Online at: https://researchtrendsjournal.com **ISSN No:** 2584-282X
Indexed Journal **Peer Reviewed Journal**

INTERNATIONAL JOURNAL OF TRENDS IN EMERGING RESEARCH AND DEVELOPMENT

Volume 2; Issue 6; 2024; Page No. 215-219

Received: 01-08-2024
Accepted: 08-09-2024

Impact of climate change on agricultural productivity: A regional analysis of climatic trends and crop yields in Rajasthan

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DOI: https://doi.org/10.5281/zenodo.15820467

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Abstract

According to research on Rajasthan's climate changes, the state's rainfall patterns were very consistent from 1985 to 2014. On the other hand, temperature patterns were rather session-specific over those years. Multiple regression analysis revealed that some climate-related factors, in the form of quadratic terms, significantly impacted the output of rubber, pepper, and rice. There was no statistically significant relationship between coconut output and any of the climatic factors examined. Better climate change mitigation strategies were associated with considerably greater crop output across the board, with the exception of rubber, in the sample families. Given the significance of the subject under investigation, the study's conclusions have far-reaching policy and grassroots practical ramifications.

Keywords: Global Warming, agricultural, population, environment, Rajasthan

Introduction

One of the greatest difficulties of the twenty-first century is guaranteeing an adequate food supply for an expanding human population without putting further stress on an environment that is already vulnerable as a result of global warming. Worldwide, but notably in African nations, people are already feeling the pinch of climate change in areas such as agricultural output, hydropower generation, human health, and water supplies. The effects of climate change and potential adaptation strategies are attracting a growing amount of funding and attention from the scientific community. A wide range of businesses, natural landscapes, forest types, agricultural yields, water resources in river basin catchments, and other factors will be considered. Crop growth models that include attributes from several climate models have been used to study soil water balance and agricultural production. Even in agricultural regions that rely heavily on technology and produce abundant crops, climate change is a major concern. This variable continues to have a significant effect on agricultural yields. Climate change has lately garnered a lot of media attention and is causing increasing concern among the general public because of the danger it presents to the food supply. One constraint on agricultural output and food security is the accessibility of water. According to Fujihara *et al.* increasing the irrigated area at current irrigation efficiency rates would lead to a water deficit. However, if the demand for water does not increase, there will be no shortage. Immediate evaluation of possible climate change effects on water supplies and agricultural output is essential for developing adaption plans. In order to explore the effects of various future climates on crop development, yield, and soil water balance, this study aims to examine the operation of global climate models and crop growth models. Implications of climate change on food security and irrigated agriculture are of interest to scientists and policymakers, as well as in developing appropriate adaptation strategies, may find this background material helpful.

Agriculture and climate change in Indian

Amidst a growing population that threatens the availability of nutritious food on a consistent basis, the agricultural sector has evolved into an integral part of India's economic development story. Consistent development in this sector is crucial for meeting other issues, since it contributes about 15% to India's GDP and 10% to total exports in 2008-09 (Annual report, 2010). It also employs 58.2% of the population. In India, the south-west monsoon is vital to the agricultural sector. As a nation, net irrigated area is 60.9 million hectares, out of a total net planted area of 140.3 million hectares, clearly indicating this. Because of how dependent the net planted area is on rainfall, India's agricultural economy is very vulnerable to shifts in precipitation patterns. As an example, the agricultural GDP growth rate fell 0.2% compared to the 1.6% increase rate from the previous year, which was brought about by the overall 23% rainfall deficiency during the 2009–10 south-west monsoon.

Northeastern Climate

The geographic region of northeastern India extends from 22° N to 29.5° N. Along its southern section, across Mizoram and Tripura, the tropic of cancer passes. As a result, its climate is largely tropical. Additionally, the area has a tropical monsoon climate due to its location inside the South and Southeast Asian monsoon belt.

Climate-Related Elements in Northeast India

- The orientation and placement inside the region's mountain ranges, plateaus, and hills.
- The variation in pressure conditions throughout the year across the northwest Indian subcontinent and the Bay of Bengal.
- The southwest monsoon, which consists of tropical oceanic air masses, that pass across this area.
- The westerly (Mediterranean) lows make an occasional winter appearance
- Mountain and valley winds are present in the area.
- Local cyclones developing; presence of several large bodies of water; large woods;

Fog rolls in in December and January when the temperature drops, lingering over the ground until late in the morning. Keep in mind that the two Assam plains, along with the rest of northeastern India, are regular storm locations. Bay of Bengal tropical cyclones are the primary genesis point for the majority of these storms. Since the lowlands are so close to the Bay's tip, cyclonic storms that originate in the Bangladesh plain eventually make their way to them. Certain storms, particularly those that occur in the spring, may be explained by local thermodynamic factors.

