Mapping shifts in production of cash crops in the American Midwest due to climate change

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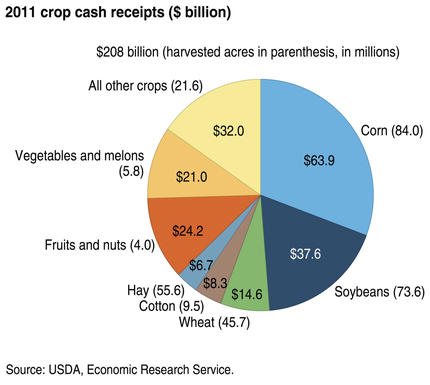
Climate change is predicted to have a significant impact on agricultural production in many parts of the world, including the United States of America. The goal of this study was to map the current production of corn, soybeans, and wheat in the United States of America, and then, using future climate data collected from numerous models, predict shifts in the location and production of those three cash crops due to changes in the climate of the continental United States. Preliminary analysis of the data found rises in temperature across the majority of crop production areas by 2050, while precipitation levels varied. Future analysis on the climate and crop data collected includes a Random Forest regression, which will identify the bioclimatic variables that have the most effect on crop production and use them to map predictions of future locations and yields of cash crops

Introduction

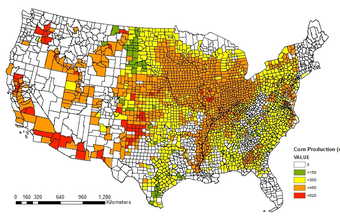
- If agricultural production in the U.S. were significantly affected by climate change, there would be a large, potentially detrimental impact on national and international food supplies and markets
- Previous climate studies done on U.S. crop production predict a general decrease in crop production due to rising temperatures[5]
    - Higher temperatures decrease growing season length and exceed optimal photosynthetic range of crop plants.
- Increases in carbon dioxide levels would mitigate crop yield decreases due to drought stress[1]
    - Some climate scenarios even predict raising production past current levels with increased carbon dioxide[3]
    - However, most climate scenarios predict crop yield decreases even with carbon dioxide levels rising.



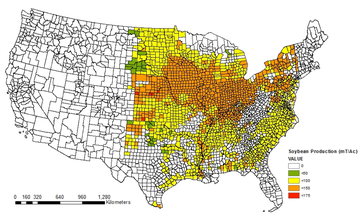
Source: USDA, Economic Research Service.

- Predicted precipitation levels vary between studies, but decreasing precipitation is associated with yield decreases.[4]
- This work is significant because it makes use of the newest climate predictions to calculate bioclimatic variables
    - Variables were used for determining crop production across an area not previously analyzed
- Previous studies done on climate change and crop production in the U.S. focused on the regional or state level[6]
    - Also only focused on one or two crops[2]
- This project analyzed changes in three main crops produced for consumption in the continental United States
- The results would be extremely useful for economists and both state and national governments trying to predict changes in agriculture markets
    - Changes could affect food supplies and unemployment rates.

