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Impact of Climate Change on Groundnut Yield and Its Variability in Andhra Pradesh, India

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

This study investigated the impact of climate change variables viz., rainfall, maximum and minimum temperatures on mean groundnut yields and its variability during both Kharif and Rabi seasons across different agro-climatic zones in Andhra Pradesh through employing Just and Pope production function. For this study, groundnut was purposefully chosen because it is one of the main oilseed crops grown in Andhra Pradesh during both the Kharif and Rabi seasons. The results from Just and Pope quadratic and Cobb-Douglas models (2005-2019) revealed that rainfall and minimum temperature are yield increasing factors and yield risk shrinking factors, whereas maximum temperature is yield reducing and risk enhancing factor during Kharif season. It was found that in Rabi season all the climatic variables were yield increasing and risk shrinking factors. Time trend was positive and significant in influencing both mean yield and yield variability during both the seasons. These findings suggested that the farmers should improve their access towards

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agro-meteorological information, cultivate climate resilient groundnut varieties, capacity building to withstand diverse impacts of climate change events at field level etc., towards sustainable groundnut production in Andhra Pradesh.

Keywords: Climate change; groundnut; just and pope production function; marginal effects.

1. INTRODUCTION

Globally, the effects of climate change and its variability on agricultural production are of high concern. Acreage, yield, and productivity of agricultural crops in a region are greatly influenced by the climate. Changes in temperature, precipitation (water), and carbon dioxide (CO2) concentration all have an impact on agricultural production and are key factors in the crop cycle. According to observed meteorological data in the Indian context, between 1901 and 2007, there was a considerable warming at the rate of 0.50^{o}C for every 100 years [1]. According to climate change forecasts, India's precipitation and temperature will rise by 10 to 15 percent and 1.7 to 2.2^{o}C, respectively, by 2030 [2], and as a result, crop yields may fall by 4.5 to 9.0 percent [3]. Reduced crop yields suggest that the cost of climate change will be around 1.5% of GDP annually given that agriculture actually constitutes about 16% of India's GDP [4]. Studies reported that the annual average, maximum, and minimum temperatures in the erstwhile state of Andhra Pradesh increased steadily and continuously between 1956 and 2010 and by 2050, the maximum and minimum temperatures are expected to rise by 1.3 to 2°C and 1.83 to 2.17°C, respectively [5].

Groundnut is one of the important legume crops of tropical and semiarid regions, major source of edible oil and protein. India is the world's leading producer of groundnuts, producing 101 lakh tonnes and the productivity is 1816 kg per hectare in 2020–21, with an annual all-season covering of 55.6 lakh hectares. In Andhra Pradesh, groundnut production accounts for 87 percent of acreage and 91 percent of production of all oilseeds (ANGRAU groundnut outlook report 2021). Groundnut is cultivated under various agro-climatic zones and the impact of climate change on these agro-climatic zones in Andhra Pradesh was varied, which demands for further study utilising more disaggregated data on various climatic variables and these findings need to be coupled to management strategies. With this background, the focus of this study is to analyse the impact of climate change on groundnut yields and its variability in Andhra Pradesh, India.

2. MATERIALS AND METHODS

For this study, Andhra Pradesh state was selected as it is the 4th largest producer contributing 7.6 per cent to total groundnut production in India. Districts namely, Srikakulam, West Godavari, Prakasam, Ananthapuramu, Chittoor with highest area under groundnut cultivation from each zone of the state were selected. The requisite secondary data was collected from published records of various Governmental agencies. Data on the groundnut yield and area under cultivation (2005-2019) of groundnut crop in the selected districts was collected from Hand Book of statistics of respective districts, Government of Andhra Pradesh and data of climate variables was collected from NASA POWER.

2.1 Just and Pope Production Function

To assess the impact of climatic variables on both the mean and variability in yield of groundnut crop, the Just and Pope production function approach developed by Just and Pope (1978, 1979) [6] was used. The main idea behind this strategy is to divide the production function into two parts: the first part relates to output level, and the second part to output variability. With this method, it is possible to estimate how an input variable such as the climate will affect the expected output and its variance. The general form is as follows:

$$y_{it} = f(x_{it};\beta) + \omega_{it}h(x_{it};\delta)^{0.5}$$

where

ω_{it} is the stochastic term with mean zero and variance σ^2; β and δ are the production function parameters; y_{it} is yield per hectare of groundnut crop i during year t and x_{it} are the climatic variables (Maximum and minimum temperature, rainfall).

