Simulating the potential impacts of future climate change on corn and soybean crop health in the Lower Chippewa River watershed

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The Power of AND

Abstract

Climate Change has the potential to affect diverse biophysical and sociocultural attributes of society. As a result, it becomes prudent to probe into the potential ramifications of future climate change on the health of key crops. Using two future climate scenarios from the Intergovernmental Panel on Climate Change (IPCC) models, the study analyzed the potential impacts of future climate change on corn and soybean health. Crop health monitoring was implemented with the WinEPIC crop simulation growth model. Results demonstrated that both corn and soybean biomass, grain yield, and harvest index overall are predicted to decrease compared to 2010 partly as a consequence of the predicted increase in the number of water stress days for both crops. Future climate scenario with higher greenhouse gas emission predicted greater corn and soybean biomass and grain yields respectively, compared to lower greenhouse gas emission scenarios. Although this suggests that increase in CO_2 can lengthen the growing season in the study area and cushion the potential reduction of productivity for these crops, crop productivity is still predicted to fall irrespective of the scenario examined.

Study Area

This study focused on the LCRW located in west-central Wisconsin. The study area covers12,521km². The population in the LCRW is estimated at 280,000 (U.S. Census Bureau, 2010). The major economic activities are agriculture, service, and frac sand mining. Farming operations in the area consist of dairy, beef, and grain. The major crops include corn, alfalfa, and soybeans. The two largest land uses in the LCRW are agriculture and forested land.

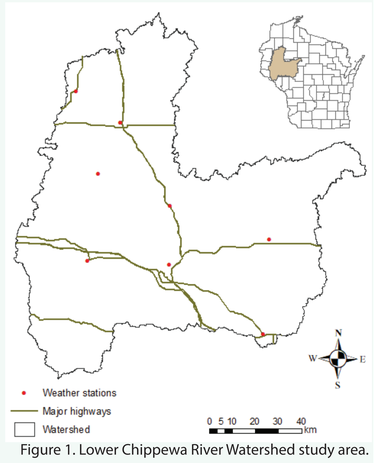


Figure 1. Lower Chippewa River Watershed study area.

Purpose

Since the 1950s, the impacts of climate change has been conspicuous across multiple scales. These impacts include but are not limited to melting of snow and ice, rise in sea level, and increase in atmospheric concentrations of greenhouse gasses. Moreover, climate change affects several biophysical processes that support crop production (Strauss et al., 2011). These processes include nutrient cycles, plant growth, and evapotranspiration. Changes in future climate can potentially alter the growth and production of crops leading to possible implications for food production and food security. As a result, it is necessary to evaluate the potential role that changes in future climate might have on corn and soybean production, two important crops in the LCRW, and eventual food security.

Methods

The IPCC identifies four specific Representative Concentration Pathways (RCPs) which approximate the overall radiative forcing concentrations which are a cumulative measure of human emissions of greenhouse gasses to be expected by the year 2100 in comparison to the year 1750. RCP4.5 and RCP8.5 pathways were independently selected to model the potential health effects on crops. RCP4.5 expects stabilization of greenhouse gas emissions in the future while RCP8.5 has a pessimistic outlook.

Datasets:

Historical Weather and Crop Data: Global Historical Climatology Network (GHCN) Daily Data (.DLY) from Blackland Texas A&M AgriLife Research and Extension Center

Projected Climate: Daily Multivariate Adaptive Constructed Analogs (MACA)

Soil Data: NRCS Soil Survey Geographic (SSURGO)

Fertilizers and Pesticides: USDA 2015 Agricultural Data Statistics Service Report

Running WinEPIC Crop Simulation Growth Model

WinEPIC is a windows based comprehensive model that has the capacity to simultaneously simulate soil and plant response to climate (Williams et al. 1989, Williams 1995). To model a particular crop indicator, for e.g. grain yield, the response function to different inputs can be summarized as follows: $Y_g = \beta_0 + \beta_1 W_d + \beta_2 S_d + \beta_3 M_d + \beta_4 F_d + \beta_5 P_d + \varepsilon$ Where W_d ,S_d ,M_d ,F_d , and P_d are the input datasets presented in figure 2, β_0, β_1, β_2, are parameter coefficients to be estimated for each input variable and ε is the error term or residual.

