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Analysing The Impact of Climate on Indian Agriculture and Subsequent Export and Import

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***Abstract*— Climate change has severe harmful effects on food production which in turn demands food security on a global scale. Peculiarly, in India in the previous decade, it has been observed that there is a continuous upward trajectory in both the minimum and maximum temperature. The research paper aspires to undertake a detailed analysis of how certain crops viz. rice, wheat, sorghum, millet, barley, and maize get affected due to climate change in India. It will further assimilate data from the study which was made earlier giving us valuable insights into the topic.**

In the initial stage, the paper delves into the impact of climate change on agriculture which comprises precipitation patterns, rise and fall in temperature. Weather events including droughts and floods have a major effect on crop production. It was observed that the production of rice and wheat is altered due to the increased temperature and differences seen in the precipitation patterns, resulting in the fall of quantities. Similarly, maize, sorghum, millet and barley are affected due to shifting temperatures and an increase in the frequency of extreme weather events.

This research paper explores the methodologies which are related to climate change and its effect on the production of food along with export and import. To address the above challenges, this research paper is structured to provide various approaches to overcome them. New knowledge has been analysed by giving precedence to the adaptation and mitigation strategies.

***Keywords*—Climate change, agriculture, analysis, rainfall, temperature, rice, wheat, barley, sorghum, millet, maize**

I. INTRODUCTION

Global warming has affected many aspects of the world, especially agriculture, which has created a socioeconomic threat to a low-income country such as India where many farmers produce crops for domestic consumption as well as exports in large quantities globally. India's 58% of the population is dependent on agriculture, and it also lies under the top 4 countries to export crops globally. However, recently agriculture sector as a whole which depends highly on climate and weather conditions has been propelled towards a downfall due to recent shifts in climatic conditions, and this has increased the vulnerability of the crops. Negative climatic changes have led to extreme weather like increased temperature, droughts, erratic rainfall, flooding, increased CO2 levels and other Greenhouse gases (GHGs)[1], [2].

These have negatively influenced the production of major crops in India like wheat, barley, maize (corn), rice, and sorghum[2]. Statistical analysis shows that there is a gap between the production and the domestic consumption as well as the trading of these crops which has become a serious threat to the food security of India in the past decade 2011-2021.

II. DATA AND METHODOLOGY

In India, the Western and Central zones are more prone to droughts, whereas, the North and Northeast regions are more prone to floods. The East and South regions are prone to extreme cyclones along with floods and droughts.

A. Climate Data

Temperature data and rainfall data for a period of 10 years from 2011 to 2021 were gathered from the (data.gov.in) database. For the analysis of temperature, year-wise average minimum and average maximum temperatures were evaluated. A graph for average minimum and maximum temperature was mapped out. Subsequently, rainfall from 34 regions was analysed. Similarly, average minimum and average maximum rainfall data were visualized.

B. Crop Data

Using crop data for six different varieties of crops namely Barley, Wheat, Sorghum (Jowar), Millet (Bajra), Maize, and Rice an unbiased assessment was made based on the popularity of the production. Crop temperature and water requirements "Table 1", Crop domestic consumption and production, and Import and export data were accumulated from the (Index-Mundi database), and (FAO database) to comprehend the impact of climate on domestic use, production and trade.

C. Data Processing and Analysis

All the collected data was analysed separately using Python 3.10. Each data was loaded in comma-separated values (CSV)

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format into Python using Pandas library which uses Data Frame object for data handling. To prepare all the data for our requirement we initially filtered the data according to our decided time frame from 2011 to 2021. Further, the data was cleaned by replacing all the NAN values with 0 in production, consumption, import and export. Then we proceeded to process the data for analysis. For rainfall data, we considered the annual rainfall from June to September for each year. All of the rainfall data was grouped by the average over all regions against the respective years. Similarly, in the temperature data, we focused on annual minimum temperature and annual maximum temperature and then grouped by their respective years. For crop-related data, no such processing was required. Finally, we performed an unbiased analysis of the processed data, we utilized Python's Matplotlib library for plotting the processed data. First, we plotted the annual rainfall trend over 10 years as an average of all regions. Then we proceeded with a trend of annual minimum and maximum temperature for the same time. For the crop data, we started with separately analysing the production and consumption data differently for each of the selected crops. After this, the production of different crops was compared against the annual consumption for the respective crops. After understanding the differences, we analysed the import and export for each crop.