The expected crop yield was given by $E(y_{it}) = f(x_{it};\beta)$ and crop variability is given by $V(y_{it}) =$

$\sigma^2\, \omega_{it} h(x_{it}; \delta)^{0.5}$ which explains the variability effect of independent variables on yield. Hence the functions $f(x_{it}; \beta)$ and $h(x_{it}; \delta)^{0.5}$ are called mean and variance functions respectively. Dependent variable is groundnut yield and the independent variables are rainfall, maximum temperature and minimum temperature.

2.2 Elasticities (Marginal Effects) of Climatic Variables

By multiplying the coefficients of rainfall, maximum temperature, and minimum temperature with the average of the respective climate change variable and dividing by the average yield, the elasticities (marginal effects) of climate change variables during both the Kharif and Rabi seasons were determined [7].

3. RESULTS AND DISCUSSION

3.1 Determinants of Mean Yield and Its Variability of Groundnut during Kharif Season

Findings from Table 1 indicated that, both in quadratic and Cobb-Douglas models, rainfall and minimum temperature showed significant positive influences on the mean yield of groundnut. If rainfall is evenly distributed during the crop's flowering, pegging, and pod-formation stages, groundnut crops can be cultivated successfully in areas receiving 500 to 1250 mm of annual precipitation. Rainfall at 25 Days after Sowing (DAS) has a beneficial impact on groundnut crops because it encourages vegetative development. However, if heavy rainfall coincides with the flowering stage, it will be detrimental as it hampers synchronization of flowering thereby effecting the peg formation and pod development due to high soil moisture during flowering-pegging stages.

The results indicated that increase in the minimum temperature had positive significant effect on mean groundnut yield. Maximum temperature showed significant detrimental effect on mean yield. Temperature has a major impact on crop growth rate, the ideal temperature for leaf and stem growth up to flowering is between 28 and 30°C, while the ideal temperature for pod formation is between 20 and 24°C. So, flowering and pod formation will be impacted if the temperature rises to 35°C, which is probable during the kharif season. The time trend variable is significant in the mean functions implying that yield is increasing over time due to the technological advancements. This finding is in tune with the work of Palanisami et al. 2011 [8]. The interaction terms were positive and insignificantly related to mean yield except interaction term of rainfall and maximum temperature (Negative and non-significant). All four district dummies have a positive (significant) impact on the average yield, indicating that the groundnut yields in these districts are significantly different from that of Srikakulam, the benchmark district.

The quadratic terms for maximum temperature and rainfall revealed a substantial negative impact on mean yield in the quadratic model, indicating that beyond the threshold levels these variables have a negative impact on mean yield. Heavy rainfall shows detrimental effect on crop growth if it causes waterlogging during the crop growth as waterlogging decreases photosynthesis rate and yield by significantly reducing the leaf area and chlorophyll content. Low soil moisture coupled with highest maximum temperature, notably over 33°C during the pod development and maturity phases, have been found to reduce yield through reducing pollen viability. During kharif season, Minimum temperature exerts positive influence as it will not fall below 20^{o}C. It is consistent with the findings of Padmalatha et al. 2006 [9] that there is a negative relation between yield and maximum temperature.

In yield variability/risk functions of both quadratic and Cobb-Douglas models, the influences of low temperatures and rainfall were found to be detrimental and significant, suggesting that these variables are decreasing the variability of groundnut yield. The maximum temperature is found to have a positive influence, suggesting that it is variance increasing in terms of groundnut yield. Time trend also found to be positive and significantly ($p<0.01$) related to yield variability indicating that the variability in groundnut yield is increasing over the time (years). On the contrary, in quadratic model, squared rainfall ($p<0.01$) and maximum temperature ($p<0.01$) had positive and significant influences on yield variability implying that there is a threshold, beyond which these factors increase the yield variability in groundnut.

