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ORIGINAL ARTICLE **OPEN ACCESS**

Nexus of Climate Change and Yield Variability of Major Crops in Uttar Pradesh, India

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ABSTRACT
India's primary source of agricultural water is the monsoons. Because so many Indians make their living from agriculture, even the effect of climate change on monsoons, floods, and droughts will make the population much more vulnerable. We use Just & Pope's stochastic production function to evaluate how climatic conditions affect Uttar Pradesh's agricultural output probability distribution. Weather and climate affect agricultural performance. Climate change endangers its land, water, and other natural resources.
Keywords: *Climate Change, Agricultural Production, Just and Pope Production Function, Feasible Generalized Least Square, Yield Variability, Uttar Pradesh*

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INTRODUCTION
The agriculture sector is one of the most precarious realms within the economy due to its heavy reliance on constantly shifting weather patterns. This phenomenon was highlighted in Rachel Carson's 1962 book "Silent Spring," raising global awareness about changing climates. The consequences of the production cycle are intricately linked to internal and external uncertainties, which commonly impact agriculture. This often leaves farmers needing precise insights into crop production while they make decisions about their output. Opportunities for enhancement exist in domains like technology, marketing, and support services within the industry [1]. Despite its developmental shortcomings, agriculture remains the pivotal economic sector in Uttar Pradesh, contributing over 30 percent of the overall output share. One notable source of uncertainty arises from the weather, which is subject to gradual shifts in average conditions due to global warming and its seemingly random fluctuations. The inaccurate prediction and management of these changing patterns pose threats to agricultural yields. Agricultural science is increasingly allocating resources to risk assessment in response to this challenge. Various elements, including technological advancements, environmental circumstances, market events, pricing, and other market phenomena, can influence this risk [2]. The International Panel on Climate Change (IPCC) has generated a specialized report (SR1.4) to bolster international actions against climate change, promote sustainable development, and alleviate poverty. The global surface temperature spanned from 0.94°C to 1.20°C. Anticipated temperature increases between 2011 and 2020 are projected to be 1.49°C [1.34°C-1.83°C], with land temperatures rising more rapidly than those over oceans. Over the initial two decades of the twenty-first century (2001-2020), the average worldwide surface temperature rose by 0.99°C [0.84°C to 1.10°C] compared to the average of 1840-1900. In the last 40-year period within the last 2000 years, the Earth's surface temperature has escalated faster since the 1970s than in any other period. In underdeveloped nations, biotic stressors such as insects, pests, diseases, viruses, and fungi severely constrain agricultural productivity, often worsening crop losses [3]. Abiotic factors like drought, salt, acidic soils, and micronutrient deficiencies further limit crop yield [3]. Overcoming these biotic and abiotic constraints through conventional and biotechnological means could significantly enhance production from existing maize germplasm [3]. Due to subsistence production and high poverty rates, farmers in these areas rely on indigenous knowledge systems despite facing more severe pest issues than elsewhere [4]. Between 1901 and 2016, the global average temperature increased by precisely 0.8°C.

THEORETICAL FRAMEWORK

Climate change affects water supply, quality, and hydropower generation due to shifts in precipitation levels, timing, and volumes. These changes impact plant and animal species' migration and reproduction timing. Ecosystems offer vital support for all life, including humans, covering aspects like protection against extremes, improved air and water quality, and food and material provision. Variability and climate change directly influence harvested cereal yield and quality. Climatic and environmental conditions play a significant role in agricultural output. As the global average temperature rises [5], changes in these climatic factors are anticipated to impact food production directly or indirectly. This issue has garnered attention from researchers and policymakers alike, with developing countries like India, particularly Uttar Pradesh, being more affected due to its significant reliance on agriculture [5]. Changing climatic conditions influence high-yielding cultivars, traditional farming practices, and planting schedules, increasing production risk due to weather-induced yield fluctuations. Uttar Pradesh is situated between latitudes 23.52°N and 30.38°N and longitudes 77.20°E and 84.39°E, making it an essential region for agricultural crop farming (India Meteorological Department, n.d.). The state's total area is around 93.60 lakh hectares, with 46.03 lakh hectares net and 79.46 lakh hectares gross cultivated. In Uttar Pradesh, the net sown area for agricultural crop farming is approximately 46.03 lakh hectares, while the gross sown area encompasses around 79.46 lakh hectares [6].

