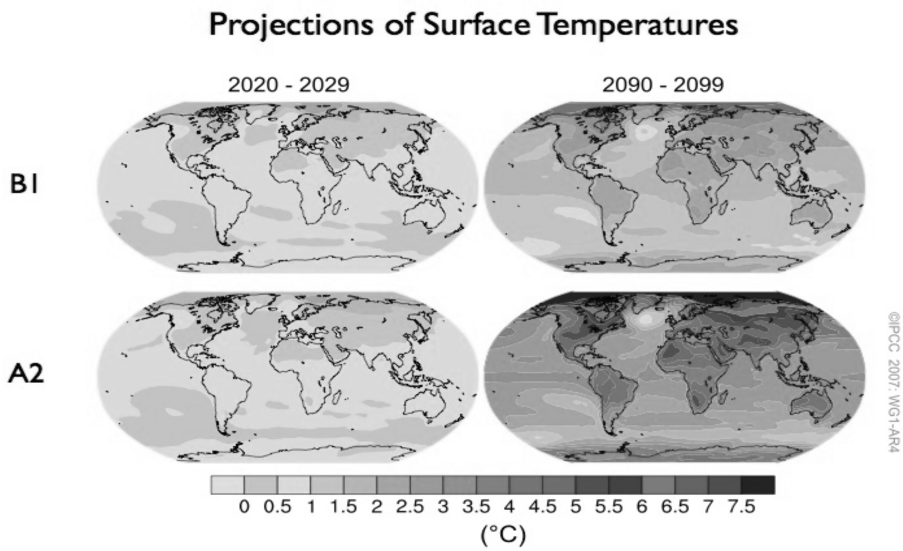

Fig. 1. Projected surface temperatures under two emission models for the periods 2020-2029 and 2090-2099.

Stöckle and his colleagues (2010) investigated the possible effects of projected climate change on four important crops for eastern Washington and Oregon (apples, potatoes, spring wheat, and winter wheat) at four locations in eastern Washington. Apples and potatoes are grown under irrigation while most of the 8 million acres wheat in the PNW is grown under dry-land conditions. They used CropSyst, a crop growth and yield model (Stöckle et al 1994, Stöckle et al 2003), to project crop yields under the forecasted climate conditions. CropSyst has been successfully tested on a variety of crops and in a variety of cropping environments (Pannkuk et al. 1998; Peralta and Stockle 2002: Scott et al 2004). While the model was run using sites in Washington state, the results are applicable to the dryland and irrigated cropping regions of north central and northeastern Oregon as the soils, weather, and cropping practices are similar. They used four GCMs that predict varying amounts of warming and precipitation in response to different emission projections. The baseline climate and projections for two GCMs are shown in Table 2. Pullman, WA is in the high rainfall region and continuous cropping is practiced while Lind, WA in the low rainfall region where the predominant cropping pattern is winter wheat followed by conventional tillage fallow. Both sites are projected to be warmer and wetter in the future.

Table 2. Baseline and projected climate for selected parameters at three dates at two locations.

Location	Parameter	Baseline	Global circulation model					
	Annual basis		CCSM3			PCM1		
			2020	2040	2080	2020	2040	2080
Pullman	Precip (in.)	21.0	21.6	21.4	23.2	22.0	22.4	23.2
	Mean T (°F)	47.3	50.4	52.2	53.6	49.3	50.9	52.5
	Mean T_{max} (°F)	58.1	61.0	62.8	64.4	60.1	61.7	63.1
	Mean T_{min} (°F)	36.3	39.6	41.4	42.8	38.5	39.9	41.7
Lind	Precip (in.)	9.1	9.8	9.6	10.5	9.7	9.8	10.1
	Mean T (°F)	50.2	52.7	54.3	55.9	51.6	53.2	54.9
	Mean T_{max} (°F)	62.4	65.1	66.9	68.2	64.0	65.8	67.1
	Mean T_{min} (°F)	37.8	40.3	41.9	43.5	39.2	40.8	42.4

Mean projected changes in region-wide annual temperatures and precipitation by season for the 2040's from 14 different models and two emissions scenarios are shown in Fig. 2 and 3. Temperatures are warmer throughout the year, but summer (JJA) temperatures increase more than the remainder of the year. Conversely, winter (DJF) precipitation increases while summer (JJA) precipitation decreases, expressed as a percentage of the baseline precipitation.