Table 1: Threshold values for optimal growth of crop

Crops	**Crop Temperature & Rainfall (Min-Max)**			
	Minimum Temperature	***Maximum Temperature***	***Minimum Rainfall***	***Maximum Rainfall***
Rice	20°C	40°C	1000 mm	1500 mm
Maize	16°C	35°C	500 mm	1000 mm
Sorghum (Jowar)	20°C	35°C	450 mm	750 mm
Wheat	13°C	24°C	300 mm	500 mm
Barley	15°C	21°C	300 mm	500 mm
Millet (Bajra)	20°C	35°C	500 mm	650 mm

Table 2: Percentage differences in production from year 2011 to 2016 and 2016 to 2010

Crop Name	**Percentage Increase/Decrease**	
	2011-2016	**2016-2020**
Barley	-13.4 %	15.02%
Maize	3.72%	40.21%
Millet	-18.79%	28.48%
Rice	4.20%	18.02%
Sorghum	-39.45%	13.49%
Wheat	6.23%	18.74%

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Figure 1: Average maximum(top) and minimum(bottom) temperature from 2011 to 2021

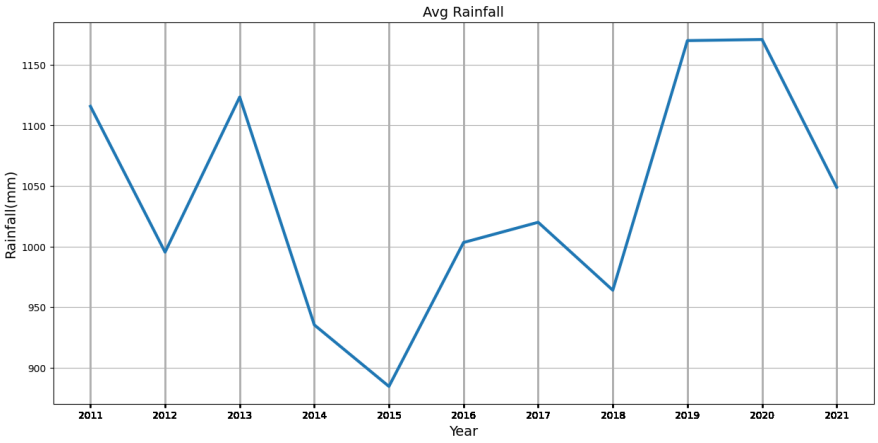

Figure 2: Average rainfall from 2011 to 2021

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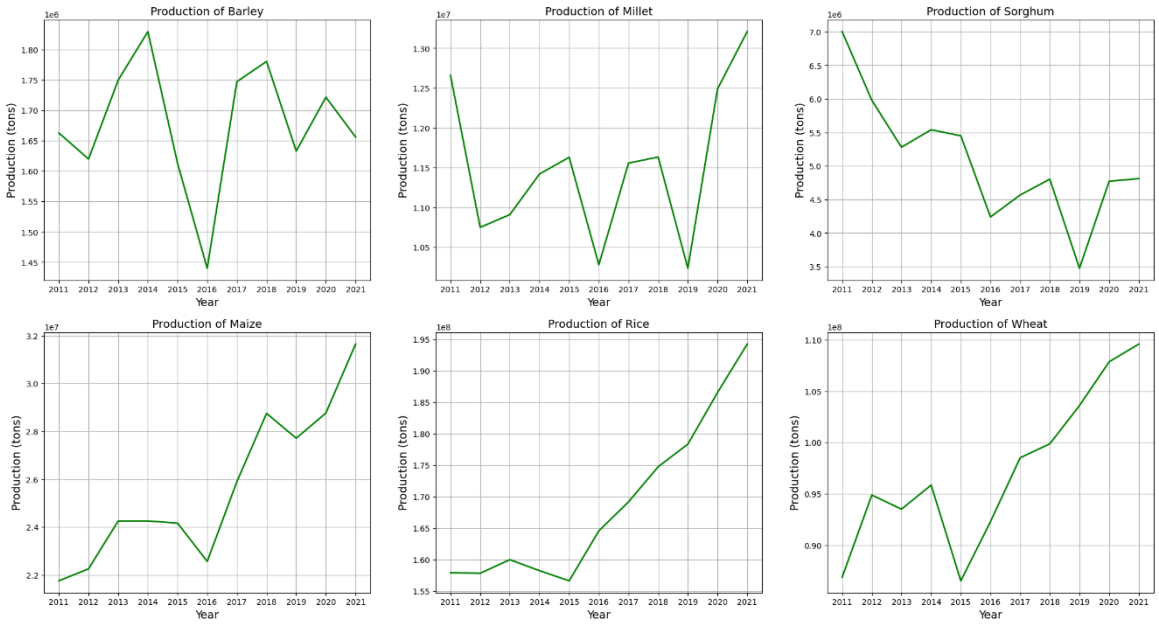

Figure 3: Production of different crops from 2011 to 2021

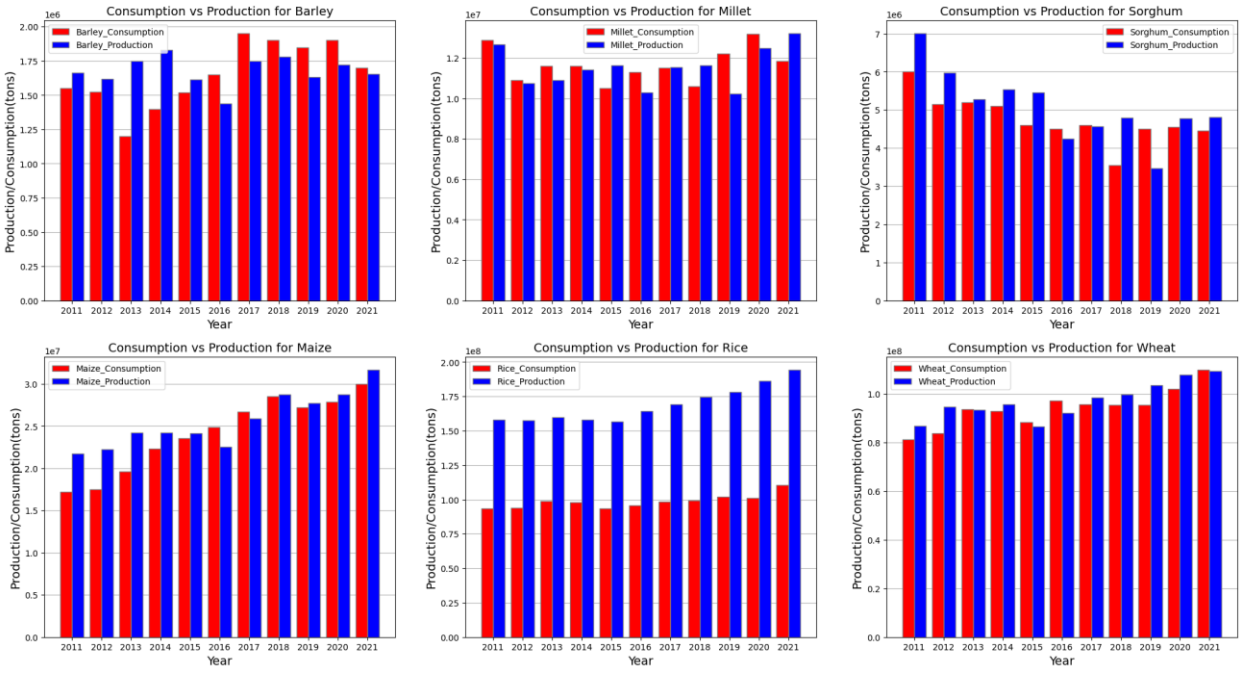

Figure 4: Comparison of production and consumption of different crops from 2011 to 2021

