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A Study on the Current Spatial Distribution of Long - Grain Rice Due to Climate Changes in India

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Abstract: ***Climate change is affecting agriculture worldwide; India is one of the largest rice producers in India, with a 20% share in gross rice production in the world. However, rice production is particularly at risk of temperature and rain limit changes. This research paper highlights a comprehensive study of the spatial distribution of long - grain rice in India. This further highlights the way long - grained rice production has been influenced by climate change. Here, it is analysed that climate data, changes in it, and rice production statistics to understand the correlation between climate variables and rice cultivation patterns. This study used changes in annual rain amounts and temperature as independent variables, which affect the production of long - grained rice throughout India. The findings provided valuable insights for both policymakers and agricultural stakeholders about the adverse effects of climate change. Regression and correlation analysis assessed the reliability and validity of the overall study. This assisted them in promoting adaptive strategies for mitigating the negative impacts of climate change, the vast threat, on long - grain rice production in India.***

Keywords: Climate change, rice production, long - grain rice, annual rain amounts, temperature

1. Introduction

Rice is one of the staple crops in India, and this has a vital role in securing the food assurance of this country. Like any other crop, rice also depends on climate conditions; hence, climate change is a significant global challenge that affects rice cultivation, along with the overall agricultural system in India. In other words, climate change poses one of the major threats to global food security. In India, a 1% change in yearly rainfall in monsoon results in a 0.34% change in annual agricultural GDP, as India accounts for 20% of the world's rice production (Bowden *et al.*2023). Long - grain rice is a high - quality rice species that provides good texture and presentation of prepared foods. This rice is lengthy and slim, and it is almost 4 to 5 times longer than its width. Long - grain rice includes different types, such as Indian Basmati rice, American long - grain brown and white rice. This type of rice produces separate firm grains which allows it to stay fluffy and separate after cooking. Long - grain rice is the most necessary food product based on the Indian economic and social state. In this concern, it is necessary to understand the relationship between spatial distribution for long - grain rice and climate change. It will assist in promoting the sustainable production of long - grain rice in this country.

This study aims to assess the relationship between spatial distribution for long - grain rice and climate change to promote insight into developing strategies for the sustainable production of long - grain rice in India. In this concern, this study is going to assess the spatial distribution of long - grain rice in India; furthermore, it will analyse the way long - grain rice production has been influenced by climate changes. Moreover, it is necessary to detect issues in crop production patterns that lead to adverse effects on climate so that it can recommend sustainable strategies for long - grain rice production and balance the Indian climate. As the delicate balance of India's long - grain rice production faces the relentless pressure of climate change, this study delves deep into the intricate tapestry of its spatial distribution. Furthermore, this research process will reveal the vulnerabilities, as well as opportunities, that lie hidden within the shifting landscapes of this agricultural cornerstone.

The world is facing a high tide in climate change; almost 50% of the world's population, or 4 billion people, is facing a severe water crisis. Hence, increasing water stress is affecting overall cultivation processes leading to a lack of world food security (Hofste *et al.*2019). In such a situation, this research process assures to unveil a dynamic map of long - grain rice by analysing the risks to global food security. Apart from that, this study also focuses on revealing the very recipe for resilience in the rice cultivation process in the face of a continuously warming world. Hence, this research process is going to emphasise a critical role and assist the policymakers in ensuring a sustainable rice production strategy for this staple crop of India to secure its food availability for future generations.

