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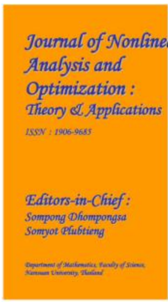

BEYOND THE BOUNDARY: CLIMATE CHANGE AND US

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Abstract
This study delves into the intricate linkages between shifting weather patterns and their profound ramifications on human lives, with a particular focus on two pivotal domains: health and agriculture. Recognizing the multifaceted impacts of climate change extending beyond environmental realms, this research endeavors to elucidate how it directly influences individuals and regions, underscoring the imperative for prompt action. Drawing upon data sourced from reputable entities such as governments, intergovernmental organizations, and NGOs (including the IPCC, WHO, and Our World in Data), our analysis scrutinizes the following key aspects. In the realm of health, our investigation scrutinizes the role of rising temperatures and evolving weather patterns in the propagation of malaria. Turning to agriculture, our inquiry examines how climate change disrupts agricultural productivity through unpredictable rainfall patterns. By leveraging existing datasets, our research endeavors to furnish valuable insights into the specific challenges and opportunities posed by climate change within these two sectors. Our findings underscore the imperatives of adaptation and collaboration. Adaptation emerges as a pressing need for individuals, communities, and governing bodies to adapt to the realities of climate change. We emphasize the significance of exploring potential adaptation strategies to mitigate its adverse impact on malaria and agriculture. Moreover, given the global dimensions of climate change, collaborative endeavors on an international scale are imperative. Our study underscores the criticality of international cooperation and knowledge exchange to effectively tackle this collective challenge. In sum, our research endeavors to offer a comprehensive understanding of the intricate dynamics surrounding climate change's impact on malaria and agriculture. It underscores the urgency for proactive measures and concerted global efforts to address this pressing issue.
Keywords*: Climate Change, Malaria, Agriculture, India, Temperature, Rainfall*

1. INTRODUCTION

"Our economic system and our planetary system are now at war. Or, more accurately, our economy is at war with many forms of life on earth, including human life. What the climate needs to avoid collapse is a contraction in humanity's use of resources; what our economic model demands to avoid collapse is unfettered expansion. Only one of these sets of rules can be changed, and it's not the laws of nature."

(Klein, 2014)

Earth's climate has always changed, shaping human development throughout history. From hunter-gatherers to farmers, past societies adapted to evolving ecosystems. Today, understanding climate change's intricate web of impacts - on ecosystems, biodiversity, societies, and well-being - is crucial. By exploring climate dynamics, environmental interactions, and human responses, we can unlock mitigation strategies, adaptation measures, and policies for a resilient, sustainable future. To grasp this transformation, we need knowledge of what constitutes climate change.

Climate refers to the long-term atmospheric conditions experienced in a specific area. The average climate could span from months to millions of years. To ascertain the average period, 30 years is usually taken as per the standards set by the World Meteorological Organization. (WMO, 2023) Climate change differs from climate, although the terms are often used interchangeably by the general public. Climate change arises from natural events and external activities such as volcanic eruptions, fluctuations in solar radiation, and anthropogenic interference. According to NASA, "These natural causes continue to influence climate, but their impact is relatively minor or occurs too gradually to account for the rapid warming observed in recent decades." (NASA, 2010). The United Nations Framework Convention on Climate Change (UNFCCC) states in its first article, '"Climate change" means a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.' Thus, the UNFCCC emphasizes human activity as a significant contributor to climate change. (UNFCCC, 1992)

The pace of global warming is accelerating rapidly, evidenced by the shrinking of ice sheets, the retreat of glaciers, the reduction of snow cover, and the rising sea levels, among numerous other observable phenomena. Carbon dioxide levels have surged to approximately 250 times higher than during the ice age, primarily due to human activities. (Gulev, et al., 2021)

Hence, climate change, arguably the defining challenge of the 21st century, casts a long shadow across diverse sectors of society, the economy, and the environment. Its effects ripple globally, disrupting delicate ecosystems, altering weather patterns, and posing significant risks to human health, livelihoods, and well-being. This research delves into the intricate links between climate change and two key sectors: health, and agriculture.

