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Impact of Climate Variability on Crop Production in Marathwada Region of Maharashtra

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Abstract: This study has been undertaken to examine the impact of climate variables on agricultural production in Marathwada region of Maharashtra, one of the major agrarian state which has adversely affected agriculture and nearly 82% area of state which fall under rainfed sector, is under severe stress. Nearly 52% of state area is drought prone with districts having a frequent unequal distribution of rainfall every 5 years and severe drought conditions for once in every decade. Out of 36 districts in Maharashtra, 21 are facing drought according to simulation studies. Variations in climatic variables affect the performance of crops and induce shifts in cropping pattern. The present paper aims at understanding climatic variability in Marathwada region of Maharashtra. The cropping pattern of Maharashtra has shifted towards pulses and cash crops like cotton from the earlier cereal-centric system. Cotton and soybean in the Marathwada shows high instability in yield. Impact of climatic variables on crops like cotton, sorghum, soybean, and red gram has also been estimated and we found that the variables like rainfall and square of rainfall have significant impact on yield of respective crops. On the other hand, minimum temperature has significant impact on cotton and sorghum yields and maximum temperature has significant impact on cotton, and red gram yield.

Introduction

Climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events. Variability can be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forces (external variability). The accelerating pace of climate change is likely to affect the agricultural production in general and food security in particular. The biggest challenge at this point would be to attain a balance between the environmental needs and development goals. Agriculture is the enterprise that is directly affected by climatic variables. With the increasing population, agriculture is perennially confronted with the task of producing more food. More and more resources are pumped in to meet this demand. The available evidence from various climate change impact studies suggests that the developing countries are likely to be more adversely affected than the developed countries due to their typical geographical location and large dependence on climate-sensitive sectors like agriculture. Higher temperature eventually reduces yields of desirable crops while encouraging weed and pest proliferation. Changes in precipitation patterns increase the likelihood of short-run crop failures and long-run production declines. India, a sub-tropical country is highly sensitive to climate change and its variability. The main reason for its high sensitivity is the variability in rainfall and temperature. About 80 % of the total rainfall in India occurs during the four months from June to September as a result of the south-west monsoon. Agriculture contributes nearly 16 % to total Gross Domestic product, employing 57 % of the population and contributing 10 % of annual exports from the country. But compared to other sectors, Indian agriculture is more vulnerable to climate change, variability and adverse impacts are severe for India because of their heavy dependence on agriculture and lack of financial resources for mitigation to climate change and its variability.

Among the agro-ecological zones in India, semi-arid zone has a prominent place in the economy, contributing about 42 % of total food grain production, supporting 60 % of livestock population and employing nearly 37 % of marginal farmers through agricultural activities. This zone comprises parts of Maharashtra, Andhra Pradesh, Karnataka, Tamil Nadu, Deccan plateau and parts of Gujarat with the cultivation of major crops like Rice, Wheat, Sugarcane, Pulses, Sorghum, and Red gram. Despite its larger area under vegetation with 62 % of cropped area and 55% of net sown area, this zone is susceptible to famine, water shortages, land degradation and

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constitutes largest proportion (34%) of the drought prone area of the country (112 of 329 million ha).

Maharashtra is one of the major agrarian states having characteristic like uncertain, insufficient and irregular rainfall pattern. Maharashtra has adversely affected agriculture and nearly 82% area of state fall under rainfed sector is under severe stress and 52% of state area is drought prone with districts having a frequent unequal distribution of rainfall for every 5 years and severe drought conditions for once in every 8-9 years. Out of 36 districts in Maharashtra, 21 are facing drought according to simulation studies, if proper mitigation measures are not taken, the agricultural productivity can decline from 5% to 18% in the state. Central Research Institute for Dryland Agriculture identified among 21districts in state, Marathwada and Vidarbha face very high risk to climate change with deficit rainfall range from 20 to 40% (Ashwini, 2015), and over 90% of the cultivated area comes under dryland farming which is highly vulnerable to fluctuations in climatic variables (Radhakrishnan Committee, 2007). Considered as 'double exposure' area, the region faces simultaneous challenges of globalization and climate change to the agriculture sector. Frequent occurrences of drought have led to crop failures that have pushed farmers into debt and resulted for the reasons for farmer's suicides (>1000) due to their inability to meet the rising cost of cultivation (Tata Institute of Social Sciences, 2015).

