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RESEARCH ARTICLE :

A ricardian analysis of the impact of climate change and adaptation strategies of millet crops in Tamil Nadu

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SUMMARY : This study was conducted in various districts of Tamil Nadu examined the climate change impacts of major millet crops. The Ricardian model is used analyze the climate change impacts in millet crops. The Multinomial logit model is used to analyze the determinants of farmer's choice of adaptation strategies. The results of multinomial logit analysis show that increase rainfall significantly reduced the likelihood of using certain adaptation strategies, but increased the probability of changing the sowing dates to adapt to the climate change.

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KEY WORDS :
Climate change, Millets, Ricardian model, Multinomial Logit (MNL)

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BACKGROUND AND OBJECTIVES

Agriculture plays a crucial role in India's economic development and provides food and livelihood to much of the Indian population. Tamil Nadu is one of the States of India where interdependence between economic growth, agriculture and climate vulnerability is most predominant. Climate change is likely to have larger impacts on predominantly rainfed crops such as millets, coarse cereals and pulses that are grown in marginal production environment. Gupta *et al.* (2012) 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 and the yield of sorghum appears to decline. Bryan *et al.* (2009) found that among those farmers who did adapt to climatic changes, the most common adaptation strategies include use of different crops or crop varieties, planting trees, soil conservation, changing planting dates, and irrigation. The main objectives of the study is to assess the impact of climate variability on yield and production of millet crops and to study the perception of climate change and coping mechanism adapted by millet growing farmers.

RESOURCES AND METHODS

The present study mainly concentrates on maize, sorghum, pearl millet and finger millet crops only. The study was conducted in predominantly millet-growing districts of Tamil Nadu *viz*., Krishnagiri, Villupuram, Erode, Namakkal, Perambalur, Dindigul and Thoothukudi districts which were purposively selected for the study. A total of 240 millet farmers were contacted individually and interviewed using pre-tested questionnaires to collect data and information on various socio-economic characteristics of farm households, millet cultivation, and the farmers' perception and adaptation to climate change. The necessary data regarding rainfall and temperature were collected for Tamil Nadu from Indian Meteorological Department. Multinomial logit model was used to investigate the factors influencing the farmers' decision in choosing adaptation strategies.

The ricardian regression model :

The ricardian technique assumes that each farmer maximizes net revenue subject to the exogenous conditions of the farm, which include climate factors.

The standard ricardian model relies on a quadratic formulation of climatic variables and the empirical Ricardian model specified for the study is given as follows:

$$\mathbf{Y = {}_0 + {}_1 SWMMAXTEMP + {}_2 SWMMAXTEMP^2 + {}_3 SWMRF + {}_4 SWMRF^2 + {}_5 NEMMAXTEMP + {}_6 NEMMAXTEMP^2 + {}_7 NEMRF + {}_8 NEMRF^2 + {}_9 SWMRAINMAXT + {}_{10} NEMRAINMAXT + {}_{11} FS + {}_{12} EXP + {}_{13} EDU + U}$$

where

Y	=	Net revenue per farm in rupees (it is proxy for rental value of the land of farm land value in individual farm)
SWMMAXTEMP	=	South West Monsoon Maximum Temperature in degree Celsius
$SWMMAXTEMP^2$	=	Squared South West Monsoon Maximum Temperature in degree Celsius
SWMRF	=	South West Monsoon Rainfall in Millimeter
$SWMRF^2$	=	Squared South West Monsoon Rainfall in Millimeter
NEMMAXTEMP	=	North East Monsoon Maximum Temperature in degree Celsius
$NEMMAXTEMP^2$	=	Squared North East Monsoon Maximum Temperature in degree Celsius
NEMRF	=	North East Monsoon Rainfall in Millimeter
$NEMRF^2$	=	Squared North East Monsoon Rainfall in Millimeter
SWMRAINMAXT	=	Interaction term (SWM Rain* SWM Maximum Temperature)
NEMRAINMAXT	=	Interaction term (NEM Rain* NEM Maximum Temperature)
FS	=	Farm size
EXP	=	Farming experience
EDU	=	Level of education
U	=	Error term