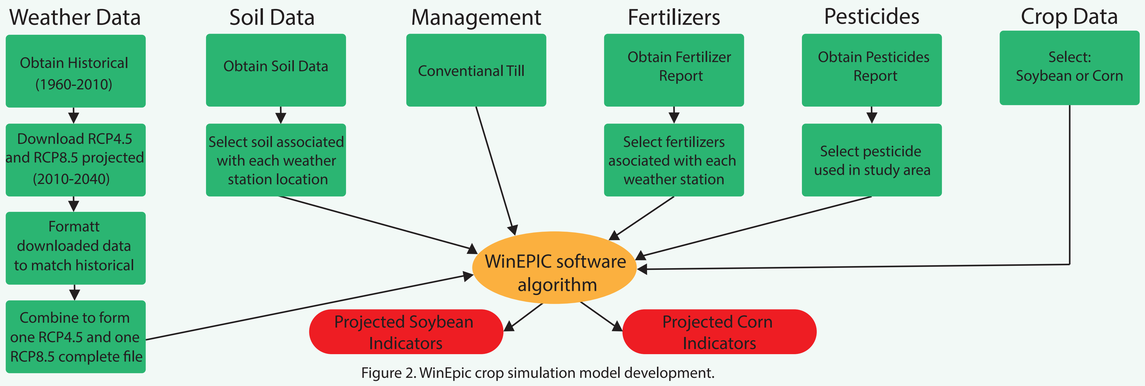


Figure 2. WinEpic crop simulation model development.

WinEpic Version 0810 was ran individually for 8 different weather station locations in the LCRW, for corn and soybeans respectively (figure 2). The generated crop health indicators of each weather station were averaged to obtain the overall values for each indicator. Soybeans could only be modeled using a rotational land use operation, therefore outputs could only be generated every other year.

Indicator Definitions:

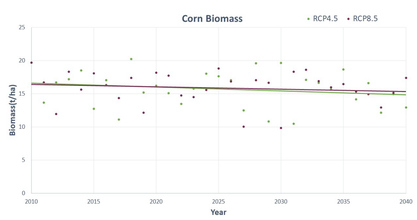
Biomass: measurement of the shoot and root weight

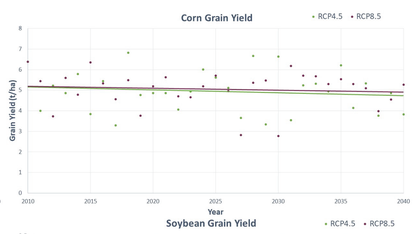
Grain Yield: weight of harvestable seed of crop

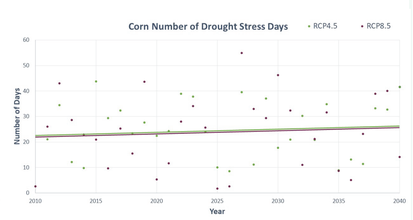
Harvest Index: harvest efficiency, the crop yield/above ground biomass

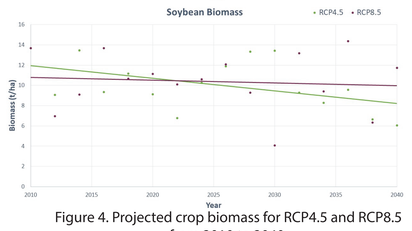
Drought Stress Days: a form of stress a pant can suffer from when it can no longer take up enough water to grow

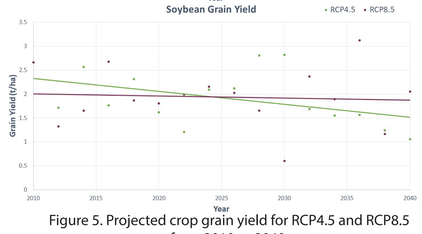
Results











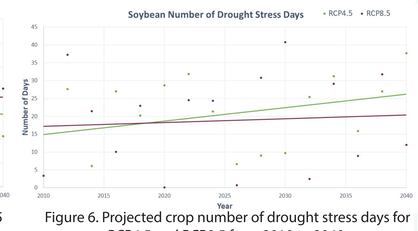


Figure 4. Projected crop biomass for RCP4.5 and RCP8.5 from 2010 to 2040.