Study Area

Maharashtra, Andhra Pradesh, Karnataka, Tamil Nadu, Deccan plateau and parts of Gujarat with the cultivation of major crops like Rice, Wheat, Sugarcane, Pulses, Sorghum, and Red gram. Despite its larger area under vegetation with 62 % of cropped area and 55% of net sown area, this zone is susceptible with famine, water shortages land degradation and had largest proportion of drought prone area in the country. Among five regions of Maharashtra, Marathwada (south-central region) was chosen for the study purposively as it is most drought prone areas of the state with average rainfall of less than 600 mm and characterized by extreme aridity, hot climate, and acute deficiency in water availability. A warming trend has been established over Maharashtra for both maximum and minimum temperatures over the past 100 years.

The region has maximum temperature of 41° C, minimum Temperature of 21°C and rainfall varies from 700 to 900 mm. Soil color ranges from black to red, Type-1) Vertisols 2) Entisols & 3) Inceptisols. Sorghum is a Predominant crop occupying 33% of Gross Cropped Area followed by cotton (22.55%), oilseeds (5.17%) and pulses (7.63%). Kharif sorghum/bajra followed by gram, pulses like red gram, mung, urad, gram & lentils and oilseeds crops are Groundnut, Sesamum, Safflower & Niger. Sugarcane & Summer Crops are taken on availability of irrigation.

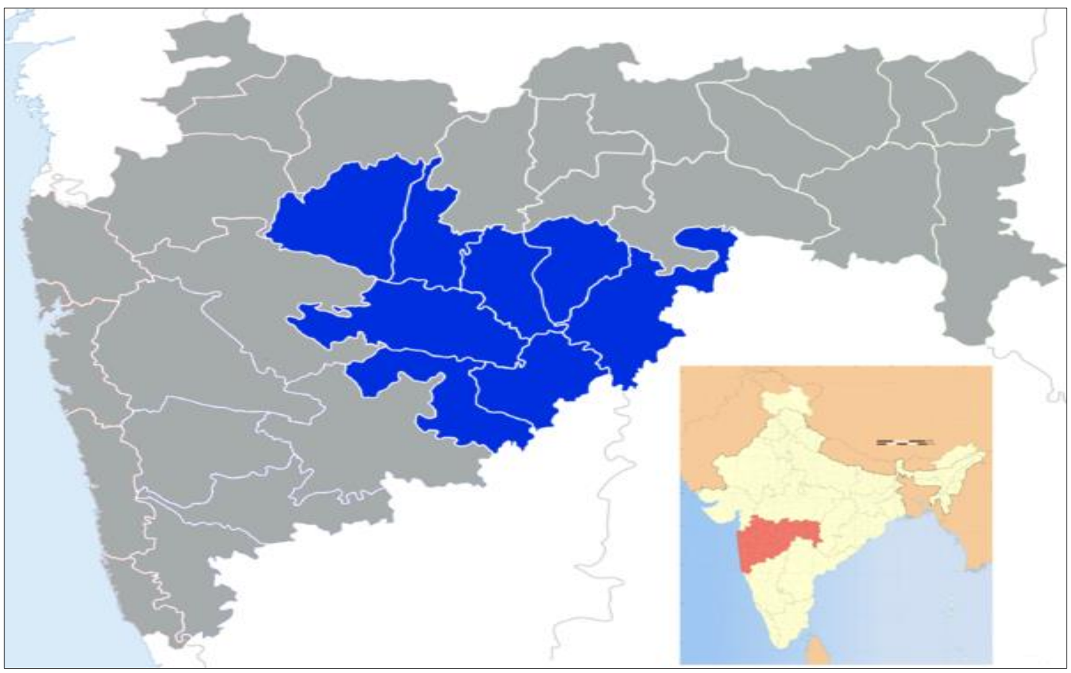

Figure 1. Map of Maharashtra state

Data and Methodology

Data Sources

District-wise data on area, production, yield, and farm harvest prices of sorghum, soybean, cotton, red gram was collected from Directorate of Economics and Statistics (DES), Government of India (GOI). Climatic variables like daily rainfall, temperature were collected from (Indian Metrological Organization) IMD. Although there are certain limitations of secondary data based assessments such as authenticity of data, data inconsistency in some cases and data gaps, still the analysis provides useful means of assessment at the macro level.