We examine the complex dynamics between these environmental factors expanding geographic reach of malaria-transmitting mosquitoes, fueled by changing climatic conditions. Understanding these intricate connections is crucial for safeguarding public health in a warming world. Feeding billions worldwide, agriculture stands as the bedrock of global food security and rural livelihoods. However, climate change disrupts agricultural ecosystems through erratic rainfall, rising temperatures, and extreme weather events. Identifying innovative technologies, policy interventions, and sustainable land management practices is crucial for fostering agricultural resilience and inclusive rural development.

1.1 Review of Literature

Manisha Sharma, Rasal Singh, and Abha Kathuria (2022) in a research paper title “Climate Change and the Indian Economy - A Review” presented empirical study on Assessment of Climate Change over the Indian Region report 2020 issued by the Indian government and several other research papers to find climate variations and how they impact economy. An increase in warmest day and night along with coldest night temperature is seen. This has also resulted in increase in rainfall, droughts and floods. In terms of economy, India has achieved equity but people involved in agriculture and are socially and educationally backward suffer from poor standard of living. It projects that India’s GDP might decrease by 2.6% by 2100. Shifting to clean and green energy and green goals will be the key for India.

“The Impact of Climate Change on Environmental Sustainability and Human Mortality” research by **Xianzhi Mara Chen, Andrew Sharma and Hua Liu (2023)** analyses three-level environmental impact risks on human mortality, associated with climate change. The primary, secondary and tertiary impacts should be carefully analyzed to monitor, understand and mitigate climate change. Creating a mortality database based on events could help facilitate the identification of geographic disparities and regions significantly affected by climate change. This database could serve to validate and enhance climate model simulations and forecasts. The development of such database is suitable for integration of remote sensing methods with on-site observations.

Maud M. T. E. Heinen, Pim Martens, Su-Mia Akin (2013) research on “Climate Change: An Amplifier of Existing Health Risks in Developing Countries” perceives climate change as an amplifier instead of stand-alone risk for existing health and food security. It talks about Green Climate Fund for mitigation and adaption and how adaptation policies and projects should be formulated.

“Impact of Climate Change on Agriculture and Its Mitigation Strategies: A Review” by **Gurdeep Singh Malhi, Manpreet Kaur, Prashant Kaushik (2021)** reviews literature using PRISMA to find the possible impact of climate change on agriculture productivity and economic impact. It finds that temperature, precipitation, greenhouse gases and increasing population are interfering with agricultural process. Strategies have to be made to ensure farmer's income without compromising sustainability. Formulation and education about climate-smart technologies have to give to farmers.

1.2 Objectives of the study

- To analyze the impact of climate change on human health in India with a main focus on understanding how changes in temperature and rainfall patterns contribute to the prevalence and distribution of malaria.
- To analyze the impact of climate change on crop production in four specific states, focusing on the relationship between changes in rainfall patterns over the years and its influence on crop yields.

1.3 Methodology & Data Source

The primary method of data collection for this research is secondary sources. These include scholarly articles, reports, and datasets obtained from reputable organizations such as the World Health Organization (WHO), Intergovernmental Panel on Climate Change (IPCC), Food and Agriculture Organization (FAO), and relevant government agencies.

The agricultural section entails an analysis spanning seven years (2015-2021) to assess the impact of erratic rainfall patterns attributed to climate change on four different crops. This analysis focuses on four distinct crops from four different states to capture regional variations and crop-specific responses to changing rainfall patterns. Statistical analysis will be conducted to examine the relationship between rainfall variability and crop yields over the specified seven-year period.

We use SPSS to see the correlate bivariate between independent variable rainfall(mm) and other dependent variable – area ('000 ha), production ('000 tones), productivity (tons/ha). Using this we try to find the correlation between rainfall and these dependent variables. Other things like temperature, groundwater resources, agricultural inputs (pesticides, weedicides, inorganic and organic manure, etc.) are kept constant.

The health section involves an analysis of conditions conducive to the growth and transmission of malaria, focusing on the impact of climate change. Secondary data related to malaria incidence rates, climate variables (e.g., temperature, precipitation), and environmental factors will be collected from reputable sources such as the WHO and Government Websites. This analysis will explore the implications of changing environmental conditions and climate variability on malaria transmission dynamics. Potential future scenarios and trends in malaria prevalence will be discussed based on current observations and projections.

1.4 Hypothesis

Null Hypothesis (H_0) –

- There is no significant impact of climate change on malaria incidence rates.
- There is no significant impact of climate change on agriculture through rainfall.

