Analyzing the Impact of Climate Change on Agricultural Productivity in Latin America

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***Abstract*—This study explores the impact of climate change on agricultural productivity in Latin America between 2015 and 2021. Using datasets from the World Bank and FAO, we analyze climate variables alongside agricultural metrics (yield, area harvested, and production). Key findings reveal a negligible correlation (0.06) between precipitation and agricultural yield, suggesting that precipitation alone may not be a primary driver of productivity changes. Country-specific findings highlight significant variability, with Colombia showing high average precipitation (3240 mm) but yields comparable to countries with less rainfall, such as Argentina (591 mm). These results emphasize the need to consider other factors like temperature, soil quality, and farming practices. The study provides insights for policymakers and researchers aiming to mitigate climate change's effects on food security.**

I. Introduction

Climate change poses a significant challenge to global food security, particularly in regions heavily dependent on agriculture. Latin America, known for its agricultural exports, is vulnerable to changes in climate variables such as precipitation and temperature. These changes directly impact crop yields, production, and land use. This study focuses on understanding how climate change affects agricultural productivity in Latin America between 2015 and 2021.

The primary question addressed is: How does climate change impact agricultural productivity in Latin America?

To explore this question, the study utilizes climate data (e.g., precipitation) from the World Bank and agricultural data (crop yields) from the FAO. By analyzing trends, distributions, and correlations, the research aims to provide actionable insights into the relationship between climate variability and agricultural output.

II. DATASET

The datasets were collected from the FAOSTAT and World Bank websites. It used for this study include:

A. Climate Data

A. The Climate Data, sourced from the World Bank Open Data repository, provides crucial insights into environmental conditions with variables such as annual precipitation (measured in millimeters) and other climate indicators. These metrics are instrumental in understanding patterns that influence agriculture, ecosystems, and socio-economic activities. The dataset is made accessible under the Creative Commons Attribution 4.0 International (CC BY 4.0) license, which allows for extensive reuse and distribution provided proper attribution is given. For this study, the dataset was filtered to focus on the years 2015 to 2021, ensuring temporal alignment with the agricultural data. Samples from the dataset (pipeline output) are shown below Figure 1.

	Country Name	Indicator Name	Year	Value
0	Argentina	Average precipitation in depth (mm per year)	2015	591.0
1	Brazil	Average precipitation in depth (mm per year)	2015	1761.0
2	Chile	Average precipitation in depth (mm per year)	2015	1522.0
3	Colombia	Average precipitation in depth (mm per year)	2015	3240.0
4	Costa Rica	Average precipitation in depth (mm per year)	2015	2926.0

Fig. 1. **Climate dataset**

B. Augriculture Data

The Agricultural Data, obtained from FAOSTAT, encompasses key metrics like crop yield (in kilograms per hectare), production volumes (in metric tons), and the harvested area (in hectares). This dataset offers a granular view of agricultural productivity and resource use across countries. Licensed under the Open Data Commons Open Database License, it ensures open access with the requirement to share any derivative database under the same terms. The data underwent preprocessing to standardize variables like country names and address any missing values. We filtered the agricultural dataset to include selected countries in Latin America and the Caribbean and focused on data from the years 2015 to 2021. Subsequently, we calculated the annual mean values of agricultural metrics for each country, creating a structured dataset of country-wise trends over time for further analysis. Samples from the dataset (pipeline output) are shown below Figure 2.