2. Literature Review

Impact of climate change on long grain rice production in India

Rice is envisaged as the paramount foodgrain in the world and the production volume of rice is around 729 million tons worldwide. It is estimated that India is the largest rice - exporting country and the second - largest rice - producing country in the world. In India, the quantity of rice production is 155.4 million (Gupta & Mishra, 2019). The production of rice has been increasing in nature since the pre - independence era as India has been an agriculture - based country since the historic period. India's long grain rice production rather than all agricultural production is mostly dependent on the classical and earliest methods and practices. Many states of India are dependent on rainfalls which are necessarily associated with climate change. Thus, it can be said that climate change is a crucial influencer for the change in rice production and overall agricultural production. Climate change has indeed impacted the long - grain rice production in India in several ways. Firstly, India's maximum state involves classical methods and old irrigation practices depending on the precipitation rate which is uncertain in nature (Nourani, 2022). Participation rate mostly depends on the temperature rate that can be altered by the change in climate. Long - grain rice needs a certain level of temperature and rainfall for its optimum flourishment and growth. Inadequate rainfall can restrict the

growth of long - grain rice and lead to less rice production. Increasing temperature increases global warming leading to the melting of glaciers and exacerbating the dryness of the cultivated land that leads to extreme drought. The favourable sowing time of rice is from June to July and its harvesting time is from November to December (Patel, 2019). Secondly, climate change can lead to changes in this growing season, disrupting the long grain rice production. Climate alteration disrupts the weather patterns and leads to more extreme and frequent intense weather such as extreme rainfall, drought, flood, or storms. These intense events can damage the sowed long - grain rice seed and can decrease the production quantity of this long - grain rice.

Thirdly, water availability is an essential contributor to producing long - grain rice. It requires a significant level of water for proper cultivation. However, climate change alters the hydrological cycle and changes the quality and availability of the water which leads to disruption in the production of the long grain rice in India. This water scarcity can restrict the irrigation practices of the farmers who rely on the rain - fed agricultural process.

This erratic rainfall pattern and water scarcity can decrease the quantity of the long - grain rice production which leads to further food scarcity.

Spatial Characteristics impacting the Distribution of long Grain Rice Production

The Green Revolution in the 1960s had a significant impact on the spatial distribution of food grains. West Bengal, Uttar Pradesh, Punjab, and Haryana comprise the maximum production of long - grain rice in India. According to the estimation, West Bengal is the largest grain rice - producing state in India with a production volume of 146.05 lakh tons. This is because West Bengal holds favourable long grain rice producing weather that helps to stimulate the rice production process and contributes a significant portion in the long - grain rice accumulation in India and all over the world as a long - grain rice exporter. In the western part of India, Maharashtra, Gujarat, and Rajasthan provide maximum long grain rice whereas in the North - east part, Assam is only the largest long grain rice contributor. Himachal Pradesh, Jammu & Kashmir, Punjab, Haryana, and western Uttar Pradesh contribute the largest amount of long - grain rice. About 47.5 per cent of 19.5 million hectares of the total geographical area is under cultivation (Madhukar, 2020). In the Southern part, the main contributors of long - grain rice are Andhra Pradesh, Tamil Nadu, and Karnataka. It is also noted that Andhra Pradesh is called the 'Rice Bowl' of India due to the highest rice production in the Southern area of India (Niranjan, 2022). Jammu and Kashmir are renowned to produce long - grain rice named Basmati rice in India. The favourable cold weather and the primitive water resources were crucial in producing high - quality and highly - flavoured long - grain rice. According to the estimation of 2021, Punjab contributes over 12 million metric tons of rice across the northern state (Statista. com, 2021). Punjab's weather is favourable for long - grain rice as it holds a tropical and subtropical monsoon season and a semi - arid land area.

Identification of risk pattern for spatial distribution of long grain rice pattern

Significant risk factors are associated with the spatial distribution of long - grain rice. The impact of the alteration of climate greatly influences the rainfall pattern and temperature which leads to a reduction in the production process of long - grain rice. Inadequate rainfall may hamper the rice production of West Bengal as the maximum rice producer depends on the rainfall for their irrigation. The precipitation rate of Punjab is decreasing in the agro - climatic zone every year. According to the last available estimation, rice production in Punjab falls by 6.92 per cent every year (Kumar & Kaur, 2019). Insufficient precipitation rate can also shatter the availability of long grain rice production of the Punjab as well as overall India as it is one of the crucial contributors in the overall long grain rice production. Extreme global warming may disrupt the production of long - grain rice such as Basmati in Kashmir as it requires significantly milder weather to produce the long - grain rice (Surendran, 2021). However, it is a great relief that Punjab's production is not decreasing much as they use modern technology in the agricultural area such as tractors, high - yield stimulating pesticides and advanced irrigation practices.