Review Literature

Singh, Naveen *et al*. (2021) [1]. The research aimed to examine the trend in climate factors and their influence on key crop yields across four ago-climatic zones that make up the Gangetic Plains Region from 1966 to 2011. This was done in light of the growing susceptibility of farming and the lives of farmers due to changes in the global climate. The zones' mean yearly and seasonal (*kharif* and *rabi*) lowest and highest temperatures have been trending upwards. In contrast, there was a clear downward trend in rainfall The degree to which climate change reduces agricultural productivity is region-specific, but generally speaking, it's a bad thing. According to the results, the whole Gangetic area might expect a decrease in wheat and rice productivity. The Lower Gangetic Plains should expect a 6% rise in maize production by the 2050s, whereas the Trans-Gangetic Plains can expect a 15% increase in pearl millet and a 3.8% increase in rapeseed and mustard. Climate change has the greatest effect on sugarcane yields, which may see a 21% drop in the Middle Gangetic Plains by the century's end. In order to make agricultural systems more resistant to climate change and other climate-related shocks, it is necessary create plans for adaptation over the long term that include into account the unique requirements of each area.

Hu, Tongxi *et al*. (2024) [2]. The key to guaranteeing food security is on comprehending how crops will react to global warming. As part of our research, we collected the latest results about the consequences of global warming on agricultural yield estimates from over 230 statistical crop modelling studies that focused on important crops. There was substantial evidence that warmer weather decreases harvest yields. Globally, Sorghum yields fell 6.8.9%, rice yields 1.2.2%, wheat yields 6.0.3%, and maize yields 7.5.3%.as a result of a 1 °C warming. However, there was a considerable amount of geographic variability, which may be attributed, partly because of the uneven and nonlinear reactions of crops to changes in temperature, such as warming-induced increases in colder locations. The studies and regions did not consistently show the same yield responses to precipitation. Climate accounted for on average, 37% of the yield variation. Machine learning techniques, like machine learning that can be understood and explained by humans, largely replaced linear regression as the preferred way of data analysis, resulting in a 44% decrease in predictive mistakes on average. We also went over some of the advantages and disadvantages of statistical crop modelling, including things like ensemble modelling, physics-informed machine learning, climate extremes, extrapolation to new climates, and the potential for technology, management, CO_2, and O_3 to cause confusion.

Singh, Yadvendra *et al*. 2024) [3]. Worldwide, farmers are facing serious problems as a result of global warming, which endangers harvests, yields, and the availability of food. This review study delves into the many ways in which climate change is affecting farming, specifically looking at how agrometeorological variables affect crop development. We take a close look at the ways in which shifts in climate characterised by extreme weather, fluctuations in precipitation, humidity, and temperature affect different parts of the growing season. Furthermore, we study how agrometeorological elements impact plant physiology, penology, and disease and pest susceptibility. We also examine methods for better understanding and controlling agro meteorological factors in order to lessen how agricultural output is impacted by climate change. By synthesising previous studies on the intricate interplay between agrometeorology, crop yields, and global warming, the study offers valuable insights to scholars, policymakers, and agricultural professionals.

Schmidt, Miriam *et al*. (2023) [4]. Sufficient, safe, and nutritional food is essential for every human being in order to keep up a healthy and active way of life. Extreme weather events are becoming more often and more severe as a result of climate change., which is negatively affecting harvest success. The rising likelihood of unforeseen losses in agricultural yield threatens both the world's food supply and farmers' ability to make a living. This article looks at the key EU producing countries' wheat, maize, and barley yield anomalies and how climate change is affecting them. The Random Forest ML model's output states that climatic indicators, which include both average and exceptional weather, account for 18% of the variation in agricultural yields observed from 1961 to 2020 worldwide. Out of all the climatic variables, 24% are most predictive for maize, 22% for barley, and 3% for wheat. In contrast to severe weather indicators, average weather conditions are more strongly linked to unusually high or low crop yields. It is more crucial to look at indications related to soil moisture and temperature than indicators related to precipitation. The findings show that the correlation between weather variables and harvest success is not linear. Reduced or increased agricultural yields are the results of thresholds. Rising temperatures under SSP3-7.0 are expected to worsen agricultural output losses until 2100 unless adequate adaptation strategies are put in place. The effect of varying soil moisture indicators on different crops and countries is country-specific. To lessen the impact of climate change on crops and strengthen the resilience of our food system, our research delves into adaptation tactics while simultaneously stressing the need of worldwide mitigation initiatives.

