Advances in Research

21(12): 41-45, 2020; Article no.AIR.62115
ISSN: 2348-0394, NLM ID: 101666096

Effect of Climate Change on Maize Productivity: Panel Data Analysis

Parthasarathi Gurusamy[1*] and Balasubramanian Rudrasamy[2]

[1]Insitute of Agriculture, Kumulur, Tiruchirappalli, Tamil Nadu, India.
[2]Agricultural College and Research Institute, Vazhavachanur, Tamil Nadu, India.

Authors' contributions

This work was carried out in collaboration between both authors. Author PG designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Author BR managed the analyses of the study. Author PG managed the literature searches. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AIR/2020/v21i1230280
Editor(s):
(1) Prof. Pradip K. Bhowmik, University of Nevada, USA.
Reviewers:
(1) Igbokwe, Gabriel Ejike, Nnamdi Azikiwe University, Nigeria.
(2) Susan Eboh, University of Port Harcourt, Nigeria.
Complete Peer review History: http://www.sdiarticle4.com/review-history/62115

Original Research Article

Received 24 August 2020
Accepted 27 October 2020
Published 31 December 2020

ABSTRACT

Aim: The maize is widely grown all parts of the world and it is consumed by all people. This paper studies the impact of climate variability on yield of maize crop in Tamil Nadu using Panel regression analysis.
Study Design: Rainfall (max and min), Temperature (max and min) and yield details were collected from the Indian Meteorological Department and crop production reports respectively used for analysis.
Place and Duration: Tamil Nadu, India.
Methodology: Panel data model was used to estimate crop production functions.
Results and Conclusion: The study focused on the impact of climate variability on yield of maize crop in Tamil Nadu using Panel regression analysis. The high rainfall leads to The effect of NEM rainfall on maize yield is dependent on the level of NEM temperature and vice-versa. This is probably because of the fact that in most of the districts in Tamil Nadu, maize is grown as a rainfed crop in north-east monsoon season with lower temperature and hence increase in temperature together with good amount of rainfall would lead to higher yield of maize.

**Corresponding author: E-mail: sarathykillikulam@gmail.com;*

Keywords: Climate change; maize; panel data.

1. INTRODUCTION

Maize is one of the most versatile emerging crops having wider adaptability under varied agro climatic conditions. Maize is also known as the queen of cereals because it has the highest genetic yield potential among the cereals. In India maize is the third most important crop after rice and wheat. In addition to staple food to human being and quality feed for animals, maize serves as a basic raw material for many industries. In developing countries like India, climate change could represent an additional stress on ecological and socioeconomic systems. The Intergovernmental Panel on Climate Change has projected that temperature increase by the end of this century is likely to be in the range 1.8 to 4.0 degree Celsius [1]. Climate change is likely to have larger impacts on predominantly rainfed crops such as maize, coarse cereals and pulses that are grown in marginal production environment. The mean annual temperature over the past four decades from 1971 to 2010 was 31.44°C with a standard deviation of 3.44°C. It has been estimated that in Tamil Nadu, by the end of the 21st century, a 10 per cent decline in rice productivity and a 9 percent decline in sorghum were projected, relative to the average yield during the base period 1971-2009 [2]. The present study has been taken up with the overall objective of analyzing economic impact of climate change on maize crop in Tamil Nadu. .

2. MATERIALS AND METHODS

2.1 The Data

Rainfall and temperature were collected from the year 1971 to 2010 for all the districts of Tamil Nadu from Indian Meteorological Department (IMD). The IMD weather stations are not present in all the districts of Tamil Nadu. For the sample districts not having the weather station, we took the averages of climatic data for surrounding districts. The yield data on maize yield was collected crop production reports of Tamil Nadu. Using the districts as panels, panel dataset was constructed using the district-wise time series data available over the period 1971 to 2010.

2.2 Panel Data Model

Gupta et al. studied the impact of climate change on major food grain yields especially in rice, sorghum and pearl millet in India and find significant impacts of climate change (temperature and precipitation) on Indian agriculture [3]. To understand the impact of climate change on maize yield, the panel data model was used to estimate crop production functions. In the present study we have a balanced panel, as each district in the sample has 40 years of observations. The study employed the following model with districts fixed effects and estimated using STATA software:

$$Y_{it} = \alpha + \theta_i + \beta_1 SWMMAXTEMP_{it} + \beta_2 SWMMAXTEMP^2_{it} + \beta_3 SWMRF_{it} + \beta_4 SWMRF^2_{it} + \beta_5 SWMRAINMAXT_{it} + \beta_6 NEMMAXTEMP_{it} + \beta_7 NEMMAXTEMP^2_{it} + \beta_8 NEMRF_{it} + \beta_9 NEMRF^2_{it} + \beta_{10} NEMRAINMAXT_{it} + U_{it}$$