3. Methods

3.1 Data source

This study uses secondary sources of data to gather relevant sources of rice production in India and the climate condition of this country. Primary sources are ignored to avoid human participation in the data collection process; moreover, the secondary data collection process reduced the time and cost of this study and made it cost - effective and time - efficient. Moreover, this study maintained a time limit while gathering secondary data sources; that limit is for the last five years, that is, from 2019 to 2023. Information from this time limit is considered the most current details which is effective in increasing the authenticity and validity of this research process.

In order to gather climate data, Historical climate data is fetched from the Indian Meteorological Department. This department provided temperature and Precipitation data to assess humidity (Dey *et al.*2021). This department is under "the Ministry of Earth Sciences of the Government of India"; its prime concern is to observe weather and changes and forecast timely so that necessary steps can be taken (Indian Meteorological Department, 2023).

Rice production statistics in India are gathered from the website of the Food and Agriculture Organization (FAO). This organisation is a unique agency of the United Nations, which leads internationally to increase efforts for defeating hunger issues throughout the world (Food and Agriculture Organization, 2023). This organisation aims at achieving worldwide food security and assuring that people receive high - quality food regularly. This is essential to live healthy and lead actively; FAO works in over 130 countries with 195 members from 194 countries along with the European Union. Hence, the data from this source is relevant and authentic to increase the authenticity of this study.

Satellite imagery is also collected for analysing land use and crop mapping; according to Burke *et al. (*2021), satellite imageries provide spatial, spectral, and temporal resolution about each detail. Information from this source has a high potential to provide effective inboard knowledge; as a result, it can help in solving the issues of unreliability and scarcity of data. In other words, satellite imageries promote sustainable data management for any study; for example, socioeconomic and agricultural studies gather satellite information to assess the production of crops (Burke *et al.*2021). In the current study, this source is used to assess the land areas allocated for long - grain rice production in India, as well as to assess the effect of climate change on rice production activities.

3.2 Methodology

(a) Data Preprocessing

In the primary step, gathered climate data is cleaned; then, it is normalised for creating a dataset of consistent time series. Here, statistical information on rice production is gathered to conduct the data processing in the Indian landscape by region and season. This step is quite crucial to conduct the best spatial analysis and statistical analysis; data processing is important to promote pre - processing optimisation and summary of overall gathered data (Mishra *et al.*2020). This allows the rearrangement of the scattered data for further analysis process and evaluation of the relationship between variables. In this concern, this step is beneficial to conduct a secondary quantitative and qualitative analysis for developing interrelationships among the variables.

(b) Spatial Analysis

This study further used Geographic Information System (GIS) techniques to assess Indian spatial distribution for cultivating long - grain rice in this subcontinent. GIS is a computer software system with hardware and data management (Ali, 2021); this allows one to enter necessary information and manipulate and analyse those to present the final result. In this case, the outcome information is closely linked to any location of the earth's surface; for this reason, this software is used to assess the spatial location of the Indian landscape for the cultivation of long - grained rice.

(c) Statistical Analysis

In order to conduct statistical analysis, a regression analysis is employed; it assisted in quantifying the relationship between climate variables and rice production. In this case, precipitation, temperature, and extreme events are the significant climate variables for this study. According to Montgomery *et al. (*2021), regression analysis is a very interesting theoretical process to conduct mathematical analysis. This is elegantly underlined mathematical calculation and well - developed theories of statistics. This properly explains explanatory variables to promote an optimal analysis of gathered data; this is beneficial for analysing the relationship between variables.

