The Relationship Between Climate and Crop Yields in the USA and China in the Last Few Decades

Michael Romero[1], Cynthia Poon[2], Ehsan Najafi [2,3], Indrani Pal[2,3]

1.Hunter College 2. The City College of New York 3. NOAA CREST

michaelhrom@gmail.com cynpoon29@gmail.com

Abstract

Due to rising population trends, food security has become a growing concern. It is expected that the demand for food will exceed the amount of food available. A country's yield of crops can be impacted by local and large scale climatic patterns such as drought, precipitation, temperature and the average of sea surface temperatures(SST). To measure SST, one uses the El Nino 3.4 index to determine a relationship. To quantify drought, the Palmer Drought Severity Index (PDSI) will be used. This project will focus on determining how the factors of drought, precipitation, temperature and SST patterns can affect crop yields in India and the United States. The rice and wheat yield data of these two countries, is taken from the Food and Agriculture Organization of the United Nations (FAO) will be considered. The association between the climatic patterns and detrended crop yields will be investigated using Multiple Linear Regression (MLR). The final model presents the yield of the crops in these countries as a function of precipitation, temperature, drought and SST in India and the United States.

Introduction

- Food Security is the availability and distribution of nutritional food throughout the world's populations.
- As populations are increasing at an exponential rate, the demand for food moves in proportion, this threatens the world's food security and will lead to unequal distribution as the available food supply cannot not keep pace with this demand.
- There are many factors that attribute to the growing cause of the unequal distribution but this project will focus on SST, precipitation, temperature, and drought.
- Climate is the prevailing weather conditions in a region such as precipitation, temperature, and humidity.
- Temperature and precipitation conditions have a large effect on crop yield.
- Drought is considered a lack of moisture in a given environment over a period of time.
- PDSI is used to measure a given environment's expected and current amount of precipitation and demand for that moisture to categorize the severity of a drought. A scale from -10 to +10 is used to indicate whether this area is suffering from a drought (below -3 means there is a severe drought).
- SST is measured through the El Nino Index, which uses 5 regions(1,2,3,3.4,4); these variations indicate the changes in SST temperatures and air pressures, across the Tropical Pacific. It can result in a change in patterns in temperatures and precipitation around the globe.
- The purpose of this project is to raise awareness to the growing problem that the world's food security will not be enough to support future generations.
- In order to solve this growing concern, the population and government must help support local food systems produce to their maximum efficiency by supplying them better technology and establish social programs that distribute food and economically assist farmers.

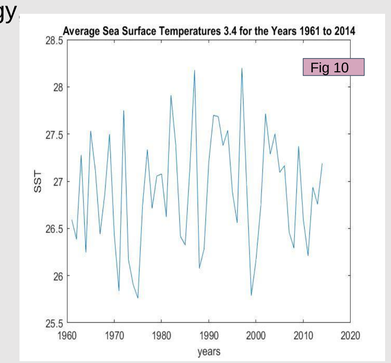
Methods and Materials

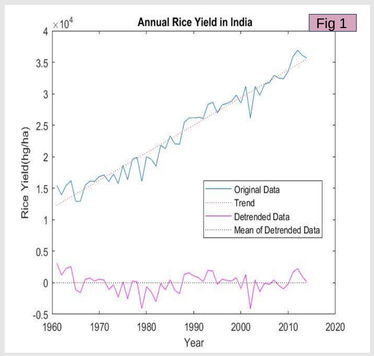
Multiple Linear Regression (MLR) can explain how the variables will affect wheat and rice yields. We will model the relationship between the multiple independent variables–precipitation, temperature, drought, and SST– and the dependent variable as shown in this equation.

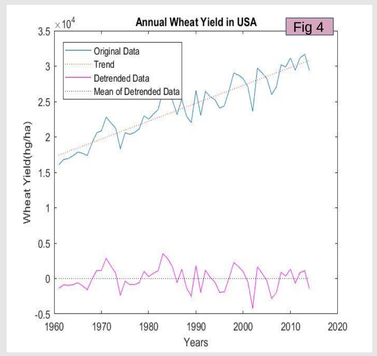
Yield= b0+(Temperature)b1+(Precipitation)b2+(PDSI)b3+(SST)b4

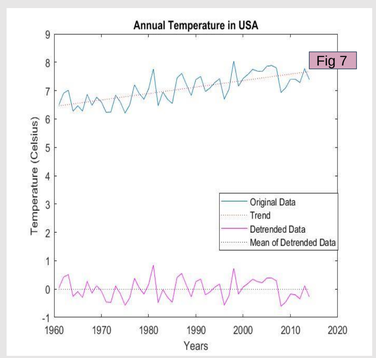
To determine association, the data will first be detrended. Annual wheat and rice yield data was taken from Food and Agriculture Organization of the United Nations, http://www.fao.org/faostat/en/#data/QC.The annual average of precipitation and temperature at the country level was obtained from the World Bank website at https://datahelpdesk.worldbank.org/knowledgebase/articles/902061-climate-data-api. Monthly PDSI data over crop lands was taken from a study of global crop yields through climate and technology https://doi.org/10.1002/2017EF000690. Data of SST through the years 1961 to 2014 will be taken from https://www.esrl.noaa.gov/psd/data/correlation/nina34.data.