Where,

Y = Yield of maize crops in district i in year t
SWMMAXTEMP = South West Monsoon Maximum Temperature in degree Celsius
SWMMAXTEMP2 = Squared South West Monsoon Maximum Temperature in degree Celsius
SWMRF = South West Monsoon Rainfall in Millimeter
SWMRF2 = Squared South West Monsoon Rainfall in Millimeter
SWMRAINMAXT = Interaction term (SWM Rain* SWM Maximum Temperature)
NEMMAXTEMP = North East Monsoon Maximum Temperature in degree Celsius
NEMMAXTEMP2 = Squared North East Monsoon Maximum Temperature in degree Celsius
NEMRF = North East Monsoon Rainfall in Millimeter
NEMRF2 = Squared North East Monsoon Rainfall in Millimeter
NEMRAINMAXT = Interaction term (NEM Rain* NEM Maximum Temperature)

U_{it}= Error term

α and β_1 to β_{10} are unknown parameters to be estimated

θ_i= fixed effects for districts
i= i^{th} cross-sectional unit {i = 1, 2, 3, 4 (districts)} and
t = t^{th} time period {t = 1, 2, . . . , 39 (years)}

2.3 Hausman Specification Test for Fixed vs. Random effects model

To decide between a random effects and fixed effects model, the Hausman specification test was performed. Gupta *et al.* studied the impact of climate change on major food grain yields especially in rice, sorghum and pearl millet in India with district and year fixed effects, and district fixed effects and district-by-year fixed effects [3]. The Hausman test is designed to detect violation of the random effects modelling assumption that the explanatory variables are orthogonal to the unit effects. If there is no correlation between the independent variable(s) and the unit effects, then estimates of β in the fixed effects model (β_{FE}) should be similar to estimates of β in the random effects model (β_{RE}).

The Hausman test statistic (H) is a measure of the difference between the two estimates:

$$H = (\beta_{RE} – \beta_{FE})[Var(\beta_{FE}) - Var(\beta_{RE})]^{-1}(\beta_{RE} – \beta_{FE})$$

Under the null hypothesis of orthogonality, H is distributed chi-square with degrees of freedom equal to the number of regressors in the model. A finding that $p < 0.05$ is taken as evidence that, at conventional levels of significance, the two models are different enough to reject the null hypothesis, and hence to reject the random effects model in favour of the fixed effects model.If the Hausman test does not indicate a significant difference ($p > 0.05$), however, it does not necessarily follow that the random effects estimator is safely" free from bias, and therefore to be preferred over the fixed effects estimator.

3. RESULTS AND DISCUSSION

3.1 Results of Panel Data Model

The impact of climate variables on maize production was also estimated using district level panel data, with the districts serving as panels. Descriptive statistics of the variables used in the panel data model are presented below followed by the results of fixed effects panel data regression model.

3.2 Descriptive Statistics

The summary statistics of the climate and crop yield variables used in the analysis are presented in Table 1. The average productivity of both maize was about 1800 kg/ha and the standard deviation of maize yield was 1065 kg/ha. The mean level of annual rainfall over the 40 years was 965.56 mm per year with a standard deviation of 343 mm. The maximum temperature was 35.26°C and the minimum temperature is 30.53°C.World Bank (notes that frequency of heavy precipitation events has increased over most land areas and widespread changes in extreme temperatures has been recorded over the last 50 years [4].

Table 1. Descriptive statistics

S. No	Variable	Unit	Mean	Standard Deviation	Maximum	Minimum
1.	Maize	kg/ha	1803	1065	6043	404
2.	Rainfall	Mm	965.56	343.28	1927.30	281.5
3.	Temperature	Celsius	33.04	1.07	35.26	30.53

Table 2. Hausmanspecification test results

Variables	Fixed Effects	Random Effects	Difference
SWM Max Temp	1318.69	752.06	566.62
SWM Max Temp^2	-18.64	-11.00	-7.63
S Rain	17.76	-3.46	21.23
S Rain^2	-0.0003	0.0001	-0.0005
SRAINMAX	-0.52	0.08	-0.60
NEM Max Temp	-1883.05	-107.51	-1775.53
NEM Max Temp^2	33.24	-0.38	33.63
N Rain	-18.17	-7.25	-10.92
N Rain^2	-0.0008	3.23E-05	-0.0008
NRAINMAX	0.65	0.24	0.40

Prob>Chi = 0.00

3.3 Fixed Effects versus Random Effects Model: Hausman Specification Test

The Hausman specification test was performed to select appropriate model.

The Hausman test is designed to detect violation of the random effects modeling assumption that the explanatory variables are orthogonal to the unit effects. If the Chi-square value is significant (<0.05) then, reject the null hypothesis, and hence to reject the random effects model. Based on the results of Hausman specification test, the fixed effects model has been employed for the study. The results of Hausman specification test are presented in Table 2.

3.4 Results of Panel Regression Model with Fixed Effects for Maize

Table 3 presents the results of panel regression with districts fixed effects for maize.