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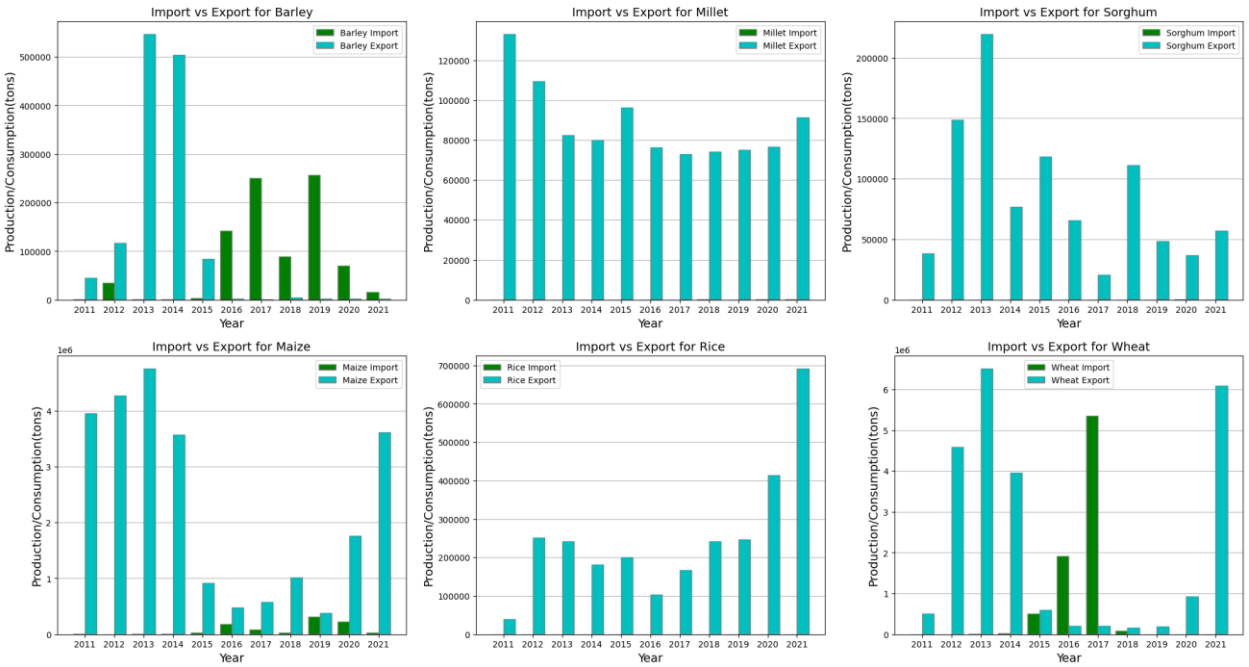

Figure 5: Comparison between import and export of different crops from 2011 to 2021

III. RESULTS

Temperature and rainfall are the two major climatic factors which have proved to negatively affect agricultural production, particularly in India.

A. Trends and Effects of Climate Changes on Crops

From the gathered climate and crop data over a decade (2011-2021), it was observed that the minimum and maximum temperatures as seen in "Fig. 1" of India have increased substantially over the years. The minimum temperature has gone from 20.35 degrees Celsius to 20.90 degrees Celsius while the maximum temperature has changed from 30.89 degrees Celsius to 30.96 degrees Celsius. When examining the data and graphs, it was observed that the all-time record high temperature reached its peak point of 31.54 degrees Celsius in 2016 making it the hottest year in the decade. Similarly, an unstable rainfall pattern is witnessed in "Fig. 2" through our study where the estimated maximum and minimum rainfall have reached the highest and lowest points along with erratic rainfall making the cultivation a challenging process. Such inclement weather conditions have proved to majorly affect consumption, and production as seen in "Fig. 4", we can observe that for the crops barley, maize, sorghum, millet and wheat, while the demand and consumption increased, there was a drop in production of the crops. We also evaluated the import and export data to perceive the impact of climate on the economy and were able to assess a significant drop in trade for millet, sorghum, maize, wheat, and barley.