Challinor, Andrew *et al*. (2014) [5]. A major difficulty for humanity is to feed a rising global population as the environment is changing. Predicted crop yields under different meteorological and agricultural situations are essential for assessing the probability of food insecurity. Prior meta-analyses have only shown climate change and its potential adaption strategies in relation to temperature; yet, they have neglected to discuss the following: the degree of uncertainty, the timeliness of consequences, and the analytical efficacy of adaptation strategies. Our new dataset contains over 1,700 published models, allowing researchers to assess how adaptation and climate change affect yield. In both tropical and temperate zones, the overall output of wheat, rice, and maize is predicted to decrease by 2 °C. in the absence of adaption strategies. Modifications made at the crop level have a greater impact on wheat and rice than on maize, leading to an average increase of 7-15% in predicted yields. In the second part of this century, yield losses are more severe than in the first part. While there is more agreement that tropical areas would have lower yields in the second part of the century, even modest warming might lower temperate agricultural yields in many places. Yield variability is projected to grow, according to the current data, even though the fluctuation between years is less well-documented than mean yields.

Analysis of Rajasthan's Climatic Trends

Individually, we examine the climatic patterns in Rajasthan's four chosen districts: Alwar, Dausa, Jaipur, and Sikar. Precipitation and temperature were the climatic variables examined, with data categorized according to the IMD pattern (Monsoon, Post-monsoon, Winter, and Summer). The variables in terms of average yearly temperature, average yearly temperature at its highest and lowest points, and temperature range are examined and discussed, as are the variables of rainfall, specifically monsoon rainfall, post-monsoon rainfall, winter rainfall, and summer rainfall. Along with the aforementioned categorization, we also include the yearly and seasonal patterns of precipitation and temperature. This means that twenty-five different climatic factors exist.

A meta-analysis of the changes in certain meteorological factors

Table 1: A synopsis of the major meteorological conditions that influence paddy harvest

Variables	F	P
Annual Mean temperature	3.03	0.29
Annual Mean Max Temp	11.31	<.001
Annual Min Temp	2.87	0.36
Annual Mean Temp Range	18.56	<.001

Log annual mean temperature was significantly lower in five-year group III (1995–1999) compared to five-year group I (1985–1989) when comparing the reference period's mean differences using the post-Hoc test (MD =.01, p =.028), and significantly higher in six-year group (2009–2013) (MD = -.01, p =.034). Statistical analysis revealed no difference between the means of the other groups.

Effects Will Climate Change Have on Rubber Yields in the Sikar District

Table 2: An Overview important climatic Factors Influencing Rubber Production

Variables	F	P
Annual Mean temperature	3.69	.013
Annual Mean Max Temp	3.73	.012
Annual Min Temp	5.71	.001
Annual Mean Temp Range	4.79	.004

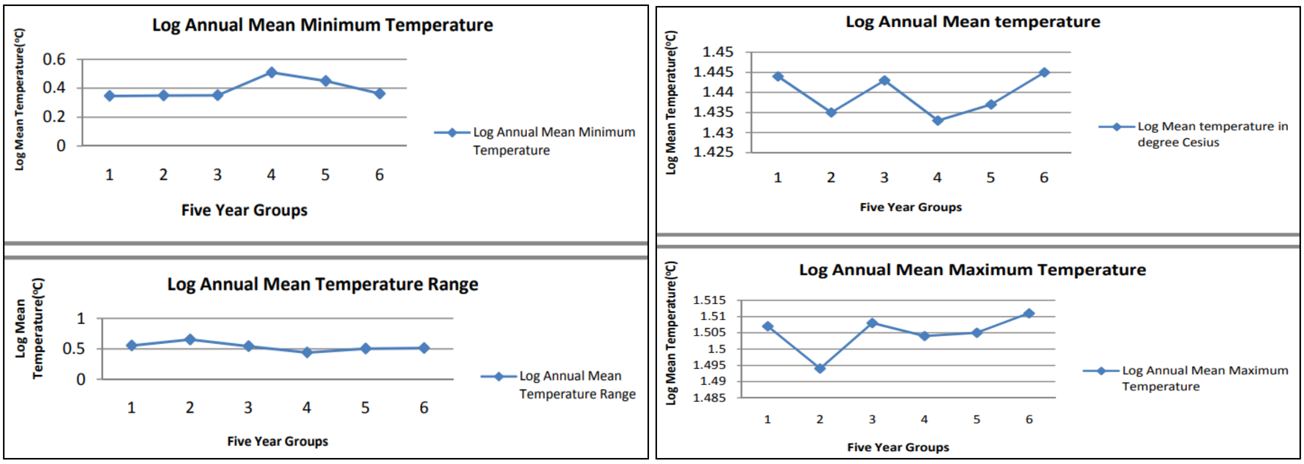

Fig 1: Trend in temperature variables in Sikar District

A study on the agro-climate change effects in Rajasthan Agricultural Production and a Crop-Wise Evaluation of Climate Change's Economic Effects