Figure 5. Projected crop grain yield for RCP4.5 and RCP8.5 from 2010 to 2040.

Figure 6. Projected crop number of drought stress days for RCP4.5 and RCP8.5 from 2010 to 2040.

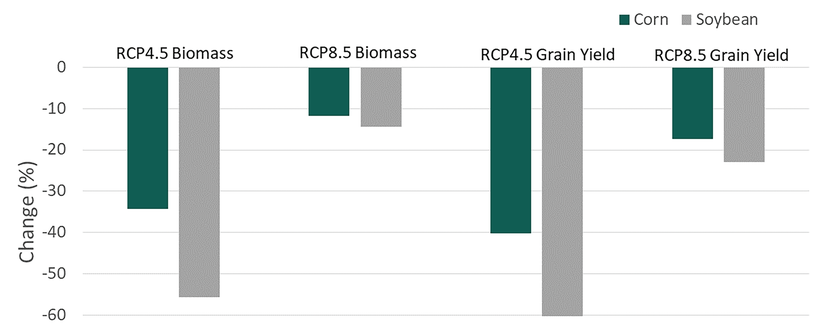


Figure 7. Percent change in corn and soybean biomass and grain yield from 2010 to 2040.

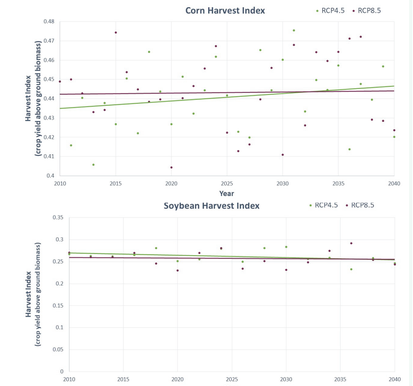


Figure 8. Projected crop harvest index for RCP4.5 and RCP8.5 from 2010 to 2040.

Discussion

-Corn and soybean biomass and grain yield are both predicted to decrease under RCP4.5 and RCP8.5 scenarios between 2010 and 2040. Water stress is predicted to be the main factor effecting crop growth under future climate change because RCP4.5 with stabilized greenhouse gas emissions demonstrated a decrease in crop biomass between 2030 and 2040. This suggests that another limiting factor must be impacting the growth of corn and soybean other than CO_2 emissions. The notable increases in water stress days suggest that lack of available water resources could be limiting corn and soybean growth.

-RCP8.5 having higher biomass and grain yield predictions across the 30-year time period compared to RCP4.5 for both crops suggests that increased greenhouse gas emissions, especially CO_2, can lengthen the growing season and to some extent act as a mitigating factor for climate change impacts on crops health.

-Large fluctuations of increasing and decreasing biomass and grain yield in the RCP8.5 predictions suggest that corn crops have the ability to better adapt to changing climate compared to soybeans. Soybeans overall are more sensitive to temperature changes than corn resulting in larger decreases in biomass and grain yield (Kukal et al. 2004). Result of this study confirms that corn has the ability to better adapt to changes in climate compared to soybeans.

Future Studies

To continue this research, it would be interesting to predict the spatial variation of the impacts of carbon emissions on crop health in relation to distances from large cities. WinEpic should be used to make predictions of soybean and corn response to future climate in croplands close to large metropolitan areas and the results of that compared to that of this study to determine whether the impacts of climate change will be experienced more in crop fields closer to urban centers due to the increased carbon emissions emitted compared to the LCRW, a mostly rural area.

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