Alternative Hypothesis (H_1) –

- Climate change significantly influences malaria incidence rates, leading to changes in transmission dynamics, prevalence, and geographic distribution.
- Climate change significantly influences agriculture production and productivity through rainfall.

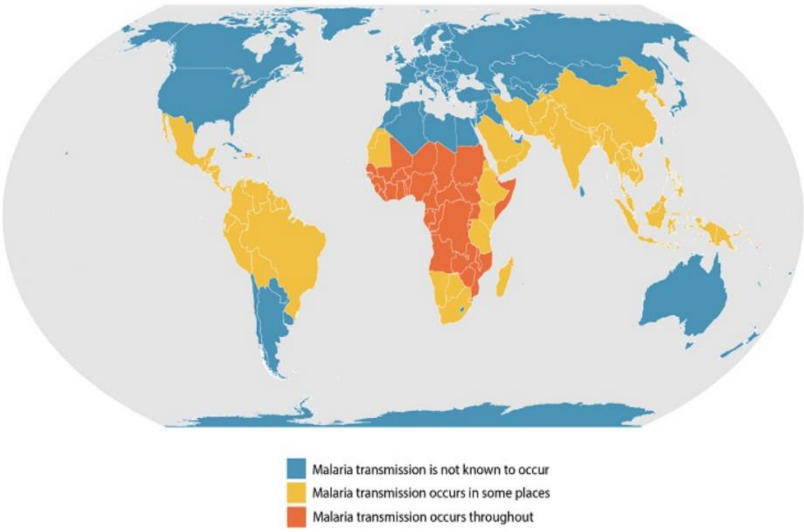
2. Impact of Climate Change on Health

Climate change poses a significant threat to human health by altering environmental conditions that favor disease transmission, particularly malaria. Rising temperatures and shifting precipitation patterns increase the suitability of habitats for mosquitoes, expanding the geographic range where malaria can be transmitted. Understanding and addressing climate change is crucial to mitigating the spread and impact of malaria on global health.

2.1 Malaria

Malaria, a parasitic disease transmitted by mosquitoes of the Anopheles genus, continues to pose a substantial public health challenge in several regions of India and worldwide. The disease can be

caused by five different species of Plasmodium, all of which are single-celled eukaryotic parasites. Plasmodium falciparum and Plasmodium vivax are particularly concerning, as they pose the most significant threat to human health and are exclusive to mammalian hosts, including humans. These two species are major contributors to the global and Indian malaria burden, underscoring their pivotal role in shaping the prevalence and impact of the disease. (Phillips, et al., 2017)
Malaria transmission risk depends on both receptivity, the inherent potential of an ecosystem to sustain the parasite-mosquito cycle, and vulnerability, the risk of parasite introduction. Temperature, humidity, and rainfall are key climatic factors impacting malaria transmission. Malaria is prevalent in tropical and subtropical regions where these conditions favor the establishment and reproduction of Anopheles mosquitoes, the malaria vectors. These environments also support the completion of the Plasmodium parasite's development within the mosquito (extrinsic incubation period). Temperature exerts a crucial influence, especially on the transmission of the most severe form, caused by Plasmodium falciparum. When temperatures fall below 20°C (68°F), this parasite cannot complete its development within the mosquito, effectively halting transmission. (CDC, 2020).
FIGURE 1: This map shows an approximation of the parts of the world where malaria transmission occur

