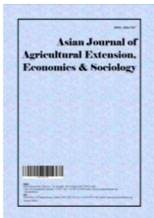

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Effect of Climate Variability on Finger Millet Productivity: Panel Data Analysis

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Authors' contributions

This work was carried out in collaboration among all 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 MSR managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Finger millet 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 finger millet crop in Tamil Nadu using Panel regression analysis. The data on maximum and minimum rainfall, maximum and minimum temperature and yield of finger millet was collected and used for analysis. Panel data model was used to estimate effect of climate variability. The temperature and its square terms shows the significant impact on finger millet yield, it means after the certain level increase in temperature leads to yield loss. The square term of the SWM maximum temperature will increase the yield of finger millet up to a threshold level, beyond which the yield will decrease. Higher temperature during north-east monsoon season would mean lower yield rates. The regression coefficient of interaction term for NEM rainfall and NEM maximum temperature was found to be positive which indicate that the joint effect of rainfall and temperature during the north-east monsoon season on finger millet yield was positive thus contributing for increased productivity. Thus increasing in climatic variables would support the millets up to a certain level and after that it lower the yield of finger millet.

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1. INTRODUCTION

Agriculture plays a crucial role in India's economic development and provides food and livelihood to much of the Indian population. Millets is an important crop, which provides nutrition to the human diet. In developing countries like India, climate variability 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]. The climatic factors like maximum and minimum rainfall and maximum and minimum temperature plays a significant role in crop productivity. Climate variability is likely to have larger impacts on predominantly rainfed crops such as millets, coarse cereals and pulses that are grown in marginal production environment. The cropping pattern in India also has undergone significant changes with a significant shift from the cultivation of food grains to commercial crops. The area under coarse cereals, which is generally cultivated in dry regions, has declined by 13.3 per cent between 1970-71 and 2007-08 [2]. Millets are traditional 'coarse cereals' whose importance is more in terms of their role as a staple crop consumed by the poor. Millets are one of the oldest foods known to humans and possibly the first cereal grain to be used for domestic purposes. Tamil Nadu is one of the States of India where interdependence between economic growth, agriculture and climate vulnerability is most predominant. The livelihoods of most of the rural and low income communities are, to a large extent, based on agriculture, livestock and poultry. For example, more than 50 per cent of the state's population is directly engaged in agriculture and allied activities for their livelihood. However, rainfall in Tamil Nadu is highly erratic with a normal annual average of 914.4 mm which is below as compared to India's annual average of 1187 mm. Due to uncertain climate there exists high variability in agricultural production and farm income. 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 [3]. So it is necessary to study the climate variability of finger millet in Tamil Nadu. The present study has been taken up with the overall objective of analyzing economic impact of climate variability on finger millet crop in Tamil Nadu.

2. MATERIALS AND METHODS

2.1 The Data

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 [4]. Rainfall and temperature data between the years 1971 to 2010 for all the districts of Tamil Nadu was obtained 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. 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

To understand the impact of climate variability on millet 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:

$$Y_{it} = \alpha + \theta_i + \beta_1 a_{it} + \beta_2 b^2_{it} + \beta_3 c_{it} + \beta_4 d^2_{it} + \beta_5 e_{it} + \beta_6 f_{it} + \beta_7 g^2_{it} + \beta_8 h_t + \beta_9 i^2_{it} + \beta_{10} j_{it} + u_{it}$$

Where,

Y	=	Yield of millet crops in district i in year t
a	=	South West Monsoon Maximum Temperature in degree Celsius

b^2	=	Squared South West Monsoon Maximum Temperature in degree Celsius
c	=	South West Monsoon Rainfall in Millimeter
d^2	=	Squared South West Monsoon Rainfall in Millimeter
e	=	Interaction term (SWM Rain* SWM Maximum Temperature)
f	=	North East Monsoon Maximum Temperature in degree Celsius
g^2	=	Squared North East Monsoon Maximum Temperature in degree Celsius
H	=	North East Monsoon Rainfall in Millimeter
i^2	=	Squared North East Monsoon Rainfall in Millimeter
j	=	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. 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_0 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 finger millet 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. 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.

3.2 Descriptive Statistics

The summary statistics of the climate and crop yield variables used in the analysis are presented in Table 1. The average productivity finger millet was about 1800 kg/ha and the standard deviation of finger millet yield was only 512 kg/ha. Ahmad and Haseen studied the performance of India's food grain production and the results revealed that growth rate in the food grains production and productivity has decelerated when India entered in the era of globalization [5]. The mean level of annual rainfall over the 40 years was 965.56 mm per year with a standard deviation of 343 mm. The mean level of annual maximum temperature was 33.03°C with the standard deviation of 1.07°C. World Bank (notes that frequency of heavy precipitation events has increased over most land areas and widespread changes in extreme temperatures have been recorded over the last 50 years [6].