Table 1. Estimates of the impact of climatic variables on mean yield and yield variability of Kharif-groundnut using the Just and Pope quadratic and Cobb-Douglas models

S. No	Variables	Quadratic model		Cobb-Douglas model	
		Mean Yield	Yield Variability	Mean Yield	Yield Variability
		Coefficient	Coefficient	Coefficient	Coefficient
1	Rainfall	0.0049**	-0.0040*	0.0321*	-0.0035*
2	Max.Temp	-0.68*	0.0142*	-0.0018**	0.0017*
3	Min.Temp	1.68**	-0.0191**	0.0042*	-0.0026*
4	Time trend	0.08**	0.1211**	0.07**	0.0668**
5	$Rain^2$	-0.0048**	0.0001**	-0.5735*	-0.1017*
6	$Max.Temp^2$	-0.0267*	0.0998**	-0.2948**	0.6823*
7	$Min.Temp^2$	0.0487	-0.0498	0.388	0.4056
8	Rain*Max.Temp	-0.0006	0.0013**	-0.3051	0.6615
9	Rain* Min.Temp	0.0017	-0.0019	0.3976	-0.4568
10	Max.Temp * Min.Temp	0.0703	-0.0032	0.0238	-0.3359
11	D2-West Godavari	0.3366*	---	0.0808	---
12	D3-Prakasam	0.3072	---	0.3245*	---
13	D4-Ananthapuramu	0.4592*	---	0.2799*	---
14	D5-Chittoor	0.2943*	---	0.5106**	---
	Constant	65.89	-54.98	-33.65	974.4516
	Model statistics				
	Observations	75	75	75	75
	F test (14, 60)	17.06**	1.43**	10.07**	2.86**
	Prob > F	0.0000	0.00598	0.0000	0.0024
	R^2 Adj	0.7524		0.6319	

** Significance at 5% confidence levels, ** Significance at 1% confidence levels*

3.2 Determinants of Mean Yield and Its Variability of Groundnut during Rabi Season

From Table 2, both in quadratic and Cobb-Douglas models, rainfall, maximum and minimum temperatures exerted significant positive influence on the mean yield of groundnut. Well distributed rainfall has positive significant effect on groundnut yield and as the maximum temperature will not be above 35°C during rabi season, it also showed positive (significant) effect on mean yield. As long as the minimum temperatures are above 18°C it will have positive effect on the mean yield of groundnut.

In quadratic model, the quadratic terms for rainfall and minimum temperatures (at significant level) showed negative effect on mean yield. In yield variability/risk functions of both quadratic and cobb-Douglas models, the influences of rainfall, maximum and minimum temperatures were found to be negative and significant, implying that these factors are variance decreasing in terms of groundnut yield. Time trend was also found to be positive and significantly related to yield variability indicating that the variability in groundnut yield is increasing over the time (years).

3.3 Elasticities (Marginal Effects) of Climatic Variables

From the Table 3 we can see that, during Kharif season both in Quadratic and Cobb-Douglas models, rainfall (0.5230~0.6080) and minimum temperature (0.0801~0.1240) are positively related and maximum temperature (0.0241~0.0790) is negatively associated with the mean yield of groundnut. It indicated that one per cent increase in rainfall will increase the average yield by 0.5230~0.6080 per cent, one per cent increase in minimum temperature will increase the average yield by 0.0801~0.1240 percent. One percent increase in maximum temperature decreases the mean yield by 0.0241~0.0790 per cent. These findings are in accordance with the results of Singh and Jyoti, 2021 [10], they indicated that maximum and minimum temperatures had negative and positive impact on groundnut yield.

Table 2. Estimates of the impact of climatic variables on mean yield and yield variability of Rabi-groundnut using the Just and Pope quadratic and Cobb-Douglas models

S. No	Variables	Quadratic model		Cobb-Douglas model	
		Mean Yield	Yield Variability	Mean Yield	Yield Variability
		Coefficient	Coefficient	Coefficient	Coefficient
1	Rainfall	0.048**	-0.004**	0.0321*	-0.0035*
2	Max.Temp	0.69*	-0.001*	0.0018*	-0.0017*
3	Min.Temp	0.2**	-0.002*	0.0042**	-0.0026*
4	Time trend	0.035*	0.1477*	0.0134*	0.0963**
5	$Rain^2$	-0.0061	0.0006	-0.0206	0.0614
6	$Max.Temp^2$	0.026	-0.2003	1.276	-0.9083
7	$Min.Temp^2$	-0.0769**	0.0859**	-1.1199*	0.9666*
8	Rain*Max.Temp	-0.001	0.0111	-0.4364	0.3358
9	Rain* Min.Temp	0.0007*	-0.0062*	0.0055	-0.1432*
10	Max.Temp * Min.Temp	-0.0172	0.2922	-1.4265**	0.2403
11	D2-West Godavari	1.3554**	---	0.5794	---
12	D3-Prakasam	1.6167**	---	0.6548**	---
13	D4-Ananthapuramu	-0.2164**	---	-0.1579**	---
14	D5-Chittoor	1.0003**	---	0.4133**	---
	Constant	-33.65	-406.92	-109.33	-1898.35
	Model statistics				
	Observations	75	75	75	75
	F test (14, 60)	12.52**	3.95**	17.70**	1.44**
	Prob > F	0.0000	0.0001	0.0000	0.0001
	R^2 Adj	0.6854		0.7596	