Methodology

The panel regression with district fixed effect was used with both OLS (Ordinary Least Square) and PCSE (Panel Corrected Standard Error) models for cotton, sorghum, red gram and soybean. PCSE assumes that no correlation is allowed within the panel, the only correlation among observation at the same period and in different panels. If PCSE allows one specific form of within panel correlation, then model is called Praise-Winston regression assuming an AR1 scheme. The results of both methods are estimated and presented in the table but we discuss the result only for PCSE estimates because it has better R squared value and is less restrictive.

Panel Fixed/Random Effect Model

To see the impact of climatic variability on crop production, we have used random effect model. In order to control unobserved district level heterogeneity that may be correlated with the explanatory variables, we estimate panel data models with fixed effects. Here we consider major rainfed crops in Marathwada region.

$$Y_{it} = D_i + \emptyset t + \beta_1 T_{it}\ max + \beta_2 T_{it}\ min + \beta_3 P_{it} + \beta_4 P_{it}^2 + \varepsilon_{it}$$

where

'i' is district and 't' is time.

Y_{it} Is yield of major crops;

D_i Represents district fixed effects which captures all district specific and time invariant factors;

T_{it} max Is mean maximum temperature in district i in year t measured in degree Celsius (℃);

T_it min Is mean minimum temperature in district i in year t measured in degree Celsius (℃);

P_itIs annual rainfall in district i in year t measured in millimeter (mm per annum);

∅t Is time fixed effects controlling changes in crop yields due to changes in technology, infrastructure, human capital etc.

ε_it is the error term;

β_(1,) β_(2,) β_(3,) β_(4,) are unknown parameters to be estimated;

Results

The long-term climate variability on crop production in Marathwada region of Maharashtra have been analyzed by using Panel unit root test, The test outcomes illustrated in table 1, null hypothesis of the unit root is rejected for a yield of sorghum, cotton, red gram, and soybean, precipitation, and temperature at the 1% level of significance. Therefore every variable is stationary and can be analyzed for different crops have been shown.

Table 1. Panel unit root test statistics

Test	T-bar	p value
Cotton	-3.3259***	<0.0001
Sorghum	-4.900***	<0.0001
Soybean	-4.0809***	<0.0001
Red gram	-4.6416***	<0.0001
Rainfall	-5.7992***	<0.0001
Min temp	-3.4514***	<0.0001
Max temp	-3.5597***	<0.0001

*Note- *** indicates 1 % significance level*

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Regression Results

Estimated parameters from panel regression model with fixed effects for cotton

We examine the PCSE regression estimates to explain the impact of climatic variables on cotton yield illustrated in table 2. The PCSE regression coefficients for rainfall indicates, it has positive relationship with cotton yield, which is significant at 5 % level, while the square term of rainfall is statistically significant at 1% level and has a negative sign. The minimum temperature is statistically significant at 10% level and has a negative sign.

We utilized the time drift variable in this review to catch technology change, inputs administration and infrastructural improvement projects, agriculturist's adjustment practices, and CO2 preparation impacts (Saravanakumar, 2015). The outcomes demonstrate that the coefficient gauge on time pattern is sure and measurably huge at 1% level.

Table 2. Panel Regression Model with Fixed Effects for cotton

Variables	Fixed effect	p value	PCSE	p value
Trend	10.375***	0.000	10.0083	0.000
Rainfall	0.1075	0.029	0.14029	0.014
Rainfall square	-0.0000293	0.045	-0.000036***	0.025
Minimum temperature	-0.080859	0.836	-0.393392	0.081
Maximum temperature	-23.5131***	0.000	-20.1391***	0.001
Constant	767.513***	0.000	655.46	0.002
Observation	200		200	
R-square	0.4666		0.5005	

*Note: *, **, & *** indicates significance at 10%, 5%, 1% % level, respectively*

Estimated parameters from panel regression model with fixed effects for sorghum

The PCSE shows that rainfall has a positive impact on the yield of Sorghum, which is statistically significant at 1% level of significance. Square of rainfall (once rainfall crosses a threshold level) has a negative influence on yield of Sorghum (Kumar et al., 2004) and

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statistically significant at 5%, while the minimum of temperature will lead to decrease in yield of Sorghum, shows statistically significant at 5% level of significance. Temperature and its square term are jointly significant at 10% significance level. The outcome is represented in table 3.