4. Results

4.1 Spatial Distribution

Increasing demand for rice as a staple crop expanded the rice production lands in the Indian subcontinent. In 2018, the total rice cultivation land was 44.1 million hectares, and this amount increased in 2022 to above 46 million hectares (Keelery, 2023). In the recent fiscal year of 2022, rice became the most highly produced food crop across the South Asian nations.

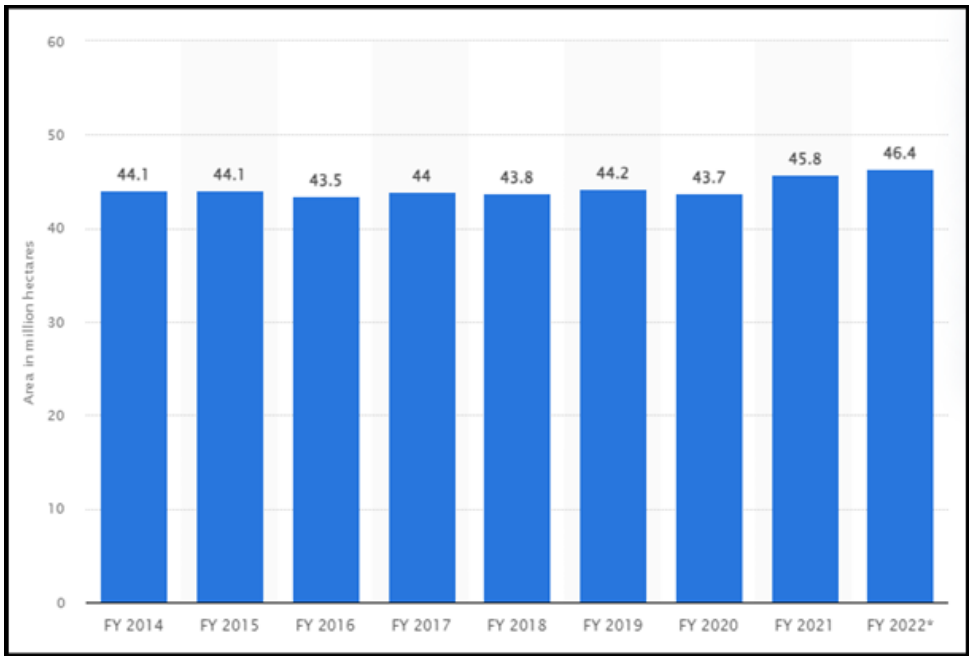

Figure 1: Changes in total areas for rice production in India

(Source: Keelery, 2023)

The spatial distribution of long - grain rice in India has experienced significant shifts over the last few decades. Figure 1 expresses the way rice production areas increased day by day. In the northern states of Punjab and Haryana,

where rice cultivation was historically common, there has been a noticeable decline due to increased temperatures and water scarcity. However, Bathinda and Mansa witnessed an increase in cultivation land of 1.90 and 1.47 lakh hectares, respectively (Chaba, 2023). Conversely, states in eastern India, such as West Bengal and Odisha, have seen an expansion of rice cultivation.

Table 1: Top 10 states in rice production in India

State by rank	*Produced Rice (lakh tons)*	*Area Cultivated (lakh hectares)*	*Production Per Area (kg)*	*Share in Indian Cultivation (%)*	*Temperature Changes*	*Rain Changes (%)*
West Bengal	146.05	15.77	2600	27	2+	12 -
Uttar Pradesh	140.22	58.6	2500	24	1.5+	20 -
Andhra Pradesh	128.95	21.6	3500	12	3+	2+
Punjab	105.42	31.67	2800	10	2.8+	3+
Tamil Nadu	74.58	79.38	3, 900	8	2+	15 -
Bihar	71.62	33	3210	6	5+	10 -
Chhattisgarh	60.28	36	3500	5	4+	23 -
Odisha	50.6	39.4	3400	5	3+	19 -
Assam	45.16	24.6	1700	4	3+	17 -
Karnataka	39.55	14	2, 700	3	5+	25 -

