Modeling precipitation patterns in South America due to the impact of water availability on crop yields

Final Project for ENV797: Time Series Analysis

Chloe Young, Gaby Czarniak, and Weilin Wang

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Introduction

This final project uses time series analysis to better understand changes in precipitation patterns in Argentina, Brazil, and Colombia, as we were interested in the continent of South America and these three countries are major agricultural producers of key crops globally. For context, Brazil and Argentina are two of the largest soybean producers in the world, with April 2025 estimates placing Brazil at producing 152 million tonnes—the largest soybean producer among Agricultural Market Information System (AMIS) countries—and Argentina producing 48.21 million tonnes—the third-largest soybean producing AMIS country—in 2023/2024, respectively (AMIS, 2025). For reference, the United States produced 113.27 million tonnes of soybean in 2023/2024 (AMIS, 2025). In terms of soybean exports, Brazil leads by far and Argentina comes in fourth among AMIS countries (AMIS, 2025). Colombia is a leading producer of coffee, bananas, flowers, rice, maize, palm oil, and more (Santana, n.d.). Brazil is also a leading producer of coffee, sugarcane, and corn, among other crops (IFAD, n.d. a.). In addition to soybeans, Argentina is a leading producer of wheat, corn, and wine, among other crops (ITA, 2022).

Motivation

Since in 2023 agriculture represented 7% of GDP in Argentina, 6.2% in Brazil, and 8.7% in Colombia, this group was interested in factors that could have a major impact on crop yield, one of which is precipitation (IFAD, n.d. b.). Not only is global supply of a crop like soybean partially dependent on crop yields in Brazil and Argentina, for example, but within Argentina, Brazil, and Colombia, crop production impacts the labor force, too. In Colombia, for instance, agriculture accounts for 16% of employment (IFAD, n.d. b.). In terms of the motivation behind looking into precipitation data, specifically, over 39 million hectares of land in Argentina are cultivated for farming and ranching, while only 5% of these lands have irrigation systems (ITA, 2022). As water availability is key to food production (FAO, 2015), precipitation variability can very crucially impact agricultural planning.

Relevance

Questions around changing precipitation patterns are particularly relevant given changing frequency and intensity of precipitation due to global warming (Myhre et al., 2019). The IPCC warns that rarer extreme precipitation events will become more frequent with more global warming (Seneviratne et al., 2021). The Food and Agriculture Organization has highlighted the importance of understanding "spatial changes in

precipitation, in intensity and seasonal distribution" (FAO, 2015). Precipitation variability differs significantly by region. Understanding regional differences can help develop targeted adaptation strategies for, it is hoped, a more secure food system.

Objectives

Given data availability and the scope of this project, we evaluate the performance of different models used for time series analysis in fitting precipitation data for Brazil, Argentina, and Colombia, at the country level. The objectives are to determine: Using a training set of historical values and testing against more recent values, which model best fits and forecasts precipitation data for Brazil, Argentina, and Colombia? Is the magnitude of seasonality changing over time? The latter question is a question of interest in relation to the IPCC findings that extreme precipitation events will be increasing in frequency and intensity, with complex spatial distributions (Seneviratne, 2021).

Dataset information

Methods

Models

Brazil

Argentina

Colombia

Summary and conclusion

Major findings

Conclusions to draw from these findings

Limitations and insights on how to improve the model

Predicting changes in frequency and intensity of extreme precipitation events is deeply complex and, as stated in the IPCC Sixth Assessment report, "increases in the intensity of extreme precipitation at regional scales will vary, depending on the amount of regional warming, changes in atmospheric circulation and storm dynamics (high confidence)" (Seneviratne et al., 2019). Regarding limitations, it should be noted that, while we use precipitation data at the country level, precipitation patterns can vary drastically within each country, which contain multiple and varying ecosystems. Forecasting precipitation levels at the country scale does not account for precipitation patterns across different regions within a country. To make these models more helpful, time series models could be used could to analyze and forecast precipitation within key crop-producing provinces; in Argentina, for instance, this could be the provinces of Santa Fe, Córdoba, and Buenos Aires, where climate, water tables, and precipitation vastly differ from the southern tip of Argentina's Misiones, Tierra del Fuego, and Jujuy provinces.

Contribution statement of this report

Introduction, motivation, relevance, objectives, and limitations within the conclusion – Gaby Dataset and methods – Chloe Summary and conclusion – Weilin Code & analysis for Brazil – Weilin Code & analysis for Argentina – Gaby Code & analysis for Colombia – Chloe

Github repository link

https://github.com/chloeyoung26/CzarniakWangYoung_ENV797_TSA_FinalProject-.git

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