Abstract

Drought is becoming an increasingly severe problem for much of the world. A drought is a sustained period of reduced rainwater or river flows, and it greatly impacts the water quality and usage of a region. As the globe warms, weather becomes increasingly erratic, and the probability of drought rises. Regions with more water experience higher rainfall, and regions with less water receive lower rainfall. Drought is an extremely problematic weather pattern because it decimates a region's food and water supply and thus destabilizes entire nations. Following the drought in California in the early 2010s, many policies were suggested and implemented to conserve water, such as limiting the water a farmer receives, increasing the static price of water, and forcefully changing irrigation techniques, along with a host of urban water restrictions. The goal of this project is to build a rough projection of how climate change affects drought regularity, how drought affects agriculture, what we can expect in the future, and which policies can best adapt to the future.

Model

This model will be split into two parts. The first will be on how climate change affects drought. Drought is generally represented through reduced soil moisture, rainfall, and river flows. To simplify the model, I will attempt to find correlations between those and increasing temperatures. Creating a model this simple is a large assumption, as higher temperatures affect other drought-related factors such as rate of evaporation as well. I may need to add the pressures of a growing human population with greater freshwater needs. I will then use these correlations to predict the regularity of drought in the future.

I am predicting based on historical averages and variances in climate data. Another assumption I will be making is to limit the model to a county in California, or Fresno. I chose to highlight Fresno because it's one of the counties that suffered the most from the extreme drought in the early 2010s in California. I am also from Southern California. The reason why this is such a large assumption is because climate is often irregular and creating weather models on limited regions suffers from variance. I am currently using government weather data for precipitation in the Fresno Yosemite station. This should be a simple 1-D simulation. However, I am currently having difficulty finding relevant river flow data and soil moisture content data. My primary goal in this section is to analyze how the consequences of climate change affect water flow around the globe. I can only use face validity to validate the model. If the trend seems right and seems similar to other weather predictions, then the model is reasonably accurate. Verification shouldn't be a problem because this is a simple 1-D model.

The second part will cover how drought influences agriculture. I have chosen 5 crops (cotton, figs, grapes, almonds, tomatoes) because they cover a wide spectrum of water usage and they represent primary exports from Fresno, California. I will discuss how changing water supply affects the crop composition of Fresno and I will create a cohabitant model of the different crops with variables that change depending on the availability of water and market demand. The beginning steps are already on the github. Essentially, I will build a discrete model of these five crops (of varying water demands and market values) which updates yearly based on incoming weather predictions from the first model. Some factors I will include to model real-world truths is to include farmer inertia (there has to be sizable benefit to change crops), changing water prices (prices will change drastically based on water availability) and slightly shifting market prices (prices will change purely on supply to prevent all farmers from only farming one crop but they won't change too much because variance destroys farmers.)

I will then describe how varying factors (irrigation techniques, water pricing policies, government subsidies, urban regulations, growing populations) affect crop composition. I will verify my model by verifying that my model creates a legitimate crop composition that reflects the crop diversity that I expect in the conceptual model. Again, validation is quite difficult because this is an extremely simplified model which uses many assumptions, but I will use face validation by confirmation that these disturbances to the model end up with the suggested shifts in crop composition.

I will develop everything on the jupyter notebooks platform using numpy, pandas, and matplotlib. I have used a variety of resources to research the topic and collect data. I am still struggling to find good soil moisture and streamflow data. Updates can be seen in the jupyter notebooks Drought.ipynb in my attached Github repository.

alu76/Drought: Drought model project for CX 4230 (gatech.edu)

Some related materials on how climate change affects drought

Drought and Climate Change | Center for Climate and Energy Solutions (c2es.org)

Earth's Freshwater Future: Extremes of Flood and Drought – Climate Change: Vital Signs of the Planet (nasa.gov)

Climate Communication | Drought

Using MLLR to predict drought from river flows

Drought Streamflow Probabilities in Virginia (usgs.gov)

Potential option for streamflow/soil moisture content data. The data is generally noisy or other unusable though. Will need to find alternative.

Custom Options - Global Summary of the Year | Climate Data Online (CDO) | National Climatic Data Center (NCDC) (noaa.gov)

National database of precipitation and temperature data

USGS Groundwater Historical Instantaneous Data for California: Build Time Series

A potential validater of my crop composition results

Effects of Drought on Crop Production and Cropping Areas in Texas - Ray - 2018 - Agricultural & Environmental Letters - Wiley Online Library

Crop data

Water footprint of crops

Crop Values 2015 Summary 02/24/2016 (cornell.edu)