(Source: Based on The Pharma Innovation, 2023; Chaba, 2023; Drdpat, 2023; India Today, 2023; Fazlani, 2023; JSTOR, 2023; International Journal of Environment and Climate Change, 2022; The Hindu, 2023)

Climate Correlation

The statistical analysis of correlation shows that rising temperatures, along with changes in rainfall, negatively impacts the cultivation processes and production of long - grain rice. Farmers experience a higher temperature during the processing of flowering and grain - filling stages. They can reduce yields and issues in rice production. In contrast, regions with more consistent rainfall throughout the growing season tend to have higher rice production.

Correlation analysis

Table 2: Correlation between rice production and temperature changes

Correlations			
		Produced Rice (lakh tons)	Temperature Changes
Produced Rice (lakh tons)	Pearson Correlation	1	- .640*
	Sig. (2 - tailed)		.046
	N	10	10
Temperature changes	Pearson Correlation	- .640*	1
	Sig. (2 - tailed)	.046	
	N	10	10

(Source SPSS)

The acceptable value of Pearson correlation is from (± 0.50) to (± 1); in Table 2, rice production and changes in temperature significantly related as both values are within this range. Hence, it can be said that changes in temperature can affect the production of long - grained rice in India.

Table 3: Correlation between rice production and rain changes

Correlations			
		Produced Rice (lakh tons)	Rain Changes (%)
Produced Rice (lakh tons)	Pearson Correlation	1	- .527
	Sig. (2 - tailed)		.117
	N	10	10
Rain Changes (%)	Pearson Correlation	- .527	1
	Sig. (2 - tailed)	.117	
	N	10	10

(Source SPSS)

The above table presents the interrelation between rain changes value and rice production in India; this table also indicates the acceptable value of Pearson correlation, that is from (± 0.50) to (± 1). Hence, it can be said that changes in annual rain can affect the production of long - grained rice in India.

Vulnerability Assessment

Regression

Table 4: Model summary of regression analysis

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.989a	.978	.933	10.49634

(Source SPSS)

The reliable value of R square is from 0.50 to 0.99; the above table shows that R square value in this study is within the mentioned limit. Hence, it can be said that this test is reliable and relevant, and not vulnerable.

ANOVA

Table 5: ANOVA analysis for vulnerability assessment

ANOVAa						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	14541.080	6	2423.513	21.997	.014b
	Residual	330.520	3	110.173		
	Total	14871.600	9			

(Source SPSS)

In linear regression, the residual value is reliable when it is closure to 0; however, in this study, this analysis highlights that this value is not closure to the mentioned number. In this case, ANOVA analysis does not prove this research process to be accurate.

Coefficientsa

Table 6: Coefficient analysis for vulnerability assessment

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	180.149	97.626		1.845	.162
	State by rank	- 13.182	9.120	- .982	- 1.445	.244
	Area Cultivated (lakh hectares)	- .289	.353	- .143	- .819	.473
	Production Per Area (kg)	- .004	.010	- .063	- .398	.717
	Share in Indian cultivation (%)	.110	2.937	.023	.037	.972
	Temperature changes	- 1.218	5.879	- .036	- .207	.849
	Rain changes (%)	.192	1.414	.037	.136	.900

(Source SPSS)

Acceptable value of t - score is less than 0.05; however, the coefficient analysis presents that this value is acceptable only for states' share in total Indian cultivation. Hence, only this unit can be reliable, while others are not.