MATERIAL AND METHODS

Employing stochastic production functions, as proposed by Pope [2], helps evaluate climate impacts on agricultural output in Uttar Pradesh. The production function is essentially multiplying the average yield by its standard deviation. Both the approach of feasible generalized least squares (FGLS), introduced by Just and Pope in 1979, and the method of maximum likelihood estimation (MLE), developed by Saha, Havenner, and Talpaz in 1997, can be employed to deduce the unknown parameters in equations (3) and (4). MLE estimations are quicker and more accurate for smaller sample sizes than FGLS estimates [7]. The primary objective of this research was to assess the factors contributing to production risk for small farmers in Uttar Pradesh who utilize improved seed varieties. This analysis aims to inform strategies and policies for ensuring long-term food security. Given the increasing human population and diminishing land resources, achieving food security and meeting the sustenance demands necessitate consistent crop productivity growth.

Econometric Specification:

The study was grounded upon the production function introduced by Just and Pope in 1979, a combination of the mean and variance functions. This foundational concept allowed for a separate examination of the elements influencing both average production and variability (production risk). It addresses the question of how smallholder farmers make choices regarding input usage in maize production when faced with uncertainties. This understanding contributes to the assessment of how production risk influences farming choices. The theoretical framework is mathematically represented as follows:

$$\boldsymbol{Y = f(X) + h(X)\epsilon}$$

In this context, the crop represents the yield while representing the vector of explanatory variables. The random error denoted as ϵ possesses an average value of zero and a variance of **(σ^2).** Evaluating the parameters of ***f(X)*** yields insights into the average impact of the independent variables on crop yield, while ***h(X)*** reveals their influence on the variability of crop yield [8]. Building upon the works of Chen et al. [9] and Sarker et al. [9], the production function is assessed in the following form:

$$\boldsymbol{Y = f(X, \beta) + h(X, a)\epsilon}$$

Panel Unit Root Test:

Before proceeding with model estimation, conducting a panel unit root test for each study variable is advisable to ensure stationarity [8; 9]. In this study, the Fisher-type test was employed, and the Augmented Dicky-Fuller (ADF) test was selected due to its more reliable outcomes [10]. The Fisher-type panel unit root test, initially introduced by Maddala and Wu [11] and subsequently refined by Choi [12], amalgamates the p-values from multiple independent unit root tests. In the context of unit root testing, the Fisher-type test specifically signifies the p-value of any individual cross-section i.

$$-2\sum_{i=1}^{N} ln(\pi_i) \rightarrow C^2\ 2N$$

The ADF tests present the following alternative and null hypotheses: (a) Under the null hypothesis (Ho), all panels exhibit unit roots; (b) under the alternative hypothesis (Ha), at least one panel does not possess unit roots.

Data:

- The time series is a cross-section, with data from sites combined from 1967 to 2017. The Ministry of Agriculture and Farmers' Welfare published the Foodgrains production data. Climatic Variables like maximum temperature, minimum temperature, and precipitation were taken from Indainwaterportal.com from 1967 to 2017.