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 Fixed Effects Panel Regression Model for Finger Millet

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

3.5 Estimated Parameters from Panel Regression Model with Fixed Effects for Finger Millet

The data were analyzed and the results were presented in Table 3. Adamgbe and Ujoh studied the variations in climatic parameters and crop yield in Nigeria [7]. 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. In this study, the coefficient of SWM maximum temperature was positive and its quadratic term was found to be negative and they were significant at one and five per cent level, respectively. This indicates that the finger millet yield has an inverted U-shaped response with SWM maximum temperature, which means that an increase in SWM maximum temperature will increase the yield of finger millet up to a threshold level, beyond which the yield will decrease. Gupta et al. studied the impact of climate change on major food grain yields especially in pearl millet and sorghum and the results revealed that pearl millet appears to withstand climate change well (its yield is predicted to go up across regions), the yield of sorghum appears to decline, given the short-run expected climate change. Here also the yield of finger millet appear to decline when there is an increase in temperature. The coefficient values of SWM rainfall and its quadratic term are found to be insignificant. The coefficient of the NEM maximum temperature was negative and it was positive for its quadratic term, which indicates that the finger millet yield has a U-shaped response with NEM maximum temperature. Higher temperature during north-east monsoon season would mean lower yield rates but lower the rate of decrease of yield with temperature. Srivastava et al. assessed the vulnerability of sorghum to climate change on India and revealed that yield loss may be huge for locations where current temperatures are already high and rainfall is low [8]. In this study also the high temperature will negatively affect the millet yield. The regression coefficient of NEM rainfall and its quadratic term were found to be negative and it was significant at ten and one per cent level respectively. The regression coefficient of interaction term for NEM rainfall and NEM

Table 1. Descriptive statistics

S. no	Variable	Unit	Mean	Standard deviation	Maximum	Minimum
1.	Finger millet	kg/ha	1801	512	3189	593
2.	Rainfall	Mm	965.56	343.28	1927.30	281.5
3.	Temperature (max)	Celsius	33.04	1.07	35.26	30.53

Table 2. Results of hausman specification test

Variables	Fixed effects	Random effects	Difference
SWM Max Temp	724.10	748.72	-24.61
SWM Max Temp^2	-10.41	-10.40	-0.009
S Rain	-0.99	0.58	-1.57
S Rain^2	0.0002	3.25E-05	0.00017
SRAINMAX	0.008	-0.02	0.03
NEM Max Temp	-964.25	-918.75	-45.50
NEM Max Temp^2	18.06	17.17	0.89
N Rain	-3.25	-2.75	-0.5
N Rain^2	-0.0006	-0.0005	-0.0001
NRAINMAX	0.13	0.11	0.020
Prob>Chi = 0.001			

Table 3. Results of fixed effects panel regression model for finger millet

Dependent variable: Finger millet yield (Kg/ha)		
Yield	**Coefficient**	**Standard error**
S Max temp	724.103***	256.84
S Max temp square	-10.418***	4.163
S Rain	-0.998	4.120
S Rain square	0.00021	0.00014
S Rain *S Maxtemp	0.0089	0.117
N Max temp	-964.25***	178.510
N Max temp square	18.069***	3.314
N Rain	-3.252*	2.018
N Rain square	-0.0006***	0.0002
N Rain * N Maxtemp	0.137**	0.065
Constant	1735.72	3039.06
Number of observations = 468		
Within R^2=0.11	Between R^2=0.22	Overall R^2 = 0.13

****, **, * indicates significant at one, five and ten per cent level respectively*

maximum temperature was found to be positive which indicate that the joint effect of rainfall and temperature during the north-east monsoon season on finger millet yield was positive thus contributing for increased productivity. 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 [9].

4. CONCLUSION

The study analyzed the impact of climate variability on yield of finger millet 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. Generally millets are climate resilient crops, even though the huge increase in temperature will reduce the yield of millets. The coefficient of SWM maximum temperature was positive which means that an increase in SWM maximum temperature will increase the yield of finger millet up to a threshold level. The regression coefficient of interaction term for NEM rainfall and NEM maximum temperature was found to be positive which indicate that the joint effect of rainfall and temperature during the north-east monsoon season on finger millet yield was positive thus contributing for increased productivity. Many studies also support this study and revealed that, the millet yield will affect when there an increase in temperature.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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