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An Economic Analysis of Climate Change Impact on Income and Adoption of Climate Smart Technologies in Dry Land Farms of Sivagangai District of Tamil Nadu, India

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ABSTRACT: The study was taken up in Sivagangai district of Tamil Nadu, India with a sample size of 210 farmers. The district is facing extremes of climate change with increased temperature and deceased rainfall and hence the present study was taken up to examine the issue of impact of climate change on net income of farmers with Ricardian model which is a novel study of the district. Adaptation strategies to climate change was analyzed with Tobit model and the policy advocacy henceforth suggested would go long way in achieving the environmental sustainability of the region. 70 farmers were selected each for the low dry land, medium dry land and high dry land areas of the district. For low dry land, the principal crop identified was paddy, for medium dry land, the principal crop identified was groundnut and for high dry land, the principal crop identified was black gram. The results indicated that paddy was the most profitable among the dryland farms of Sivagangai District followed by Black gram and Groundnut crops. The maximum and minimum temperature had a detrimental effect on the net income of farmers and the effect was varied with intensity of dry land. In the case of average rainfall, the increase effect showed a different picture with medium dry land farmers responding more as against high dry land farmers. Farm size, family size, education and extension contact were found to be having positive impact on the climate smart technology adoption while the farm experience had a negative impact on the climate smart technology adoption. Social forestry and frequent extension contacts should be undertaken by Agriculture Department to promote climate resilient technologies.

Keywords: Low dry land, medium dry land, high dry land, maximum temperature, minimum temperature, rainfall, Ricardian model and Tobit model.

INTRODUCTION

The negative impacts of climate change are being felt in India with increased temperatures of 0.62^{o}C over the past century. Tamil Nadu is one of the severely affected states by natural calamities as it depends on both monsoons for the water requirement. Recently a study based on the sixth International Panel on Climate Change (IPCC) (2021) report warned that with almost 41 per cent of coastal areas being eroded, the state capital city would go under water within a century period. In Tamil Nadu, due to those uncertain weather and extreme droughts and insufficient water form perennial rivers, the gross cropped area had reduced from 60.74 lakh hectares in 2015-16 to 59.42 lakh hectares in 2019-20 (Season and crop report 2019-20, Government of Tamil Nadu). The district is facing extremes of climate change with increased temperature and deceased rainfall. Hence the present study was taken up in Sivagangai district to examine the impact of climate change on net income of farmers and factors influencing the climate smart technologies to climate change.

A. Review on Ricardian model

Nhemachena *et al.* (2010) measured the economic impacts of climate change on crop and livestock farming systems in Southern Africa. The authors employed the Ricardian model to study the response of net revenue from crop and livestock agriculture across various farm types and systems in Africa to changes in mean rainfall and temperature. Results showed that warmer and drier climates adversely affect net farm revenues. Gonzaez and Velasco (2008) analyzed the impact of climate change on the economic value of land in Agricultural systems in Chile. They found that Ricardian model explained 37 per cent of land value variation. The highest values were in areas with moderate temperature and precipitation. Temperature had a lower relationship to land value than precipitation. Kurukulasuriya and Mendelsohn (2008) examined the impact of climate change on cropland in Africa, using a Ricardian cross-sectional approach. The study confirmed that current climate affects the net revenues of farms across Africa. Seo and Mendelsohn (2007) in the World Bank Development Research Group, Sustainable Rural and Urban Development team report used Ricardian analysis to study climate change in African Agriculture. The result indicated that with climate change, the farm income would fall by 50 per cent. Deressa and Hassan (2009) investigated the impact of climate change on the net revenue. The results showed that the climatic, household and soil variables had significant impact on net revenues per hectare over Ethiopian farmers. Increasing temperature during summer and winter lower the net revenue per hectare by US$997.85 and US$1277.25. Annual temperature reduces net revenue per hectare by US$32.61. Rainfall increases the net revenue per hectare by US$225.88. Thapa and Joshi (2010) attempted to measure the impact of climate change on production and used Ricardian technique of regressing net farm income with the climatic parameters in 14 districts of Nepal. There was a positive association between summer rainfall and net farm income but negative with temperature parameters. These above studies researched on the impact of temperature and rainfall on net income of farmers with Ricardian model. The present study is specific and analyzed the impact of maximum temperature, minimum temperature and rainfall with Ricardian model in dry land farms of Tamil Nadu, India.