In this part, we will examine how the study region's four main crops-rice, pepper, coconut, and rubber-have been affected by the changing seasons. The effects of climate change will have a disproportionately negative impact on the agricultural sector., thus researchers in Rajasthan state conducted a microscopic investigation of the study region using the state's agro-climatic characteristics. Climate change, ecological services, and agricultural output all interact with one another is complex. According to studies conducted by the International Institute of Sustainable Development at the University of California, Berkeley, the most noticeable effect of climate change on the agricultural industry is the observed rise or reduction in crop yields around the world. Climate change has several unintended consequences, including but not limited to: lower yields; more crop shifting or diversification; less water available for irrigation; more crop loss due to insects, pests, and plant diseases; and more pesticide and insecticide use.

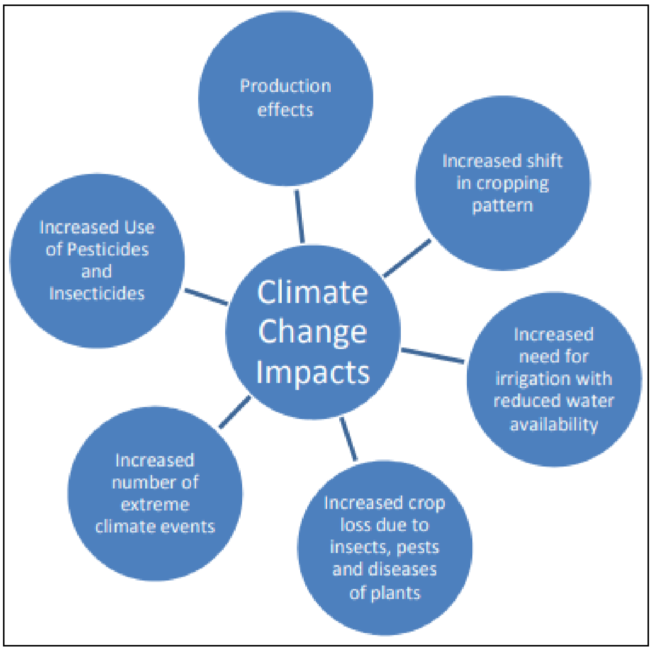

Fig 2: Five main effects of climate change on farming, shown schematically

Discussion, Findings and Conclusion

An Examination of Rajasthan's Climate Trends

Among the study's primary goals was the compilation of a report detailing the climate patterns seen by Rajasthan from 1985 to 2014. The widely used Null Hypothesis Significance Testing (NHST) method was used. In order to Using the non-parametric Mann-Kendal test to look at the time series data, and the five-year trend was discovered by one way ANOVA.

We started with two sets of assumptions:

H_0 = Rainfall in several parts of Rajasthan has not been trending significantly.

H_1 = Some areas of Rajasthan are seeing a dramatic increase or decrease in precipitation.

Each of the four districts had its own set of yearly and seasonal rainfall patterns calculated and examined. The yearly rainfall varied to a certain extent during the thirty-year period, but no discernible pattern of growing or decreasing amounts was found, hence the null hypothesis (Ho) remained unrejectable. Aside from the monsoon and post-monsoon, almost all of the seasonal rainfall factors retained similar values. While there was a trend towards less rain during the monsoon, it was not statistically significant; in contrast, rainfall after the monsoon rose sharply. Research by Auffhammer, Ramanathan, and Vincent (2012) [16] found comparable outcomes and noted that the post-monsoon rainfall in India is now more severe than ever before, despite its decreased frequency. Krishnakumar *et al.* (2008) [17] examined longitudinal data over 135 years (1871–2005) and discovered that post-monsoon rainfall in Rajasthan increased whereas monsoon rainfall decreased significantly. Their results showed a pattern of rather constant winter and summer rainfall, which is consistent with the current study's findings.

The Effects of Global Warming on Rajasthan's Farming Sector

The third goal of the research was to find out how different parts of Rajasthan have fared in terms of agricultural output due to climate change. The Economic and Statistical Department of Rajasthan provided the secondary data utilized for this research, which focused on the output of certain crops. details Using primary data on agricultural production obtained from 400 randomly selected households throughout the four districts, we examined five separate problems caused by global warming. So as to acquire reliable findings, the NHST approach was used, and the following set of hypotheses were formulated:

H_0: In Rajasthan, agricultural output is unaffected by a few climate conditions.

H_1: Agricultural output in Rajasthan is highly sensitive to a number of climate conditions.

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