** Significance at 5% confidence levels, ** Significance at 1% confidence levels*

Table 3. Elasticities of climatic variables

Yield function	Climate variables	Quadratic model	Cobb-Douglas model
	Kharif season		
Mean yield	Rainfall	0.6080	0.5230
	Maximum Temperature	-0.0241	-0.0790
	Minimum Temperature	0.0801	0.1240
Yield variability	Rainfall	-0.4963	-0.4210
	Maximum Temperature	0.3938	0.4902
	Minimum Temperature	-0.3980	-0.4900
	Rabi season		
Mean yield	Rainfall	0.6422	0.6800
	Maximum Temperature	0.0551	0.0540
	Minimum Temperature	0.0254	0.0230
Yield variability	Rainfall	-0.0589	-0.0520
	Maximum Temperature	-0.0138	-0.0120
	Minimum Temperature	-0.0157	-0.0167

The results further indicated that rainfall and minimum temperature decreases yield variability by 0.4210~0.4963 and 0.3980~0.4900 while maximum temperature increases yield variability by 0.3938~0.4902. hence, rainfall and minimum temperature are risk-shrinking factors and maximum temperature is risk enhancing factor.

In rabi season, both in Quadratic and Cobb-Douglas models, rainfall, maximum and minimum temperatures are positively related to the average groundnut yield. This means that one percent increase in rainfall, maximum and minimum temperatures increase the average yield by 0.6422~0.6800; 0.0540~0.0551 and 0.0230~0.0254 respectively. Hence these factors reduce the yield variability by 0.0520~0.0589; 0.0120~0.0138 and 0.0157~0.0167 respectively.

These results indicated that both in Kharif and Rabi season rainfall and minimum temperatures are yield enhancing and risk shrinking factors. Maximum temperature is yield decreasing and risk enhancing factor in Kharif season and yield enhancing and risk shrinking factor in Rabi season.

4. CONCLUSION AND SUGGESTIONS

The results showed that during Kharif season, rainfall and minimum temperature are yield increasing factors and risk shrinking factors and maximum temperature is yield decreasing and risk enhancing factor. During Rabi season all the three climatic factors are yield increasing and risk shrinking factors. Time trend is positive and significant in influencing both mean yield and yield variability. The empirical finding demonstrated that the impact of technological change on the groundnut yield was positive therefore the yield would be increased with the adoption of advanced technologies in the cultivation.

During Kharif season, Rainfall (0.5230~0.6080) and minimum temperature (0.0801~0.1240) are positively related while maximum temperature (0.0241~0.0790) is negatively related to the mean yield of groundnut. This indicates that with one per cent increase in rainfall and minimum temperature decreases yield variability by 0.4210~0.4963 and 0.3980~0.4900 per cent respectively and one per cent increase in maximum temperature increases yield variability by 0.3938~0.4902 per cent. During Rabi season, one percent increase in rainfall, maximum and minimum temperatures increase the average yield by 0.6422~0.6800; 0.0540~0.0551 and 0.0230~0.0254 per cent and reduce the yield variability by 0.0520~0.0589; 0.0120~0.0138 and 0.0157~0.0167 per cent.

The empirical findings from the study demonstrated that the impact of technological change on the groundnut yield was positive therefore the yield would be increased with the adoption of advanced technologies in the cultivation under changing climatic conditions. Hence, farmers should undertake adaptation and mitigation strategies like adjusting planting dates, crop insurance to combat the adverse impact of climate change. Government should provide higher input subsidies to the farmers who practice Climate Resilient Agricultural (CRA) technologies and it should focus on providing farmers the real time access to accurate data related to weather conditions (through collaboration with IBM, the weather company), so that they will incorporate this in their decision-making process. Krishi Vignan Kendra's (KVKs) should arrange regular training sessions to the farmers to increase their understanding of climate change thereby, they will then be well-positioned to utilise various adaptation techniques to lessen the negative effects of climate change on production. Agricultural universities should arrange for extensive data collection and field trials to assess the impact of prevailing climate conditions in different agro-climatic zones that can help in designing future CRA technologies.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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