Table 7: Analysis of one sample test

One - Sample Test						
	Test Value = 0					
	t	df	Sig. (2 - tailed)	Mean Difference	95% Confidence Interval of the Difference	95% Confidence Interval of the Difference
					Lower	Upper
Produced rice (lakh tons)	6.675	9	.000	85.80000	56.7209	114.8791
Share in Indian cultivation (%)	3.893	9	.004	10.400	4.36	16.44
Production per area (kg)	14.622	9	.000	2981.000	2519.82	3442.18
Area cultivated (lakh hectares)	5.552	9	.000	35.40200	20.9783	49.8257

(Source SPSS)

95% Confidence Interval of the Difference is effective when the value is within (+1.96) and (- 1.96) for 2 - tailed significance. Table 7 shows that these values are maintained in each variable; hence, the one sample test proves the reliability and validity of overall test processes and rejects vulnerability here.

5. Discussion

The overall findings of this study accentuate the requirement for "climate - resilient practices" of agriculture or cultivation in India. Significant steps for ensuring food security to encounter altering climate conditions are the implementation of heat - resistant and drought - tolerant rice varieties, improving the adaptive capabilities of farmers, along increasing the efficiency of water usage. Amoghavarsha *et al. (*2022) opined that after the "RBD or Rice Blast Disease" reported in India, traditional ecosystems of rice cultivating have been increasing. although, with most of the non - traditional regions transformed towards "rice cultivation".

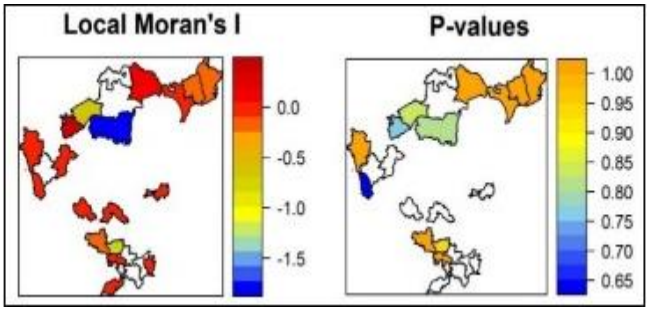

Figure 2: Spatial distribution of rice production in Southern India
(Source: Huded *et al.*2022)

The climate condition in India is changing, which can be seen in Karnataka; threatening change in Indian climate is effective in increasing eco - system issues (Amoghavarsha *et al.*2022). This reduces rice production, leading to the lower economic value of the Indian long - grain rice market. It is significant to comprehend the RBD spatial distribution in various non - traditional and traditional ecosystems of rice cultivation in India. different strategies have been used to analyze the "spatial pattern" of crop disease, among those, "the geostatistical process" is broadly used in this matter. Drastic climate change has indeed affected long - grain rice cultivation in India in different ways. Long - grain rice requires definite rainfall and temperature for its optimum development, due to global warming these conditions also changing simultaneously.