$\beta_0, \beta_1, \ldots, \beta_{14}$ are parameters to be estimated

The marginal impact of a climate variable on net farm revenue evaluated at the mean was calculated as demonstrated in Kurukulasuriya and Mendelsohn (2008). The result of the first order derivative with respect to concerned climatic variables (linear and squared terms) would be its marginal effect. Marginal effects represent the marginal changes in net revenue for unit change in the respective climatic variables, which are calculated as follows

$$E\left[\frac{dv}{df_i}\right] = \beta_{1,t} + 2*\beta_{2,t}*E[f_i]$$

where, $E\left[\frac{dv}{df_i}\right]$ is first order derivative of the expected net revenue of a farm

Multinomial logit model (MNL) :

Multinomial logit model was used to analyze the determinants of farmers' choice of adaptation strategies in the study area.

The MNL model is expressed as follows:

$$P\left(y = \frac{j}{x}\right) = \frac{\exp(x\beta_j)}{[1 + \sum_{h=1}^{J} \exp(x\beta_h), j = 1,\ldots\ldots j]}$$

To describe the MNL model, let y denote a random variable taking on the values {1, 2, . . ., J} for J, a positive integer, and let x denote a set of conditioning variables. X is a 1*K vector with first element unity and βj is a K*1 vector with j = 2, …, J. In this case, y denotes adaptation options or categories and x contain different household and environmental attributes. The question is how the changes in the elements of x affect the response probabilities [P(y = j/x), j = 1, 2, . . ., J]. Since the probabilities must sum to unity, P(y = j/x) is determined once we know the probabilities for j = 2, . . ., J.

For this study, the adaptation options or response probabilities are seven as described in below;

– Change in variety
– Change in cropping pattern
– Change in sowing dates
– Mixed/Inter cropping
– Growing tree crops
– Soil and water conservation practices
– No adaptation

The parameter estimates of the MNL model provide only the direction of the effect of the independent variables on the dependent (response) variable. The marginal effects represent the actual magnitude neither change nor probabilities. Differentiating the above equation with respect to the explanatory variables provides marginal effects of the explanatory variables given as:

$$\frac{\delta P_j}{\delta x_k} = P_j \left[\beta_{jk} - \sum_{j=1}^{J} P_j \beta_{jk} \right]$$

The marginal effects or marginal probabilities are functions of the probability itself and measure the expected change in probability of a particular choice being made with respect to a unit change in an independent variable from the mean. To estimate the parameters of the model we consider the method of maximum likelihood.

OBSERVATIONS AND ANALYSIS

The results obtained from the present study as well as discussions have been summarized under following heads:

Results of ricardian model :

The impact of climate change on agriculture is estimated using ricardian approach. The results of the estimated ricardian regression model are furnished in Table 1. The estimated ricardian regression model indicated that the co-efficient of multiple determination (R^2) was statistically significant with a value of 0.83 implying that 83 per cent of the variation in net farm income was explained by the variables included in the model. Most of the co-efficients of the quadratic terms have turned out to be statistically significant, implying that the relationship between climate variables and farm net revenue is non-linear.

The co-efficient of SWM maximum temperature was positive and significant at ten per cent level. The quadratic term of SWM maximum temperature was found to be negative and significant at ten per cent level, indicating that the SWM maximum temperature having a hill shaped relationship with farm net revenue, implying that increases in SWM maximum temperature tend to benefit farm net revenue with diminishing marginal benefits upto a maximum turning point, after which further increase in SWM maximum temperature start to have negative effects on farm net revenue. The co-efficient of SWM rainfall is negative and its quadratic term was found to be positive and both were significant at one per cent level indicating that net farm revenue function has a U-shaped response with SWM rainfall. The co-efficient of quadratic term of NEM maximum temperature is positive and significant at ten per cent level indicating that NEM maximum temperature square having U-shaped response with farm net income. This relationship seems to be plausible given the fact that temperature during north-east monsoon season was significantly lower than the other seasons with sky remaining overcast for most part of the season. Hence, an increase in north monsoon temperature beyond a threshold level might have a positive impact on farm income through higher crop yields. The co-efficient of NEM rainfall found to be positive and its square term was found to be negative and both were significant at one per cent level, indicating