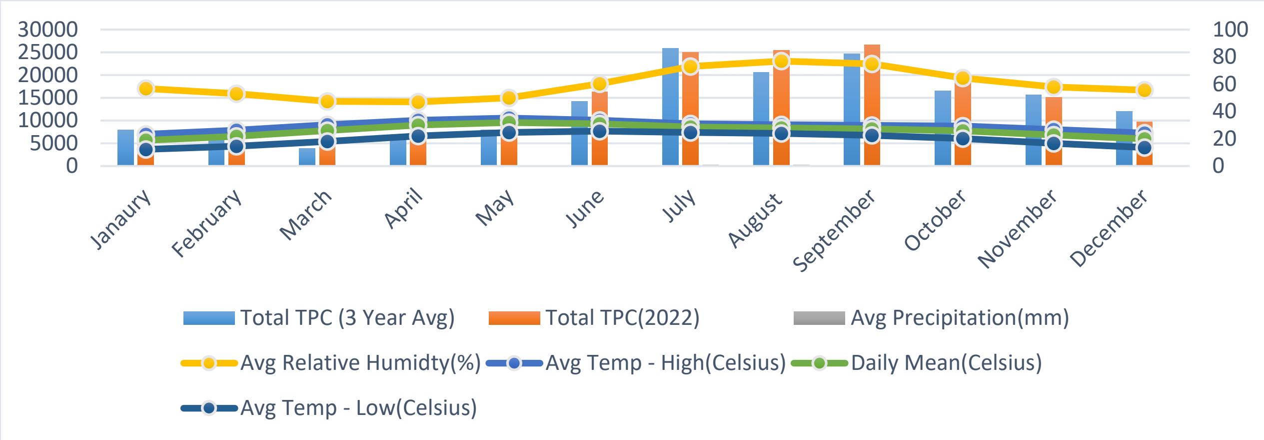


Source: (CDC, 2020)
The 2023 World Malaria Report by the World Health Organization recognizes that, theoretically, global warming and associated alterations in temperature, rainfall, and humidity, if other factors remain constant, could exert diverse direct and indirect effects on malaria transmission dynamics and the overall disease burden. Among these potential impacts, the report highlights the potential expansion of geographical limits for malaria transmission. (World malaria report 2023, 2023)
Malaria in India, though widespread, isn't uniform. Even within tropical zones, altitude, seasonality, and aridity create pockets with low or no transmission. Cooler high altitudes hinder mosquito development and parasite spread. Colder seasons do the same. Even deserts, except oases, see limited transmission. Importantly, targeted interventions successfully eliminated malaria in certain areas. Beyond climate zones, factors like topography, microclimates, and human efforts significantly influence malaria's presence and intensity**.** (CDC, 2020)
Approximately 95% of India's population resides in malaria-endemic areas. Notably, 80% of reported malaria cases are concentrated within tribal, hilly, and geographically remote regions, despite these areas only comprising 20% of the total population. This highlights the disproportionate burden borne by these communities. Malaria transmission typically occurs within a temperature range of 15-40 °C. However, the specific duration required for the mosquito vector to complete its development cycle depends on the persistence of specific temperature ranges, assuming favorable relative humidity remains constant. (Bhattacharya, Sharma, Dhiman, & Mitra, 2006)

2.1.1 The Scope for Future Vulnerability for Climate Change induced Malaria Transmission Risk

Rising temperatures due to climate change can alter the spread of malaria. The extrinsic incubation period (EIP) of malaria, or sporogony, describes the time parasites take to mature within mosquitoes. This period is influenced by temperature, affecting the transmission window for malaria. The temperature must be conducive for parasites to complete development within mosquitoes before transmission. (Casman & Dowlatabadi, 2002)

FIGURE 2: Trends of average monthly temperature, precipitation, relative humidity and malaria cases in India for 3 years average (2020,2021,2022) and 2022.



TPC: number of total positive malaria cases

TPC source: (Monthly Malaria Information System (MMIS), 2022)

Avg Precipitation, Avg Relative Humidity, Avg Temperature (High and Low), Daily mean source: (Weather and Climate, 2024)

FIGURE 2 illustrates a notable pattern during the South-West monsoon season in India (June-July-August-September), where humidity levels rise above average, consequently elevating the TPC. Remarkably, the incidence of malaria cases aligns closely with the humidity trend and, to some extent, correlates with fluctuations in temperature as well. It's important to note that a temperature increase may not always correlate with an increase in transmission risk if accompanied by a decrease in precipitation. Precipitation plays a crucial role in promoting malaria transmission primarily by providing breeding sites for mosquito larvae. Studies have observed a decrease in malaria transmission stability in the South Europe, primarily attributed to projected reductions in rainfall and the consequent decline in vector occurrences due to drought-induced inhibition of the mosquito's aquatic life cycle. (Hertig, 2019)

Coinciding with the peak season for malaria cases (June-October), our data reveals a conducive range of average relative humidity (50-85%) primarily during this period. Interestingly, despite substantial rainfall confined to June-September (>100mm), malaria cases persist even in drier months. Additionally, the observed average temperature remains consistently within the malaria transmission window (18-31°C) throughout the year, suggesting potential factors beyond rainfall influencing transmission dynamics.