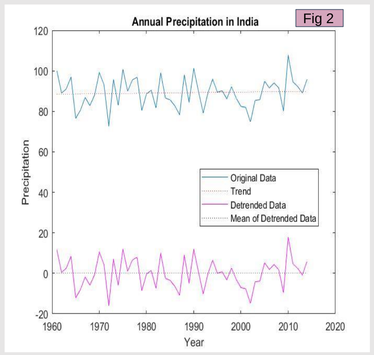
The detrended yield data and the detrended data of temperature and precipitation anomalies will be used to find a relationship among each other. Using Matlab, yield was detrended to take away variations from technological advancements, temperature and precipitation was detrended to remove the impact of climate change and SST was transformed from monthly data to yearly data. It was also used to run a code for MLR to find coefficients for the function of yield. The detrended data was graphed to compare how each country has multiple factors that affect each of their respective crop yields.

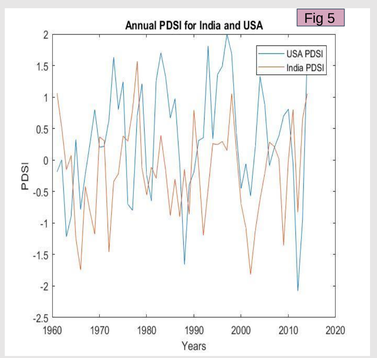


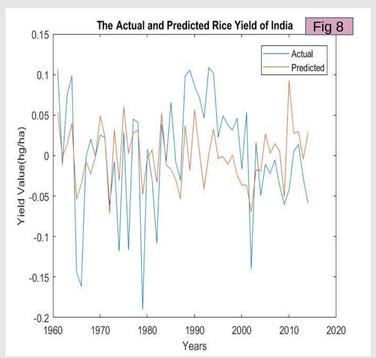


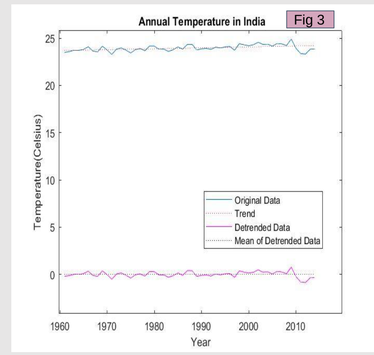


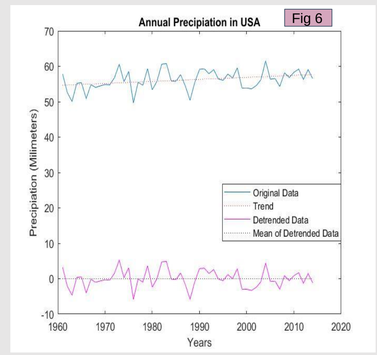


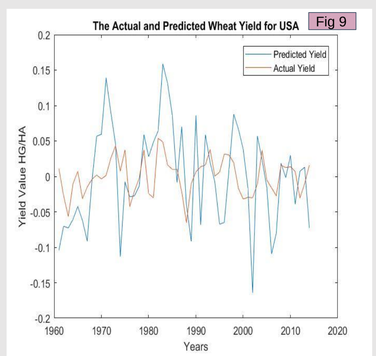












Results

Each country has different Multiple Linear Regression(MLR) equations to find the association between the variables and crop yield. The regression coefficients represent the mean change in the dependent variable for one unit of change in the independent variable. Using these coefficients, one could accurately predict future crop yields and identify different relationships among these variables. With the coefficients found below to substitute into the MLR formula, we created a function that represents predicted rice yield in India and predicted wheat yield in India in terms of Temperature, Precipitation, PDSI, and SST.

Rice Yield in India=
-0.07-0.014(Temperature)+0.005(Precipitation)-0.0064(PDSI)+0.0026(SST)

Wheat Yield in USA=
-0.101-0.02(Temperature)+0.006(Precipitation)+0.0125(PDSI)+0.0036(SST)

Variables	Rice Yields in India	Wheat Yields in America
b_0	-0.0710	-0.1013
b_1 (Temperature)	-0.0143	-0.0203
b_2 (Precipitation)	0.0051	0.0061
b_3 (PDSI)	-0.0064	0.0125
b_4 (SST)	0.0026	0.0036

Conclusions

To conclude the project, one will understand that using the coefficients found through Matlab, one could predict future yields using this equation and substitute the different variables. In recent years, it can be seen that India has a higher yield in rice than the USA's wheat yield. When the four variables are compared, it is seen that India has a higher temperature and precipitation; these conditions are best suitable for growing rice while the USA has a higher PDSI. India's proximity to the Tropical Pacific allows its monsoons to be greatly affected by irregular wet and dry conditions. The USA's precipitation is greatly affected by SST throughout the nation as well. Using MLR and detrended data, one is able to see the relationship of these different factors among each other and explain the differences in yields.

References

Dai, Aiguo & National Center for Atmospheric Research Staff (Eds). "Palmer Drought Severity Index (PDSI)." *Standardized Precipitation Index (SPI) | NCAR - Climate Data Guide*, National Science Foundation, Sept. 2012. https://climatedataguide.ucar.edu/climate-data/palmer-drought-severity-index-pdsi.

Najafi, E., Devineni, N., Khanbilvardi, R. M., & Kogan, F. (2018). Understanding the Changes in Global Crop Yields Through Changes in Climate and Technology. *Earth's Future*, 6, 410–427. https://doi.org/10.1002/2017EF000690.

Acknowledgements

NOAA-CREST program is funded by NOAA/EPP Grant # NA16SEC4810008" and "NOAA CREST HIRES program is a part of the Science Research Mentoring Program and funded by the Pinkerton Foundation.