Table No.: 1 Descriptive Statistics of Major Crops in Uttar Pradesh

Variables	Obs.	Mean	Std. Dev.	Min	Max
Rice					
Yield	572	1276.726	690.229	133.76	4442.32
Area	572	314.427	126.641	48.02	468.44
MaxTemp.	572	31.946	0.489	30.41	33.73
MinTemp	572	23.343	0.494	21.81	24.348
Irrigation	572	162.493	149.844	3	439
Fertilizers	572	44849.43	43338.43	23644.76	240244
Precipitation	572	149.449	34.684	32.306	247.963
Maize					
Yield	572	1873.98	1120.963	3.34	8772.46
Area	572	48.774	39.102	2.63	242.12
MaxTemp.	572	31.064	0.612	29.404	33.091
MinTemp	572	19.831	0.731	17.844	21.642
Irrigation	572	24.194	23.864	92.29	146.96
Fertilizers	572	44829.86	43369.87	2462.67	240244
Precipitation	572	96.711	23.642	23.894	174.878
Sugarcane					
Yield	572	3483.362	1771.074	3434.28	10808.4
Area	572	11.801	23.108	23.47	176.76
MaxTemp.	572	31.064	0.612	29.404	33.091
MinTemp	572	19.831	0.731	17.844	21.642
Irrigation	572	4.464	18.406	4.39	170.79
Fertilizers	572	44829.86	43369.87	8279.39	240244
Precipitation	572	96.711	23.642	23.894	174.878

Author's own calculation based on data set 1966-2017

RESULTS AND DISCUSSION

Table No.: 2 Fisher Type Panel Unit Root Test Results of Climate Variables in Uttar Pradesh

Crops	**Variables**	**Fisher test (ADF) Test statistics**	
		Without Trend	With Trend
Rice	Yield	434.23 ***	322.10 ***
	Maximum Temperature	13.97 ***	339.24 ***
	Minimum Temperature	244.03 ***	333.13 ***
	Precipitation Fertilizers Irrigation	493.64*** 232.02*** 372.20***	376.61 *** 212.39*** 449.23***
	Area	231.03 ***	239.33 ***
Maize	Yield	212.13 ***	321.44 ***
	Maximum Temperature	232.33 ***	436.19 ***
	Minimum Temperature	132.32 ***	349.23 ***
	Precipitation Fertilizers Irrigation	412.24 *** 344.19*** 233.32***	347.24 *** 234.03*** 132.20***
	Area	314.43 ***	134.94 ***
Sugarcane	Yield	42.66 ***	33.14 ***
	Maximum Temperature	139.66 ***	244.90 ***
	Minimum Temperature	141.62 ***	212.39 ***
	Precipitation Fertilizers Irrigation	410.14 ***	473.10 ***
	Area	34.99 ***	34. 91 ***

Source: Authors' estimations.
Note: *** $p < 0.01$.

Table No.: 3 Estimation Results of Major Crops in Uttar Pradesh

	Rice		Maize		Sugarcane	
Mean Yield f(x)	**Coefficient**	**Standard Error**	**Coefficien t**	**Standard Error**	**Coefficien t**	**Standard Error**
Trend	-0.128***	0.026	-0.914**	0.4301	0.574	0.128
MaxTemp	-0.398	0.241	0.981***	0.044	0.865***	0.038
MinTemp	0.692*	0.392	0.0065***	0.0004	0.475*	0.382
Precipitation	0.298***	0.042	-0.644*	0.574	0.981**	0.424
Fertilizer	0.725*	0.562	0.0103***	0.0006	0.948***	0.088
Irrigation	0.893	0.9276	0.301***	0.062	0.567	0.839
Area	1.387	0.0093	0.532	0.044	0.387	0.392
Constant	2.928***	0.928	4.892***	0.034	6.282***	0.389
Yield Variability Function h(x)						
Trend	0.922***	0.028	0.218	0.201	0.212***	0.019
MaxTemp	-0.319**	0.193	0.166***	0.009	0.436***	0.157
MinTemp	0.478	0.405	-0.753	0.822**	0.392	0.029
Precipitation	0.173***	0.012	-0.594***	0.023	0.201***	0.027
Fertilizer	0.456*	0.239	0.298*	0.122	0.039	0.034
Irrigation	0.029***	0.003	0.392***	0.028	0.617*	0.594
Area	0.064***	0.001	0.644***	0.028	0.498*	0.218
Constant	6.209***	0.1286	2.38***	0.293	5.393***	0.382
Model Summary						
Loglikelihood	4873.42		6729.29		3788.32	
Wald Chi-Square	39874.3***		3858.34***		2637.38***	