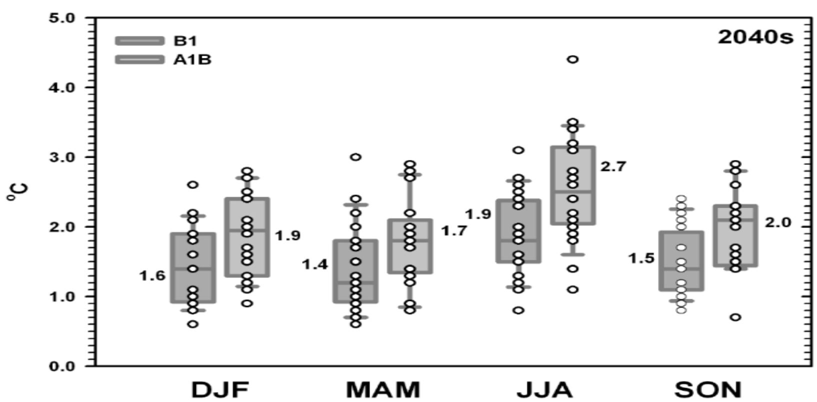

Fig. 2. Seasonal mean temperatures in the PNW under two emission scenarios in 2040 compared to baseline.

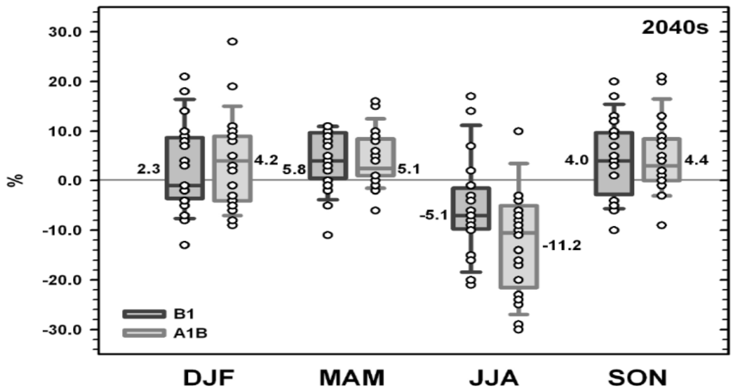

Fig. 3. Seasonal mean precipitation in the PNW under two emission scenarios in 2040 compared to baseline.

This shift in the amount and timing of precipitation has important implications for dry-land winter wheat production. They found that winter wheat yields increased in response to the increased CO_2 concentration coupled with increased winter precipitation and more moderate winter temperatures at three locations in eastern Washington (Table 3). Winter wheat is grown annually at Pullman, often in rotation with pulse crops such as peas or lentils. Winter wheat is grown after fallow at St. John followed by a spring grain. Winter wheat after summer fallow is the predominant cropping pattern at Lind. Yields of apples, potatoes, and spring wheat were relatively unchanged in the crop model. However, it is important to note that these yield predictions do not include any management or genetic adjustments that may offset the potential adverse effects of changes in temperature or precipitation.

Table 3. Winter wheat yield under projected CO2 concentrations and climate at three dates and at three locations.

Location	Annual ppt	2000	2020	2040	2080
	inch	--------------------------------	-------- lbs/acre	--------	-------------------------------
Pullman	21	5,100	5,885	5,770	6,450
St. John	17	4,150	4,790	5,175	5,100
Lind	9	3,550	4,095	4,330	4,795

These yield projections are based on availability of adequate nutrients and good pest management. Changes in pest populations and corresponding impacts on the crop were not included in their study, but the warmer and wetter winter climate could lead to more diseases, insects, and nematode pests as well as increasing weed challenges that may affect the crop yield.

It is ironic that the greater yields predicted by the CropSyst model will require additional plant nutrients, especially N, with the corresponding potential for greater GHG emissions in manufacturing, transportation, application, and so forth.