Table 1: Climate determinants for malaria parasite development in mosquito vector and transmission

	Transmission Window (°C)	**Corresponding no. of days when malarial parasite thrives**
P. vivax	15-20	20 ± 5 days
	20-25	15 ± 5days
	25-30	8 ± 2 days
P. falciparum	20-25	25 ± 5 days
	25-30	20 ± 5 days
	30-35	10 ± 2 days

Source: (Bhattacharya, Sharma, Dhiman, & Mitra, 2006)
The table above (Table 1) illustrates that an increase in temperature provides a conducive environment for the malaria parasite to thrive.
While rainfall is not the sole factor influencing malaria transmission, other variables such as temperature, humidity, and environmental conditions also play significant roles. Therefore, the connection with climate change lies in the broader context of how changes in climate patterns can impact the complex dynamics of disease transmission, including malaria. Climate change can alter these variables, potentially extending the transmission window and affecting the distribution and intensity of malaria outbreaks.
Testing of Hypothesis: Rejects null hypothesis and accepts alternative.

3. Impact of Climate Change on Agriculture

Climate change disrupts precipitation patterns, resulting in intense downpours, prolonged droughts, and unpredictable cycles. These extremes pose significant challenges to crop production: heavy rainfall floods fields, washes away topsoil, and damages crops, while prolonged dry spells lead to stunted growth and reduced yields.
This study examines the impact of climate change on rainfall patterns and its subsequent effects on agricultural productivity in Uttar Pradesh, West Bengal, Gujarat, and Karnataka. We aim to determine whether the erratic rainfall caused by climate change has impacted agricultural production in these regions over the years.

3.1 Uttar Pradesh

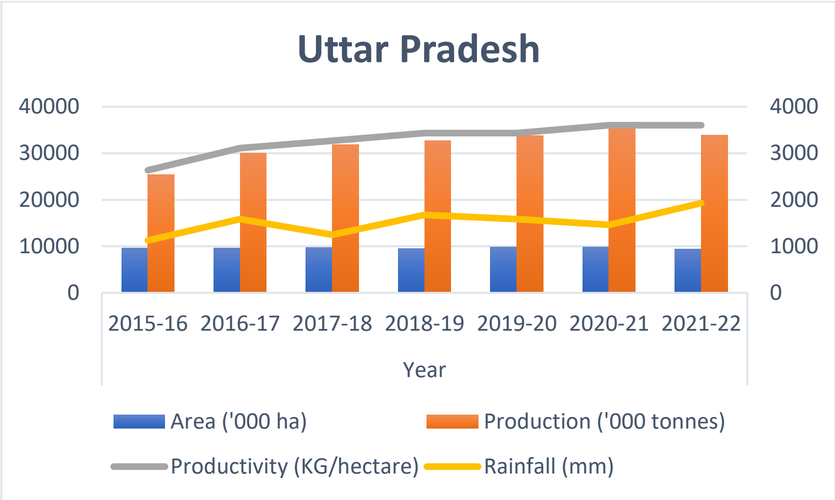
In this section we analyze the impact of rainfall on wheat grown in Uttar Pradesh. Wheat occupies a significant position as India's second most crucial cereal crop. Primarily, it serves as the primary food crop in the northern and northwestern regions of the country. Wheat contains gluten, pivotal for forming the dough in bread and baked goods. Additionally, wheat provides vital amino acids, minerals, vitamins, phytochemicals, and dietary fiber, particularly abundant in whole-grain products. This nutrient density underscores wheat's significance in promoting holistic nutrition and well-being. (Shewry, 2009)

Table 2: Correlation between Area, Production, Productivity and Rainfall in Uttar Pradesh

		('000 ha)	('000 tons)	(tons/ha)	(mm)
('000 ha)	Pearson Correlation	1	0.179	0.01	-0.529
	Sig. (2-tailed)		0.702	0.983	0.222
	N	7	7	7	7
('000 tons)	Pearson Correlation	0.179	1	.986**	0.614
	Sig. (2-tailed)	0.702		0	0.142
	N	7	7	7	7
(tons/ha)	Pearson Correlation	0.01	.986**	1	0.715
	Sig. (2-tailed)	0.983	0		0.071
	N	7	7	7	7
(mm)	Pearson Correlation	-0.529	0.614	0.715	1
	Sig. (2-tailed)	0.222	0.142	0.071	
	N	7	7	7	7

Source: Author’s own calculation using SPSS.
Data source: (indiastat, 2015-2022)

Graph 3: Area, Production, and Productivity of Wheat and Rainfall in Uttar Pradesh