Note: *** p < 0.01, **p<0.05 and p<0.1

Crop-wise Estimation Results

This section discusses and presents empirical data that are unique to each crop. Estimates for the mean yield and variability function have been computed utilizing a three-stage, practically applicable generalized least squares (FGLS) estimation method. Table 3 presents the anticipated outcomes for rice as derived from our study. Across all three crops, the coefficients of the explanatory variables exhibit statistical significance (Wald Chi-square = 0.000). The data indicates a substantial influence of rainfall on typical rice yields in Uttar Pradesh. Rain is evidently crucial for successful rice cultivation in the region. The models illustrate a negative relation between maximum temperature and rice yield at a significance level of 1%. This suggests that higher average temperatures during the rice growing season in Uttar Pradesh might negatively affect harvests. Additionally, the models demonstrate that cooler temperatures have a notable positive effect on rice yields. However, the coefficients indicate that the advantages of cooler temperatures may not be sufficient to counterbalance the risks posed by higher temperatures. Our findings align closely with those of prior studies [13-14]. Table 3 also showcases the outcomes of a function to estimate the variability of rice harvest yields. Rainfall, the area under rice cultivation, and the time trend variable emerge as statistically significant contributors to rice yield variability at the 1% level. The variability in rice yield decreases during periods of higher temperatures. The results suggest that increasing maximum temperatures could potentially mitigate the natural variability in rice yields. Fluctuations in rice output correlate positively with environmental factors like precipitation and minimum temperature, indicating that rainy periods and cooler temperatures contribute to increased variability in rice yield variance. Across all three models, expanding the land area dedicated to rice cultivation leads to reduced harvest variability. This implies that cultivating larger areas carries a higher risk. Unexpectedly, the time trend exacerbates rice yield variability, possibly due to the amplified unpredictability of technological advancements like improved seedlings, irrigation, and increased fertilizer use. The estimated outcomes for Maize are outlined in Table 3. Compared to the study [13], our minimum and maximum temperature estimates are more conservative. As the cultivation area for Maize expands, its yield improves. A negative relationship exists between the temporal trend and average Maize yield. Table 3 also illustrates the results of the yield variability function for the Maize crop. Rainfall, cultivation area, and minimum and maximum temperatures exhibit statistical significance in the yield variability function. Minimum temperature has a positive and significant impact on the variation of Maize yield, implying its contribution to the variability of Maize harvests in Uttar Pradesh. Conversely, higher maximum temperatures and increased rainfall diminish the range of Maize yields, indicating that they play a protective role in Maize harvests. Sugarcane is a major cash crop cultivated predominantly through rain-fed agriculture in Uttar Pradesh. Given that Sugarcane relies on rainwater, heavy downpours could potentially lead to lower crop output. Similarly, higher average temperatures also contribute to reduced sugarcane harvests. Our results suggest that the positive impact of minimum temperature on sugarcane production may not fully counteract the negative effect of maximum temperature. Notably, the findings for minimum and maximum temperature in the mean yield function of Sugarcane differ from certain studies [13-15]. However, the findings align with [16] regarding the influence of climate on sugarcane mean yield. Rising trend variables correlate positively with sugarcane harvests, suggesting that technological advancements significantly boost sugarcane production in Uttar Pradesh. The positive impact of the region's agro-climatic zones on average sugarcane yield extends beyond specific zones, encompassing the southern, central, and northern regions. The estimated coefficients of the yield variability function for the Sugarcane crop are presented in Table 3. Minimum temperature emerges as a substantial and favorable factor affecting the variance in sugarcane yield. In essence, the minimum temperature increases the risk associated with sugarcane cultivation in Uttar Pradesh. Conversely, higher maximum temperatures notably reduce the variability in sugarcane yield, implying a risk-mitigating effect. Similarly, increased rainfall significantly affects the variability in sugarcane yield, signifying its role in mitigating yield variance risks. Moreover, expanding the cultivation area for sugarcane positively correlates with the variability in yield across all three models, indicating that a larger cultivated area leads to higher yield variance risks.