Soil organic matter (SOM) is the major soil component that stores and releases CO_2. There is confounding evidence about the role that applying additional N can play in sequestration and emission of C from soil organic matter. Khan et al (2007) reported that fertilizer N promoted the decomposition of crop residue and soil organic matter, and hence the release of CO_2. This view was challenged by Grove et al (2009) who found no evidence that fertilizer N led to the loss of soil organic matter. Data from the long term experiments at the Pendleton Station of the Columbia Basin Agricultural Research Center show that N fertilizer applications have little beneficial effect on soil organic matter in winter wheat-summer fallow system. The tillage-fertility LTE was initiated in 1940 and wheat has been grown in alternate years with three tillage systems (plow, disk, sweep) and five N rates (0, 40, 80, 120, and 160 lbs N/acre) for more than 70 years. Tillage had little effect on the total SOM, although the SOM concentration was slightly greater at and near the surface in the disk and sweep treatments compared to the plow treatment. Increasing N application rate had no significant effect on soil organic carbon in the top two feet of the soil (Table 4), although the higher N application rates produced greater yield and biomass (Machado, personal communication).

Table 4. Effect of fertilizer N rate on soil organic carbon in the top two feet of the soil in Tillage-Fertility Experiment.

	Fertilizer N application rate				
	------------------------------- lb N / acre -----------------------------				
	0	40	80	120	160
Soil organic C (%)	0.78a	0.80a	0.79a	0.81a	0.79a

The Crop Residue Experiment was established in 1931 and consists of ten residue management and nutrient application treatments that are replicated twice. Both phases of the winter wheat – summer fallow system are present so data is collected every year. Treatments in the CR trial range from the application of 10 tons of steer manure once each crop cycle to burning in the fall after harvest with no additional nutrients applied. The only treatment that has maintained SOM since 1930 is the application of 10 tons of manure biennially. All other treatments, including the application of 1 ton of pea vines biennially, lost SOM. The application of 40 or 80 lbs of N/acre produced more grain and biomass but did not stem the decline of SOM (Fig. 4). Fall burning of crop residue resulted in the greatest decline in SOM.

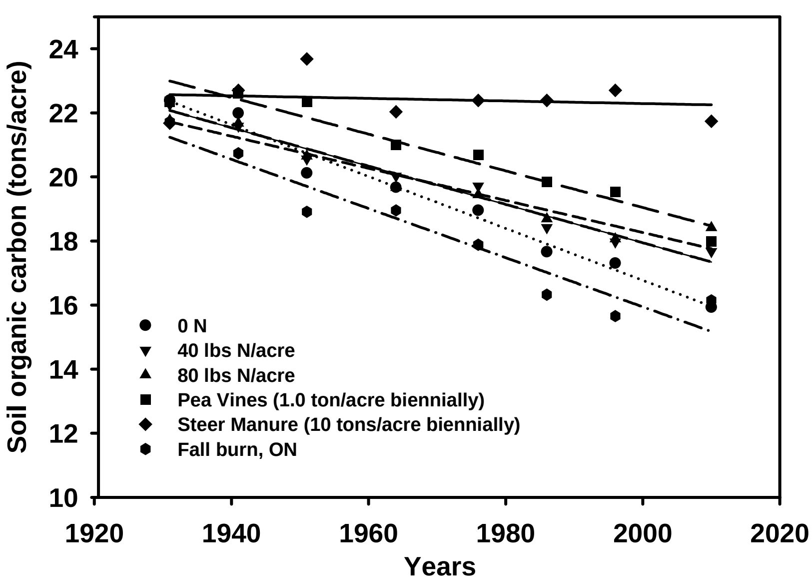

Fig. 4. Changes in soil organic carbon in the top 12 inches of the soil from 1931 to 2010 in the Crop Residue experiment at the Pendleton Station, Pendleton, OR.

SUMMARY

Agriculture is a relatively small emitter of GHG contributing only about 7% of US GHG emissions. Climate models project that the winters will be warmer and wetter while the summers will be warmer and drier than currently in the intermountain region of the PNW by 2080. These conditions are linked to greater dryland winter wheat yields with little effect on spring wheat, potatoes or apple yields. Increased yields will require more nutrients with the potential for greater loss of SOM and resulting release of CO_2. Data from the LTEs at the Pendleton Station show that N fertilizer application increases dryland winter wheat yield and biomass but does not increase the loss of SOM nor does it halt the decline of SOM.

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