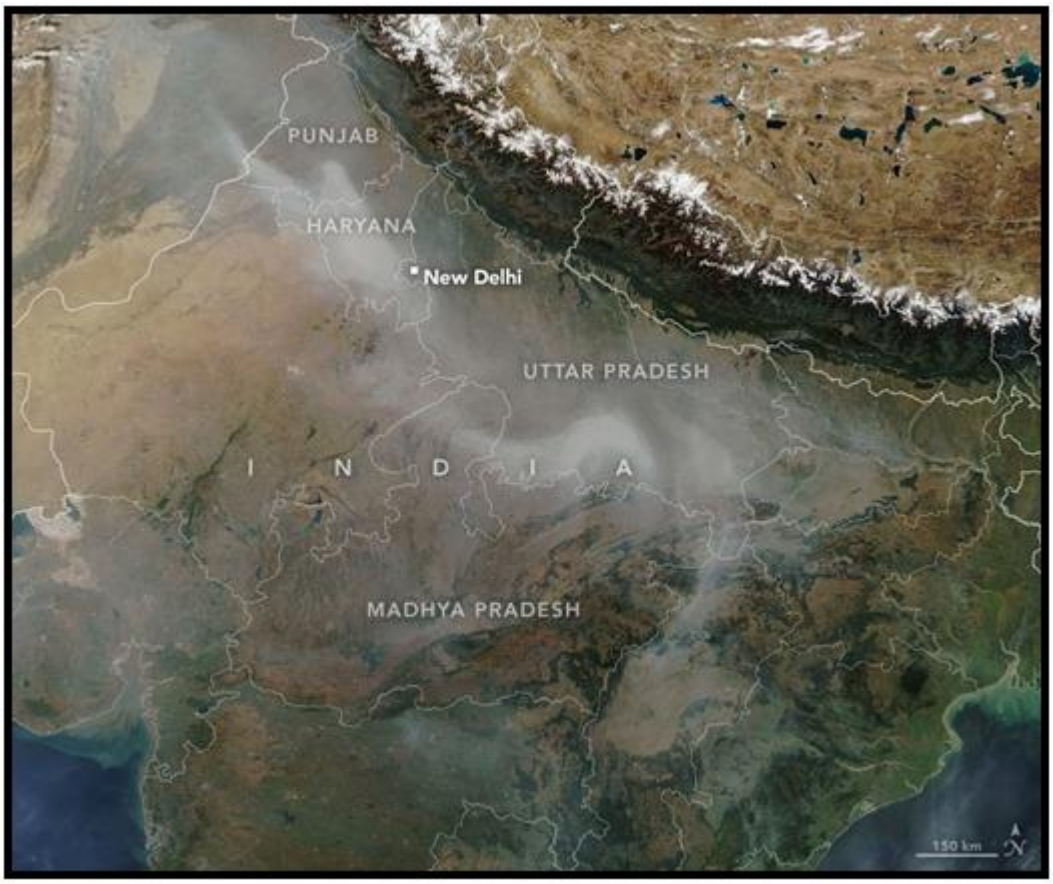

Figure 3: Satellite view of climate condition for long - grain rice production in Northern India (Source: NASA, 2020)

Each year, in September and December, Northern India is covered with thick clouds; according to the experts, good monsoon and adequate rain are effective to increase rice production. However, too much rain often results in the harm of rice fields and this increases the price of rice in these regions (NASA, 2020). Uttar Pradesh, Punjab, and West Bengal are within the northern region of India, which highly depends on weather conditions and climate changes.

These intense incidents have been damaging the growth and development of rice grain, it also affects its quality as well as quantity. “Climate change” has a crucial effect on the “spatial distribution of rice” mainly in areas with high latitudes. Yearly “accumulation temperature” is the fundamental factor to rice cultivation within the higher latitude area. henceforth, due to the variations in temperature in different crop - growing seasons, there are distinct spatiotemporal traits have been observed in rice production. comprehension of the trends in changing climatic conditions and spatiotemporal characteristics has been proven helpful measures for farmers. “Climate change” has become an incontestable matter and is affecting different regions of social and ecological activities globally. In the context of this, agriculture is the most vulnerable and sensitive area to climate change.

6. Conclusion

From the above study, it can be concluded that emerging spatial distribution in terms of long - grain rice in India has occurred due to constant climate changes. Comprehending the effects of climate change on rice production is crucial for facilitating practical policies to ensure sustainable agriculture and food security. the result of this study could serve as an important source for researchers, agricultural stakeholders, and policymakers seeking to reduce the impacts of constant climate change on rice cultivation in India. The rate of rice production, rice quality, and the types of rice are different in every state of India. The main reason for these different rice varieties is that every state of India comprises different climactic conditions. However, due to this changing climate condition, these diverse characteristics of rice in India slowly destroying, directly harming the nation’s economic prosperity.

7. Recommendations

From the above discussions and results it can be recommended that promoting and developing rice varieties that are climate resilient is important. Furthermore, improving the irrigation infrastructure and the practice of water management is also crucial. In addition, providing necessary assistance and increasing awareness to farmers for climate adaptation approaches is the critical step. Thereafter, conducting further study to evaluate the long - term impacts of constant climate change on rice cultivation is necessary.

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