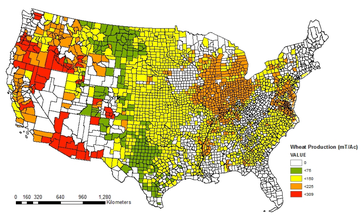
Methods



Corn



Soybean



Wheat

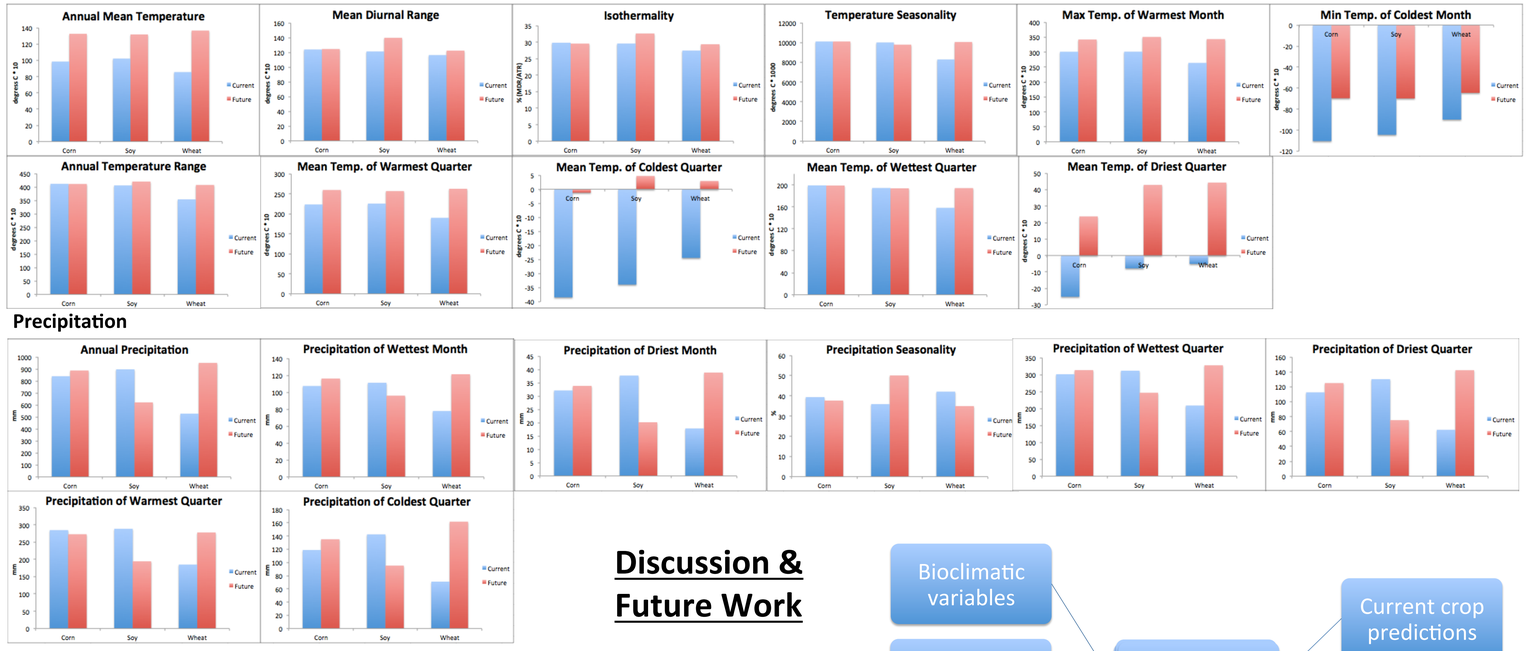
BIO1 = Annual Mean Temp.
BIO2 = Mean Diurnal Range (Mean of monthly (max temp - min temp))
BIO3 = Isothermality (BIO2/BIO7) (* 100)
BIO4 = Temp. Seasonality (StDev * 100)
BIO5 = Max Temp. of Warmest Month
BIO6 = Min Temp. of Coldest Month
BIO7 = Temp. Annual Range (BIO5-BIO6)
BIO8 = Mean Temp. of Wettest Quarter
BIO9 = Mean Temp. of Driest Quarter
BIO10 = Mean Temp. of Warmest Quarter
BIO11 = Mean Temp. of Coldest Quarter

BIO12 = Annual Precipitation
BIO13 = Precipitation of Wettest Month
BIO14 = Precipitation of Driest Month
BIO15 = Precip. Seasonality (Coefficient of Variation)
BIO16 = Precipitation of Wettest Quarter
BIO17 = Precipitation of Driest Quarter
BIO18 = Precipitation of Warmest Quarter
BIO19 = Precipitation of Coldest Quarter

Bioclimatic variables averaged from 14 different models used in the IPCC AR5 Report
Current climate: average of historic data from 1950-2000
Future climate: average of model data from 2041-2060 for rcp 8.5
Model data collected from WorldClim.org

Results

Temperature



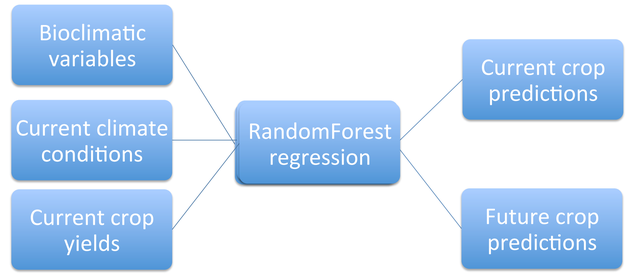
Precipitation

Discussion & Future Work

- There are increases in the majority of bioclimatic variables related to temperature across the areas where corn, soybeans, and wheat are produced.
- Areas where corn is produced exhibit the smallest temperature variable changes between current and future climates of the three crops
    - May be due to varied corn distribution across the U.S.
- Larger increases are seen in temperature variables across soybean areas
    - Soybeans and corn are both grown in the Midwest
    - Corn/soybean crops may be subjected to future heat stress
- Wheat areas exhibit increases across all temperature variables, indicating heat stress on wheat crops
- Precipitation changes vary across the areas where each crop is grown
- Corn areas generally see a slight increase in precipitation
- Soybean crop areas see decreases in all precipitation variables except for precipitation seasonality
- Wheat areas see large increases in precipitation

Conclusions

- With the distributions of crop production and projected changes in climate:
    - Corn production will hold fairly steady, may decrease
    - Soybean production will decrease due to drought stress
    - Wheat production may see decreases due to heat stress, counteracted by increases in precipitation
- Examining geospatial patterns of crop production and climate provides more accurate analysis, as these crops have a large distribution throughout the U.S.
    - Distinct regions and crops grown there will be affected differently by climate change



A Random Forest regression analyzes geospatial patterns and differences in crop and climate data

- Current crop production predictions can be compared to actual yield maps
    - Shows accuracy of regression and highlights areas that may not be suitable for crop growth, but are currently being utilized (irrigated lands)
- Prediction of future crop production areas shows areas that gain or lose suitability for crops
    - Important implications for local and national economies
    - Adaptation and mitigation strategies may be discussed

References

[1]Easterling, W.E., Mearns, L.O., Hays, C.J., Marx, D. 2001. Comparison of Agricultural Impacts of Climate Change Calculated from High and Low Resolution Climate Change Scenarios: Part II. Accounting for Adaptation and CO_2 Direct Effects.
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