Source: Author's own compilation.
Data source: (indiastat, 2015-2022)

3.2 Karnataka

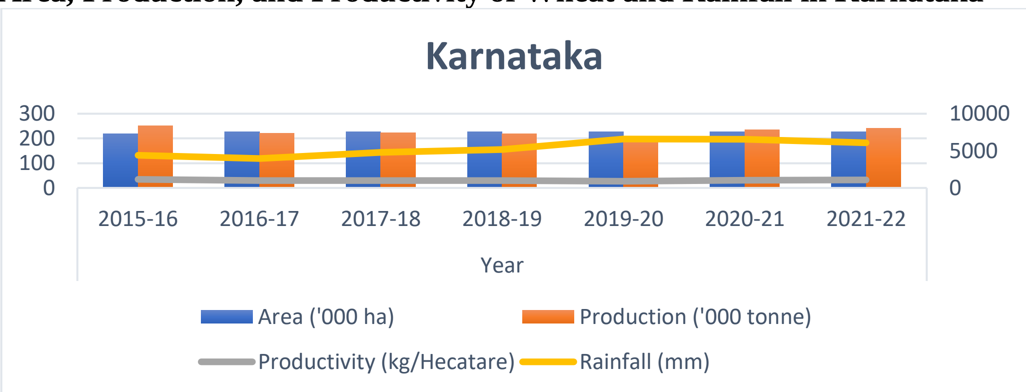
India occupies a significant position in the global coffee market, ranking among the top 10 producers and contributing approximately 3% of the global output in 2020. India cultivates two primary coffee varieties: Arabica, known for its delicate aroma, and Robusta, valued for its bold flavor and dominance in blends. While Robusta comprises 72% of total production, concentrated primarily in southern India (Karnataka leading at 70%, followed by Kerala and Tamil Nadu), the Nilgiri district in Tamil Nadu is a notable Arabica producer. Despite being a major export commodity, domestic consumption minimally affects coffee prices in India. The nation primarily exports Robusta beans, valued for their low acidity and robust taste compared to Arabica. Notably, processed coffee preparations, particularly instant coffee (accounting for nearly one-third of total exports), have witnessed a steady growth at a 4% CAGR over the past decade. (Indian Trade Portal, 2020)

Table 3: Correlation between Area, Production, Productivity and Rainfall in Karnataka

		('000 ha)	('000 tons)	(tons/ha)	(mm)
('000 ha)	Pearson Correlation	1	-0.576	-0.702	0.502
	Sig. (2-tailed)		0.176	0.079	0.251
	N	7	7	7	7
('000 tons)	Pearson Correlation	-0.576	1	.987**	-0.199
	Sig. (2-tailed)	0.176		0	0.67
	N	7	7	7	7
(tons/ha)	Pearson Correlation	-0.702	.987**	1	-0.271
	Sig. (2-tailed)	0.079	0		0.557
	N	7	7	7	7
(mm)	Pearson Correlation	0.502	-0.199	-0.271	1
	Sig. (2-tailed)	0.251	0.67	0.557	
	N	7	7	7	7

Source: Author's own calculation using SPSS.
Data source: (indiastat, 2015-2022)

Graph 4: Area, Production, and Productivity of Wheat and Rainfall in Karnataka



Source: Author's own compilation.

Data source: (indiastat, 2015-2022)