B. Outliers

While analysing the six crops, it was observed from "Fig. 3" that rice and wheat were outliers which had a stable production up until 2015 and eventually grew steadily.

1) Rice: This happened due to suitable weather conditions for rice which can thrive in higher average temperatures up to 40 degrees Celsius and up to 1500mm of rainfall as shown in "Table 1". Moreover, different varieties of rice have minimum water requirements, enhanced resilience to drought, higher pest tolerance and can also survive flooding and salinity[3]. Whereas other crops have a baring temperature of 35 degree Celsius and rainfall of 1000mm. While rice production increased gradually, domestic use was stable as it is one of the staple foods in India. Hence, such suitable weather conditions for rice in India helped the crop cultivate well and the import and export gradually proved to increase in the same period as other crops.

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2) Wheat*:* During the pre-COVID period, the government of India introduced new policies for agriculture to intensify the production of staple crops, especially rice and wheat [4]. Due to this particular reason, the production of wheat and rice was increased by the Indian government as the main motive was to focus on nutrition, safety and increasing the income for the farmers and giving less focus to agricultural productivity[5]. This is also evident through our graphs "Fig. 3" as we can see that there is an increase in the production of wheat as well as rice after 2015.

IV. CONCLUSION

India is the second largest producer of wheat and rice, which consists of the world's major food staples. The agricultural sector is the largest source of earning a livelihood. It employs over a hundred million people in India. The major crops grown in India are Rice, Barley, Wheat, Sorghum, Millet, and Maize based on various geographical areas.

According to "Fig. 2", the variations in rainfall and temperature have a far-reaching effect on agriculture and trade counting on both imports and exports. According to "Table 2", we can see a drastic fall in production in sorghum, millet and barley whereas maize remained stable, and wheat and rice saw major growth. This in turn is an effect of variation of rainfall and temperature in 2016. This also impacted the import and export of crops as in "Fig. 5". The climate in India was suitable for the production and sustenance of the rice crop. Similarly, Government Policies supported the increase in production of the wheat crop. According to our overall analysis, rainfall and temperature are crucial for the optimal growth of crops and counter-productive measures and policies are needed to promote an increase in the production of crops. This in turn will help to decrease outsourcing of crops and instead increase exports helping the Indian economy [4], [5].

V. FUTURE SCOPE

The study of the impact of climate change on agriculture showed that during extreme climatic conditions, the production and trade of crops had been affected significantly. To mitigate these challenges posed by the unpredictable climate a holistic approach is needed.

One solution to this would be multi-stage farming in which multiple crops are grown in the same field at the same time. This can also be done as multi-storey farming where crops of different heights are planted together so that varieties of crops can be harvested, overall production can be increased and most importantly the income of the farming can be increased. This sequential farming helps to produce maximum yield and at the same time helps to minimize the effect of severe climatic conditions.

Hydroponic farming is an extremely effective method for sustainable farming and can be adopted by farmers to maximize their crop production. Hydroponic farming is a method of growing crops without soil using a water-based nutrient solution. In a drought-prone area, this method would prove to be effective and would enable farmers to grow crops which usually cannot be grown in those areas.

Lastly, crop diversity or varietal diversity which means planting different species of the same crop can be used as an effective measure to mitigate the climate change effect on crop and crop production. This means that an original species of a crop is mutated to sustain in excessive environmental conditions, it is adaptable in extreme climatic conditions, and it has more resistance to pests and diseases.

All of the above measures can be taken into consideration to lessen the effect of climate on crop production and increase overall productivity as well as the income of the farmers.

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