An Ensemble Precipitation Prediction Model for Sub-Saharan Africa using a Dendrochronological Reconstruction and Satellite Data

Background

The region of sub-Saharan Africa has one of the highest rates of subsistence farming in the world. In addition, many of the countries in the region rely on hydroelectric power to support their energy grids. This makes the people, environment, and economy, of sub-Saharan Africa, very sensitive to changes in precipitation levels. Additionally, sub-Saharan Africa is severely lacking in past climate data. This makes it extremely difficult to do climatic studies of the region.

In this project, I attempt to remedy this by creating a precipitation reconstruction using a dendrochronological proxy, as well as by creating a prediction model for the region using my reconstruction, and satellite data for the region.

Methods

Using a chronology I collected in Zambia, as well as other chronologies from the region, I create a 200 year precipitation reconstruction using a nested Principal Component Analysis. I validate said reconstruction with a spatial correlation analysis, RE and CE statistics, and other methods. Next, I collect relevant satellite data from NASA and run the satellite data and my reconstruction through three gradient boosting models, XGBoost, LightGBM, and CatBoost. I stack the outputs of these models using a standard weighted stacking method to create a prediction for precipitation in the sub-Saharan region 100 months into the future.

Results

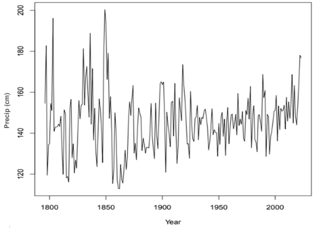

Fig 1. 200 year dendrochron-ological precipitation reconstruction

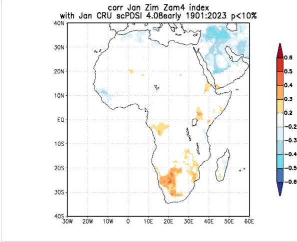

Fig 2. Spatial correlation between my reconstruction and the Palmer Drought Severity Index (PDSI)

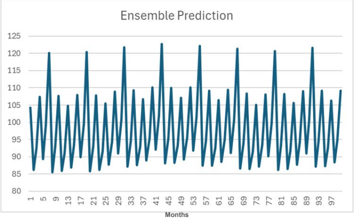

Fig 3. Fully stacked precipitation prediction model

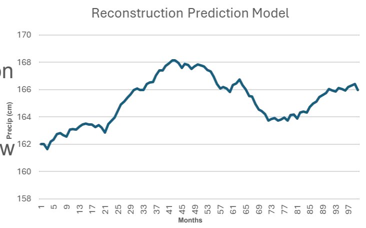

Fig 4. Stacked precipitation prediction model showing low frequency variability

Results and discussion

My reconstruction showed high variability in it's beginning, though I suspect this to be an artifact of low sample depth at that age. The spatial correlation matrix against PDSI, which is an index of how much water plants are able to get, demonstrated sufficient correlation in the area of study. My final model favors seasonality over low frequency variability, though said variability does exist. The seasonality demonstrates the pattern we would expect, given the region's wet and dry seasons. I included Figure 4 to better demonstrate the low frequency variability that the models predicted, trained on my reconstruction. I found it interesting how both the reconstruction and the prediction said that precipitation has, and will continue to increase, which was not what I was expecting. However, I also demonstrated an increased range in the modern era, indicating more severe storms and droughts. While further research is certainly needed in this region to continue to remedy the lack of historical climate data in the region, given these results, I would advise the countries of sub-Saharan Africa that further severe weather is likely to come in the future, and to invest in climate resilient infrastructure and sustainable practices region-wide.