3.3 Gujarat

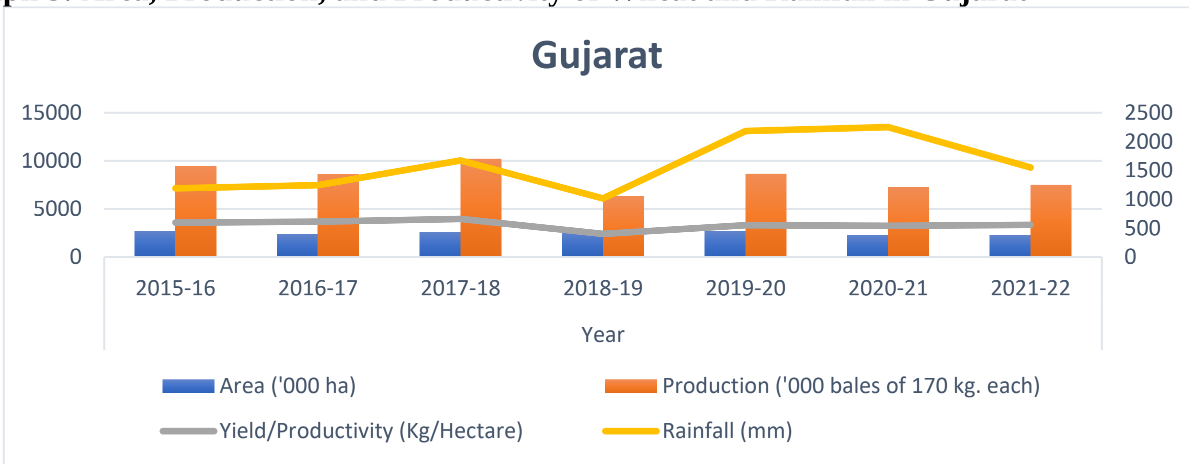
Cotton stands as a pivotal commercial crop in India, contributing roughly 25% to global cotton production. It sustains the livelihoods of approximately 6 million cotton farmers and supports 40-50 million individuals involved in ancillary activities like processing and trade. India's Textile Industry utilizes a varied array of fibers and yarns, with a cotton-to-non-cotton ratio of 60:40, contrasting with the global average of 30:70. Cotton is a major contributor to India's foreign exchange through exports of raw cotton, yarn, fabric, and finished products like garments and knitwear. Due to its economic significance, it's often dubbed "White-Gold" in the country. (Ministry of Textiles, 2022)

Table 4: Correlation between Area, Production, Productivity and Rainfall in Gujarat

		('000 ha)	('000 tons)	(tons/ha)	(mm)
('000 ha)	Pearson Correlation	1	0.381	-0.078	-0.32
	Sig. (2-tailed)		0.399	0.868	0.484
	N	7	7	7	7
('000 tons)	Pearson Correlation	0.381	1	.891**	0.074
	Sig. (2-tailed)	0.399		0.007	0.875
	N	7	7	7	7
(tons/ha)	Pearson Correlation	-0.078	.891**	1	0.208
	Sig. (2-tailed)	0.868	0.007		0.654
	N	7	7	7	7
(mm)	Pearson Correlation	-0.32	0.074	0.208	1
	Sig. (2-tailed)	0.484	0.875	0.654	
	N	7	7	7	7

Source: Author's own calculation using SPSS.
Data source: (indiastat, 2015-2022)

Graph 5: Area, Production, and Productivity of Wheat and Rainfall in Gujarat



Source: Author's own compilation.
Data source: (indiastat, 2015-2022)

3.4 West Bengal

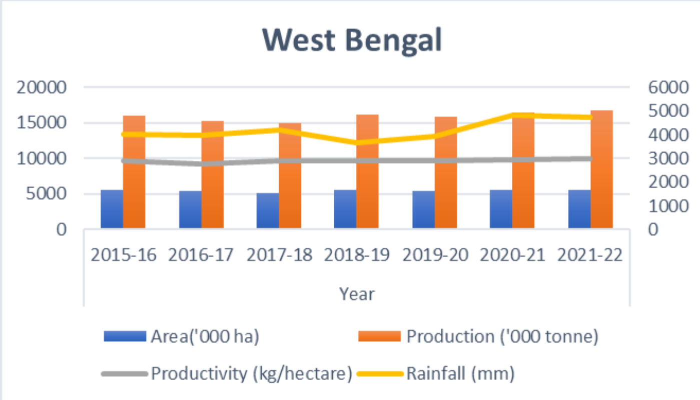
Rice cultivation in India spans 43.86 million hectares, yielding 104.80 million tons with a productivity of approximately 2390 kg/ha (Agricultural Statistics at a Glance-2015). Despite diverse soil and climatic conditions, productivity remains low compared to global standards. With 90% of cultivated land owned by Marginal, Small, and Medium farmers, enhancing rice productivity faces challenges. Rice serves as a vital staple, offering instant energy primarily from carbohydrates, albeit low in nitrogenous substances (8%) and fat (1%). Its starch-rich flour finds applications in various foods and even brewing. Rice straw is utilized in porcelain, glass, pottery production, paper pulp, and livestock bedding. (Farmers' Portal, 2021)

Table 5: Correlation between Area, Production, Productivity and Rainfall in West Bengal