	Area	Element	Unit	Year	Value
0	Argentina	Area harvested	ha	2015	382.00
1	Argentina	Yield	kg/ha	2015	1873.50
2	Argentina	Production	t	2015	714.86
3	Argentina	Area harvested	ha	2015	8431.00
4	Argentina	Yield	kg/ha	2015	864.70

Fig. 2. **Agriculture dataset**

III. METHODOLOGY

There are several steps in methodology. The complete analysis involved the following steps:

A. Preprocessing

To prepare the datasets for analysis, several preprocessing steps were conducted to ensure alignment and relevance of the data. Initially, irrelevant columns such as 'Indicator Code' and 'Country Code' were dropped from the climate and agricultural datasets to streamline the data and focus on key variables. This step reduced noise and retained only the most relevant information for the study. The data was then filtered to include records from 2015 to 2021, aligning the timeframes across both datasets for consistency and comparability. To address missing values, rows with incomplete information were removed to preserve the quality and accuracy of the dataset. The filtered datasets were subsequently merged based on the shared fields of 'Country Name' and 'Year', creating a unified dataset. This comprehensive dataset combines climate indicators such as precipitation with agricultural metrics like crop yield and production, enabling a robust analysis of the relationship between climatic conditions and agricultural outcomes

B. Exploratory Data Analysis (EDA)

Exploratory Data Analysis (EDA) was conducted to uncover patterns and relationships in the combined dataset. The bar chart visualizes agricultural data for selected Latin American and Caribbean countries from 2015 to 2021. Each bar fig 3 represents a specific country's annual agricultural metric values ('Value'), grouped by year and distinguished by color. Notable patterns, such as Brazil's significantly higher values compared to other countries, indicate disparities in agricultural production or metrics. The x-axis lists the countries, while the y-axis represents the agricultural metric values in the dataset.

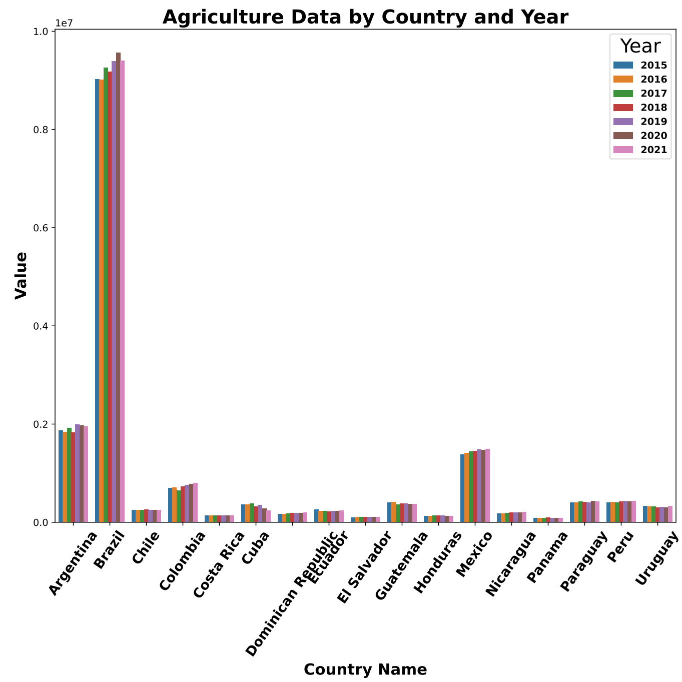

Fig. 3. **Trends of each country in agriculture by value**

Figure 4 illustrates the trends in agricultural mean values for six selected countries over the years 2015 to 2021. The x-axis represents the years, while the y-axis shows the mean agricultural metrics. Cuba shows a declining trend, while Peru and the Dominican Republic display steady growth, indicating improvements in agricultural performance. In contrast, Honduras, Ecuador, and Panama exhibit stable trends with minimal fluctuations, highlighting regional variations in agricultural productivity over time.