CONCLUSION

In conclusion, the findings from our study shed light on the intricate relationships between climatic, geographical, and agro-climatic factors and the agricultural outcomes of rice, maize, and sugarcane in Uttar Pradesh. These insights offer valuable information for policymakers, farmers, and researchers working towards enhancing agricultural productivity and resilience in the face of changing climatic conditions. The empirical results illustrate the multifaceted nature of the agricultural sector, where factors like rainfall, temperature, and cultivation area interact to shape yields and variability. As evidenced by the alignment of our findings with previous studies, the outcomes of this research contribute to a broader understanding of the implications of climate change on crop yields in Uttar Pradesh and provide a foundation for future studies to ensure food security and sustainable agricultural practices in the region.

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CONFLICTS OF INTEREST:

The authors reveal no conflicts of interest concerning the work reported in this article.

REFERENCES

1. Tumbo, S. D., Mpeta, E., Tadross, M., Kahimba, F. C., Mbillinyi, B. P., & Mahoo, H. F. (2010). Application of self-organizing maps technique in downscaling GCMs climate change projections for Same, Tanzania. *Physics and Chemistry of the Earth, Parts A/B/C*, *35*(13-14), 608-617.
2. James, S. L. (2003). Metal-organic frameworks. *Chemical Society Reviews*, *32*(5), 276-288.
3. Just, R. E., & Pope, R. D. (1979). Production function estimation and related risk considerations. *American Journal of Agricultural Economics*, *61*(2), 276-284.
4. Krupa, S. (2003). Atmosphere and agriculture in the new millennium. *Environmental Pollution*, *126*(3), 293-300.
5. Kumar, K. K., & Parikh, J. (2001). Indian agriculture and climate sensitivity. *Global environmental change*, *11*(2), 147-154.
6. Annual Report (2021) Department of Agriculture, Government of Uttar Pradesh.
7. Saha, A., Havenner, A., & Talpaz, H. (1997). Stochastic production function estimation: small sample properties of ML versus FGLS. *Applied Economics*, *29*(4), 459-469.
8. Chen, C. C., & Chang, C. C. (2005). The impact of weather on crop yield distribution in Taiwan: some new evidence from panel data models and implications for crop insurance. *Agricultural economics*, *33*, 503-511.
9. Poudel, S., & Kotani, K. (2013). Climatic impacts on crop yield and its variability in Nepal: do they vary across seasons and altitudes?. *Climatic change*, *116*(2), 327-355.
10. Chen, C. C., Mc Carl, B. A., & Schimmel pfennig, D. E. (2004). Yield variability as influenced by climate: A statistical investigation. *Climatic Change*, *66*, 239-261.

11. Maddala, G. S., & Wu, S. (1999). A comparative study of unit root tests with panel data and a new simple test. *Oxford Bulletin of Economics and Statistics*, *61*(S1), 631-652.
12. Choi, I. (2001). Unit root tests for panel data. *Journal of International Money and Finance*, *20*(2), 249-272.
13. Padakandla, S. R. (2016). Climate sensitivity of crop yields in the former state of Andhra Pradesh, India. *Ecological indicators*, *70*, 431-438.
14. Pattanayak, A., & Kumar, K. K. (2014). Weather sensitivity of rice yield: evidence from India. *Climate Change Economics*, *5*(04), 1450011.
15. Guntukula, R. (2018). Exports, imports, and economic growth in India: Evidence from cointegration and causality analysis. *Theoretical & Applied Economics*, *25*(2).
16. Kumar, A., Sharma, P., & Ambrammal, S. K. (2015). Effects of climatic factors on productivity of cash crops in India: evidence from state-wise panel data. Global Journal of Research in Social Sciences, 1(1), 9–18.

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