Table 1 : Parameter estimates of ricardian analysis
Dependent variable =Net returns per ha in rupees ('000)

Variables	Co-efficient	Standard error
Intercept	81.68	66.00
SWM Maximum temp	26.06*	16.43
SWM Maximum temp square	-0.43*	0.27
SWM Rain	-0.54***	0.03
SWM Rain Square	0.001***	0.00
NEM Maximum temp	-30.49*	20.52
NEM Maximum temp square	0.52*	0.35
NEM Rain	0.39***	0.11
NEM Rain square	-0.001***	0.00
SWM temperature× SWM rain	0.003***	0.001
NEM temperature × NEM rain	0.002	0.004
Farm size	1.16***	0.28
Experience	-0.10*	0.06
Education	0.07	0.44

R^2 =0.83 N=240 NS = Non-Significant, *, ** and *** indicate significance of value at P=0.10, 0.05 and 0.01, respectively hill shape relationship with farm net revenue, whenever there is an excess rainfall during this season beyond the threshold level. This result also corroborate the practical experience of Tamil Nadu in northeast monsoon season which leads to lot of crop loss whenever there was excess rainfall. The co-efficients of interaction terms between rainfall and temperature in both the seasons (SWM and NEM) were found to be positive, which means the effect of SWM rainfall on net farm revenue was depending on the level of SWM maximum temperature and *vice-versa*. The co-efficient of farm size was found to be positive and significant at one per cent level, indicating that the increase in farm size would results in increase in farm net revenue per ha.

Marginal effects:

The estimated marginal effects of impact of climatic variables on farm income are presented in Table 2.

Table 2 : Marginal effects of climatic variables on income of millet growers

Variables	Co-efficient
SWM Maximum temp	35.43
SWM Rain	-4.91
NEM Maximum temp	-28.85
NEM Rain	0.34

For the climate variables (temperature and precipitation), marginal effects were estimated (Table 2), in order to help interpret the climate co-efficients. One degree celsius increases in maximum temperature during south west monsoon would increase the net income per hectare by Rs. 35430 and one millimetre increase in total rainfall during north east monsoon would increase the net income per hectare by Rs. 340.

Farmers adaptation strategies :

The various adaptation strategies followed by millet growers in the study area are shown in Fig. 1. Majority of the farmers (42.5 %) resort to changing the sowing dates to cope with changing climatic conditions. Maize has become an important substitute crop for traditional dry land crops such as cotton, sorghum and pearl millet in some of the districts such as Dindigul and Perambalur in view of good market potential and higher income.

Determinants of farmers' choice of adaptation methods - Multinomial logit model :

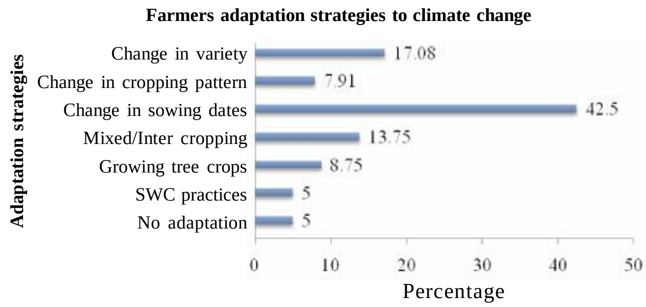

Fig. 1 : Farmers adaptation strategies

The Multinomial logit (MNL) model is used to analyze the determinants of farmer's choice of adaptation strategies. The advantage of the MNL is that it permits the analysis of decisions across more than two categories. The dependent variable in the empirical estimation is the choice of an adaptation option from the set of adaptation measures listed below:

- Change in variety
- Change in cropping pattern
- Change in sowing dates
- Mixed/Inter cropping
- Growing tree crops
- Soil and water conservation practices
- No adaptation

The explanatory variables used in MNL model like farm size, education, experience, farm income, non-farm income, rainfall and temperature were taken as continuous variables. Training/Extension, information/ knowledge on climate change and credit facilities was taken as dummy variables.