Adamgbe and Ujohstudied the variations in climatic parameters and crop yield in Nigeria. The result showed that the seven climatic parameters (onset and end of the rains, duration of rainy season, rain days, annual amount, temperature and sunshine) jointly accounted for 78% of variance in yam yield, about 71% of variance in cassava and sorghum yields, 60% of variance in soya beans yield, 49% of variance in maize yield, 48% of variance in rice yield and 36% of variance in groundnut [5]. The sign of the regression coefficient of SWM maximum temperature was positive and its quadratic term was found to be negative at five per cent level of significance, which means that an increase in south west monsoon temperature will increase the yield of maize up to a threshold level beyond which the yield will decrease. All the climatic variables during north east monsoon were significant at one percent level except the NEM rainfall quadratic term (ten per cent). The partial regression coefficient of NEM rainfall and its quadratic term were found to be negative, which means that the increasing rainfall during the season will decrease the maize yield.

The coefficient of the NEM maximum temperature was negative and it was positive for its quadratic term, which indicates that the maize yield has a U-shaped response function with NEM maximum temperature. Higher temperature would mean lower yield rates though at a decreasing rate. In case of the interaction terms, the north east monsoon shows positive sign with one per cent significance level and it was negative in south west monsoon with five per cent significance level. The effect of NEM rainfall on maize yield is dependent on the level of NEM temperature and vice-versa. Sultan *et al.* assessed the climate change effects on sorghum and millet yields and found that, the major effect of climate change on the yields of millet and sorghum in West Africa was yield losses induced by higher temperature leading to increased potential evapotranspiration, crop maintenance respiration and a reduction of the crop-cycle length [6]. This is probably because of the fact that in most of the districts in Tamil Nadu, maize is grown as a rainfed crop in north-east monsoon season with lower temperature and hence increase in temperature together with good amount of rainfall would lead to higher yield of maize.

Table 3. Estimated parameters from panel regression model with fixed effects for maize

Dependent variable: Maize yield (Kg/ha)

Yield	Coefficient	Standard error
S Max temp	1318.691**	574.319
S Max temp square	-18.640**	9.355
S Rain	17.767**	9.242
S Rain square	-0.0003	0.0003
S Rain *S Maxtemp	-0.523**	0.264
N Max temp	-1883.05***	402.17
N Max temp square	33.246***	7.449
N Rain	-18.174***	4.543
N Rain square	-0.00084*	0.00047
N Rain * N Maxtemp	0.658***	0.149
Constant	4325.38	6725.07

****, **, * indicates significance at one, five and ten per cent level respectively*
Number of observations = 429
Within R^2=0.10; Between R^2=0.17; Overall R^2 = 0.0003

4. CONCLUSION

The study focused on the impact of climate change on yield of maize crop in Tamil Nadu using Panel regression analysis. Based on the results of Hausman specification test, the fixed effects model has been employed for the study. The effect of NEM rainfall on maize yield is dependent on the level of NEM temperature and vice-versa. The regression coefficient of SWM maximum temperature was positive and its quadratic term was found to be negative at five per cent level of significance, which means that an increase in south west monsoon temperature will increase the yield of maize up to a threshold level beyond which the yield will decrease. This is probably because of the fact that in most of the districts in Tamil Nadu, maize is grown as a rainfed crop in north-east monsoon season with lower temperature and hence increase in temperature together with good amount of rainfall would lead to higher yield of maize. Climatic factors viz., temperature and rainfall were very important in the impact of maize yield. Thus maize yield will increase when the increase in temperature along with the increase in rainfall.

ACKNOWLEDGEMENTS

I thank the Co-author for his immeasurable effort in managing the analysis of the study.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. IPCC (Intergovernmental Panel on Climate Change). "Summary for Policymakers. In: Climate Change, (2007). Impacts, Adaptation and Vulnerability", Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE. (Ed.). Cambridge University Press, Cambridge, UK. 2007;7-22.
2. Saravanakumar. Impact of Climate Change on Yield of Major Food Crops in Tamil Nadu, India, South Asian Network for Development and Environmental Economics(SANDEE). 2015;91-15.
3. Gupta S, Sen P, Srinivasan S. Impact of Climate Change on the Indian Economy: Evidence from Foodgrain Yields, Centre for Development. 2012;218.
4. World Bank, Africa Rainfall and Temperature Evaluation System, World Bank, Washington D.C; 2003.
5. Adamgbe M. Emmanuel, Fanan Ujoh, Variations in Climatic Parameters and Food Crop Yields: Implications on Food Security in Benue State. Confluence Journal of Environmental Studies, Kogi State University, Nigeria. 2012;7:59-67.
6. Sultan B, Roudier P, Quirion P, Alhassane A, Muller B, Dingkhun M, Ciais P, Giumberteau M, Traore S, Baron C. Assessing Climate Change Impacts on Sorghum and Millet Yields in the Sudanian and Sahelian Savannas of West Africa, Environment Research Letters.2013;8:1-9.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/62115