Visualization in Figure 5 illustrates climate values for selected countries in 2021 from the climate dataset. The x-axis represents the country names, while the

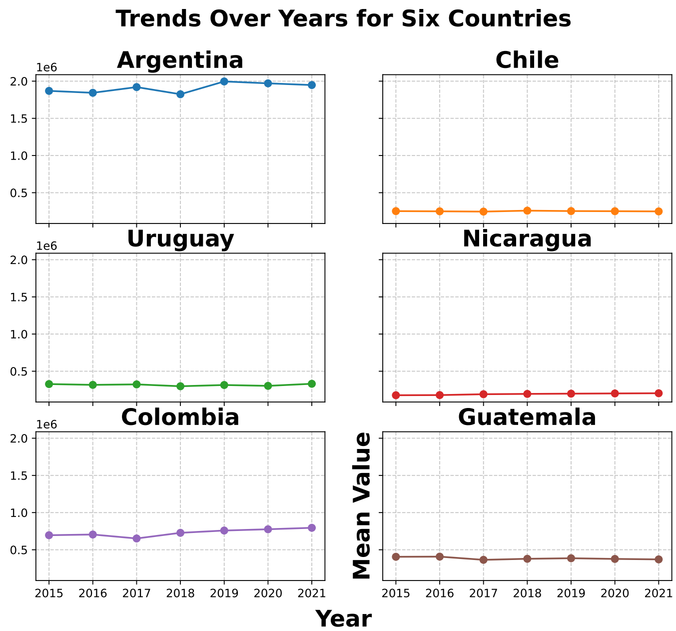

Fig. 4. **Agricultural Productivity Over Time**

y-axis shows the corresponding climate metric values. Colombia and Costa Rica exhibit the highest values, followed by Panama and Nicaragua, suggesting stronger climate-related indicators or activities in these regions. In contrast, Argentina and Mexico display significantly lower values, indicating regional disparities in climate metrics. This visualization provides insights into country-level variations in climate data for 2021.

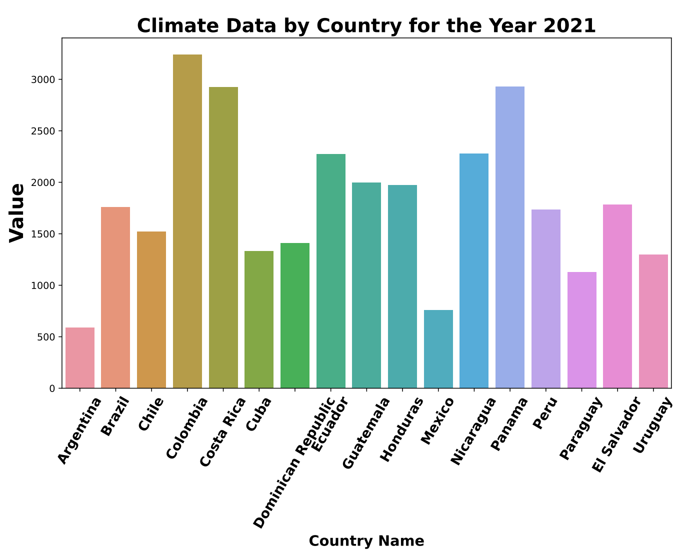

Fig. 5. **: Visualization of Climate Dataset for 2021**

C. *Correlation*

Figure 6 displays the correlation heatmap between two variables: the mean value of total production in the agriculture dataset and the GDP value of the climate dataset. The coefficient correlation is 0.06, suggesting a very weak positive relationship between the two variables. This low correlation indicates that changes in one metric do not strongly predict changes in the other, highlighting limited dependency between these variables in the dataset.