It could be observed from Table 3 the chi-square value of 344.37 shows that likelihood ratio statistics highly significant ($p<0.0001$) suggesting the model has a strong explanatory power. The pseudo-R square was 0.43 indicating that the explanatory variables explained about 43 per cent of the variation in choice of adaptation strategies.

It could be observed from Table 3 that education of the farmer increased the probability of adapting to climate change. Education significantly increases change in variety, change in cropping pattern and mixed farming as possible adaptation strategies to cope with changing climate. A one unit increase in the number of years of schooling would result in a 6.0 per cent, 3.4 per cent and 12.2 per cent increase in the probability of change in variety, change in cropping pattern and mixed farming

Table 3 : Marginal effects from the multinomial logit climate change adaptation model

Sr. No.	Explanatory variables	Change in variety	Change in cropping pattern	Change in sowing dates	Mixed / Inter Cropping	Growing tree crops	SWC Practices	No adaptation
		Co-efficients	Co-efficients	Co-efficients	Co-efficients	Co-efficients	Co-efficients	Co-efficients
1.	Farm size	-0.037	0.019	-0.092*	0.128***	-0.009	-0.087	0.0009
2.	Education	0.060**	0.034*	-0.228***	0.122***	0.004	0.022	-0.005
3.	Farming experience	-0.010***	0.003*	0.029***	-0.14***	-0.0003	-0.001	0.0008
4.	Farm income	1.24e-06	-3.37e-07	-4.23e-07	-6.94e-06	1.34e-06***	1.38e-06**	-3.35e-08
5.	Non-farm income	-2.90e-06	-1.28e-06	-2.21e-06	-5.83e-06	7.37e-06***	4.73e-06*	1.20e-07
6.	Temperature	0.067***	0.056***	-0.141***	-0.006	0.0164	0.006	0.001
7.	Rainfall	-0.001***	-0.0001	0.0020***	-0.0003	-0.0001	-0.0003	6.96e-06

*, ** and *** indicate significant of value at P =0.10, 0.05 and 0.01, respectively

practices so as to adapt to climate change. The farm size of the households had a positive and significant impact on mixed / inters cropping strategy. Large farms have higher possibilities of adopting mixed farming/inter cropping, probably because of the potential for higher flexibility when farm size is larger. Length of farming experience also affects the adaptation to climate change. A one unit increase in farming experience resulted in 2.9 per cent increase in the probability of changing the sowing dates and 0.3 per cent increase in the probability of changing the cropping pattern as the adaptation strategy. The farm income as well as the non-farm income of the farms had a positive and significant impact on growing tree crops and soil and water conservation practices.

Farms with higher annual maximum temperature over the survey period were more likely to adapt to climate change through the adoption of a suite of coping strategies. A one unit increase in maximum temperature has resulted in 6.7 per cent increase in the probability of changing the varieties and 5.6 per cent increase in the probability of changing the cropping pattern.

This paper examines the climate changes impact on major millet crops in Tamil Nadu, India through Ricardian analysis. Net revenues are regressed on seasonal and other socio-economic variables. The ricardian results revealed that the increase in maximum temperature during north east monsoon would harmful and resulted in significant reduction in farm net revenue since north east monsoon is the most important cropping season for farmers in Tamil Nadu. The increase in south west monsoon maximum temperature would increase the farm net income up to a certain level. The higher rainfall during SWM season will affect the net farm income negatively. The results of multinomial logit analysis show that increase rainfall significantly reduced the likelihood of using certain adaptation strategies, but increased the probability of changing the sowing dates to adapt to the climate change. Majority of the millet farmers in the study area were adopting changing the sowing dates as a strategy to cope with climate change.

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