		('000 ha)	('000 tons)	(tons/ha)	(mm)
('000 ha)	Pearson Correlation	1	.808*	0.094	0.217
	Sig. (2-tailed)		0.028	0.84	0.641
	N	7	7	7	7
('000 tons)	Pearson Correlation	.808*	1	0.646	0.483
	Sig. (2-tailed)	0.028		0.117	0.273
	N	7	7	7	7
(tons/ha)	Pearson Correlation	0.094	0.646	1	0.56
	Sig. (2-tailed)	0.84	0.117		0.191
	N	7	7	7	7
(mm)	Pearson Correlation	0.217	0.483	0.56	1
	Sig. (2-tailed)	0.641	0.273	0.191	
	N	7	7	7	7

Source: Author's own calculation using SPSS.
Data source: (indiastat, 2015-2022)

Graph 6: Area, Production, and Productivity of Wheat and Rainfall in West Bengal



Source: Author's own compilation.
Data source: (indiastat, 2015-2022)

3.5 Finding

In Table 3, 4, 5, 6 we observe no significant correlation between rainfall and area, production, and productivity. Despite erratic rainfall patterns due to climate change from 2015 to 2021, there has been no notable impact on yield. In the above four graphs we can see that despite the fluctuations of rainfall throughout the given time period, the production in ratio to their area has almost been stable.

Testing of hypothesis: Accepts null hypothesis and rejects alternative

4. Conclusion

- Malaria exhibits a notable sensitivity to climate change, with potential implications despite governmental efforts that have led to a decrease in malaria cases over the years. However, vigilance is warranted due to unpredictable climatic conditions. According to IPCC predictions, a temperature increases of 2°C may prompt shifts in global climate patterns, potentially leading to the emergence of new malaria hotspots.
- Climate change has led to erratic rainfalls over the year due to rising temperatures and frequent. Despite this, keeping other factors constant, we don't see rainfall's impact much on production and productivity. Other factors such as improved seeds, pesticides, and agricultural methods may have contributed. However, in the future, rainfall and temperature may play a more significant role, potentially overshadowing other factors and impacting production and productivity.

5. Solutions and Suggestions

Water storage and distribution play pivotal roles in managing water resources efficiently. Constructing reservoirs, canals, and irrigation systems aids in storing and distributing water effectively, lessening reliance on unpredictable rainfall and mitigating drought impacts on agriculture. Additionally, these

measures contribute to controlling mosquito breeding grounds by preventing stagnant water accumulation.
Implementing sustainable drainage systems, such as swales, bioretention basins, and permeable pavements, offers another solution. These green infrastructure solutions capture and slowly release rainwater, thus diminishing flooding risks and replenishing groundwater. Moreover, they foster natural habitats for mosquito predators like dragonflies and fish, aiding in controlling mosquito populations.
Developing and planting crop varieties tolerant to dry conditions can help maintain yields during droughts, bolstering food security and diminishing reliance on irrigation, which is susceptible to erratic rainfall patterns.
Adopting water-efficient irrigation techniques, including drip irrigation and precision agriculture, is instrumental in conserving water resources and enhancing agricultural productivity even during periods of low rainfall.
Moreover, larval source management is critical in curbing mosquito populations. Identifying and eliminating mosquito breeding sites, such as stagnant water bodies, can significantly reduce mosquito populations through environmental modification, biocontrol agents, or larvicides.
Early warning systems for extreme weather events and malaria outbreaks are indispensable. Forecasting droughts, floods, storms, and monitoring mosquito populations and malaria cases enable communities to prepare and take preventive measures. These systems facilitate adjustments in agricultural practices, such as planting drought-resistant crops or delaying planting until after heavy rains.

6. Scope for further research

While this study provides a broad examination of climate change's impact, future research could offer deeper insights by focusing on specific regions and localities. Additionally, this study's analysis of agriculture could be expanded to include a wider range of crops or agricultural practices vulnerable to climate-related disruptions.
Moreover, exploring potential feedback loops between climate change, agriculture, and malaria transmission could enhance our understanding of their interconnectedness. For instance, examining how shifts in agricultural practices influenced by climate change impact mosquito breeding grounds and malaria transmission can inform comprehensive mitigation strategies.
Finally, while this study focuses on climate change as the primary driver, future research could incorporate other influential factors such as socioeconomic disparities, land use changes, and deforestation. Understanding the interplay of these factors with climate change in shaping the impacts on malaria and agriculture is crucial for developing holistic approaches to address these complex challenges.

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