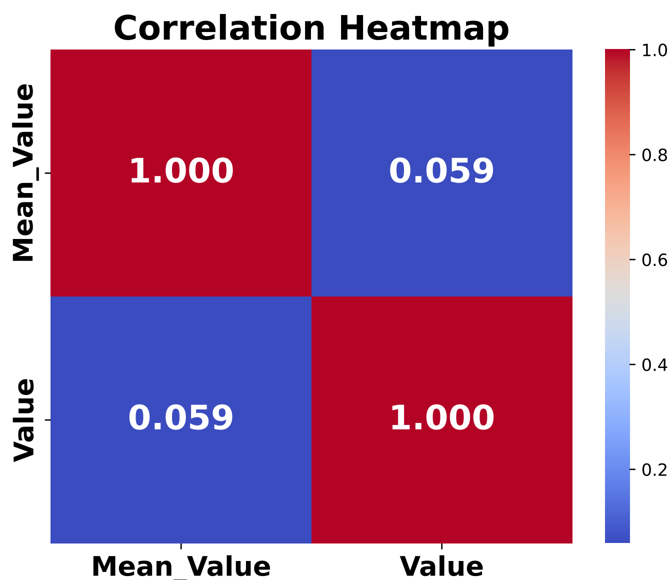

Fig. 6. **Heatmap of correlation matrix**

IV. Analysis and Results

This section explores the distribution and variability of climate and agricultural productivity metrics across countries, alongside their interrelationships. Key analyses include precipitation-yield correlations, country-specific trends, and factors influencing agrarian outcomes.

A. *Distribution Analysis*

1) *Climate Variable:*

Precipitation ranged from 500 mm to over 3,000 mm annually, with significant variability across countries. Countries like Colombia reported high average precipitation (3240 mm/year), while Argentina experienced much lower levels (591 mm/year).

2) *Agricultural Productivity:*

Average yields varied widely, from 11,561 kg/ha in Cuba to over 19,672 kg/ha in the Dominican Republic. This variability suggests that other factors, such as technological advancements and soil quality, play critical roles in productivity.

B. *Correlation Analysis*

The Pearson correlation coefficient between precipitation and yield was calculated as 0.06, indicating an extremely weak positive relationship. This suggests that precipitation levels alone have minimal influence on yields, and other factors such as soil quality, crop type, and agricultural practices likely play a more significant role in determining yield outcomes.

C. *Country-Specific Trends*

1) *Argentina:*

Precipitation remained stable at an average of 591 mm/year, with yields averaging 15,288 kg/ha. Yield variability was significant, driven by external factors such as market conditions and farming practices.

2) *Brazil:*

High precipitation levels (1761 mm/year on average) were observed alongside average yields of 14,348 kg/ha, indicating resilience due to advanced farming techniques.

3) *Colombia:*

Despite the highest precipitation levels (3240 mm/year), yields (15,377 kg/ha) were not significantly higher, suggesting limitations in water management or other structural factors.

V. DISCUSSION

The findings reveal that precipitation alone cannot fully explain variations in agricultural productivity. The negligible correlation of 0.06 suggests that additional factors such as temperature variability, soil health, and farming practices likely play more significant roles. High precipitation in countries like Colombia does not consistently translate into higher yields, underscoring inefficiencies in resource utilization and management. The study also highlights the importance of regional disparities. Countries like Brazil, with advanced agricultural infrastructure, exhibit greater resilience to climatic variability, while smaller nations with limited resources and infrastructure face heightened challenges in maintaining agricultural productivity.

VI. CONCLUSION

This study provides valuable insights into the relationship between climate variability and agricultural productivity in Latin America. The negligible correlation between precipitation and yields underscores the complexity of factors influencing agricultural outcomes. Policymakers should prioritize the following actions:

- Enhancing irrigation and efficient water management systems to mitigate the effects of uneven precipitation.
- Promoting sustainable farming practices to address environmental challenges and improve soil health.
- Investing in climate-resilient crop varieties and adaptive agricultural technologies.

Future research should investigate the combined impacts of temperature variability, soil quality, and socio-economic factors on agricultural productivity. Leveraging advanced techniques such as regression analysis, machine learning, and integrated climate models could provide more comprehensive insights into these intricate dynamics and support evidence-based decision-making.

References

[1] World Bank, "World Bank open data," https://data.worldbank.org/indicator/AG.LND.PRCP.MM.

[2] FAO, "FAOSTAT data," https://www.fao.org/faostat/en/#data/QCL/metadata.

[3] World Bank, "World Bank licenses," https://datacatalog.worldbank.org/public-licenses#cc-by.

[4] FAO, "FAO terms and conditions," https://www.fao.org/contact-us/terms/en/.