Table 3. Panel regression model with fixed effects for sorghum crops

Variables	Fixed effect	p value	PCSES	p value
Trend	-2.0753	0.554	-6.608	0.392
Rainfall	0.56869	0.011	0.0643	0.019
Rainfall square	-0.00015	0.023	-0.0001	0.054
Minimum temperature	-1.0349	0.557	-2.156	0.089
Maximum temperature	-28.0248	0.277	-35.400	0.255
Constant	1757.98	0.053	2011.14	0.061
Observation	200		200	
R-square	0.0482		0.528	

Estimated parameters from panel regression model with fixed effects for red gram

Red gram yield has increased significantly with increase in rainfall, rainfall square and maximum temperature, which shows significant at 1 % level of significance. The PCSE results shown in the table 4.

Table 4. Panel regression model with fixed effects for red gram

Variables	Fixed effect	p value	PCSES	p value
Trend	22.577***	0.000	21.037***	0.000
Rainfall	0.5554***	0.000	0.6181***	0.001
Rainfall square	-0.00015***	0.001	-0.0001547	0.002
Minimum temperature	-1.581	0.185	-0.7225	0.406
Maximum temperature	-53.918	0.002	-39.1823	0.033
Constant	1747.68	0.005	1214.123	0.055
Observation	200		200	
R-square	0.3548		0.4605	

*Note: *, **, & *** indicates significance at 10%, 5%, 1% % level, respectively*

Estimated parameters from panel regression model with fixed effects for soybean

Soybean yield has increased in association increase in rainfall, shows statistically significant at 1%, rainfall square crosses it's limit shows negative impact on yield and statistically significant at 2%, while the minimum of temperature lead to decrease in the yield and shows statistically significant at 5% level of significance. Temperature and its square term are negatively related to yield but not statistically significance level. Values are represented in table 5.

Table 5. Panel regression model with fixed effects for soybean

Variables	Fixed effect	p value	PCSES	p value
Trend	22.2049***	0.000	25.43069	0.020
Rainfall	0.6922	0.018	0.8486	0.021
Rainfall square	-0.000188	0.030	-0.0002137	0.025
Minimum temperature	0.4496	0.847	-1.0800	0.645
Maximum temperature	-51.916	0.128	-58.080	0.138
Constant	2029.026	0.090	2091.493	0.117
Observation	200		200	
R-square	0.1354		0.1604	

*Note: *, **, & *** indicates significance at 10%, 5%, 1% % level, respectively*

Conclusion

We examined the impact of climatic variables on yield of crops namely cotton, sorghum, soybean, red gram. Variables like trend, rainfall, rainfall square, minimum temperature and maximum temperature were used in the model based on theoretical expectation and existing literature.The panel regression with district fixed effect for OLS (Ordinary Least Square) and PCSE (Panel Corrected Standard Error) models were employed for all the crops. But here discussion is restricted to only for PCSE estimates because it has better R-square; Also, PCSE assumes that no correlation is allowed with in panel, only correlation among observation at same period and in different panels, which is a distinct advantage over OLS.

PCSE regression estimates for cotton shows rainfall and trend is positively related with cotton yield at 1% significance level. While, after the threshold limit of rainfall which is indicated by rainfall square (Saravanakumar, 2015) yield is negatively related and is statistically significant at 1 %. Impact of climatic variable on sorghum crop yield shows positive relation with rainfall and negative relation with rainfall square at 1% and 2% of significance respectively. Impacts of climatic variables on red gram and soybean shows positive relation with trend and rainfall which are significant at 1%, rainfall square were negatively related and significant at 1%. Maximum temperature was significant only for red gram and having negative sign. The results clearly indicate the importance of rainfall in determining yield of the crops. But, it is interesting to note that, rainfall beyond a threshold is as disastrous as shortage of rainfall which is indicated by negative and significant coefficient for quadratic term for rainfall.

Policy Implications

Based on the research, the following implications are drawn

- As the cereal production is diminishing and non-cereal productionis expanding, it willaffect the sustenance of food security of the country. The appropriate strategies to sustain the cereal crops in light of climate change are very much necessary. Demand driven research backup is also needed in this direction.
- Efficient weather forecasting catering to location specific needs of the farmer should be put in place. Agriculture extension system should assist farmers in having scientific crop plans and in case of droughts with contingent plans. .

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