B. Review on Tobit model

Laxmi *et al.* (2007) studied the adoption of zero tillage practice among paddy farmers of Indo-Gangetic plains and revealed the significant and positive impact of extension contact towards adoption of technology. Idrisa *et al.* (2012) employed the Tobit regression model to establish the effects of socio-economic characteristics on the use of climate change adaptation measures among farmers. The main constraints on climate change adaptation measures by farmers in the study area were poor financial resources (86.67 per cent) and unavailability of weather information (77.78 per cent). Etwire *et al.* (2013) studied the factors that influence the adoption of climate related technologies introduced by research institutions in Northern Ghana. The empirical results revealed that sex, age, farm size, access to formal agricultural extension, agro ecology and noticing of unpredictable temperatures were the factors influencing farmers' adoption of a climate related strategies introduced by research institutions. Omolehin *et al*. (2020) reported that among the farmers in Nigeria, the age of farmers and farming experience had negative impact on the adoption of technologies. These above studies researched on the factors influencing climate smart technology adoption with Tobit model. . The present study is specific and analyzed the factors influencing climate smart technology adoption with Tobit model in dry land farms of Tamil Nadu, India.

METHODOLOGY

The study was taken up in Sivagangai district of Tamil Nadu, India with a sample size of 210 farmers. 70 farmers were selected each for the low dry land, medium dry land and high dry land areas of the district. For low dry land, the principal crop identified was paddy, for medium dry land, the principal crop identified was groundnut and for high dry land, the principal crop identified was black gram

A. Ricardian model

In the present study, Ricardian model as specified by Deressa (2007) was employed to measure the economic impact of climatic variables on crop production in Sivagangai district.

Ricardian model is given by

$V = \beta 0 + \beta_1$ MAXTEM+ + $\beta 2$ MINTEM+ + $\beta 3$ RAIN+ + $\beta 4$ $MAXTEM^2$ +$\beta 5 MINTEM^2$ + β_6 $RAIN^2$ + + β_7 EDU+ β_8 FARMEXP+ β_9 FAMSIZE + β_{10} EXTN + μ

where,

MAXTEM = Maximum temperature in degree Celsius

MINTEM = Minimum temperature in degree Celsius

RAIN = Rainfall in mm

$MAXTEM^2$ = Squared maximum temperature in degree Celsius

$MINTEM^2$ = Squared minimum temperature in degree Celsius

$RAIN^2$ = Squared rainfall in mm

EDU = Education in years

FARMEXP = Farm experience in years

FAMSIZE = Family size in numbers

EXTN = Extension contacts in number of times

b_0 = intercept

μ = error term

b_1, b_2, b_3, b_4…. B_{18} are coefficients of respective variables.

B. Determinants of climate smart technologies

The determinants of adoption of climate smart technologies were studied by using tobit model. Certain factors positively influence the climate smart technology adoption in high, medium and low dry land areas and accordingly, the tobit model was developed.

Hence the tobit model employed for the study is

Y1 =f (FARMSIZE, EDU, EXTOFF, AGE, FEXP) +$\mu 1$

Y1 = Actual expenditure on green technology adoption in rupees per hectare

= 0, otherwise

FARMSIZE = Total farm size in hectares

EDU = Education of the respondent in terms of number of years

EXTOFF = Frequency of extension visit in number, 0-otherwise

AGE = Age of household head

FEXP = Farming experience in years

FAMILYSIZE = Family size in numbers

$\mu 1$ = Random error term

The tobit model was analyzed using STATA11 econometric package.

RESULTS AND DISCUSSION

A. Cost and return of principal crops

The cost and returns for the sample farms in Paddy, Groundnut and Black gram cultivation was worked out and the results are given in Table 1. It could be observed from the table 1 that the share of total variable cost to the total cost of cultivation was highest among Paddy farmers with a proportion of 74.98 per cent followed by Groundnut and Black gram farmers with a proportion of 74.71 per cent and 64.07 per cent respectively. Fixed cost occupied lowest proportion among cost of cultivation with highest fixed cost among Black gram farmers with a proportion of 35.93 per cent followed by Groundnut and Paddy farmers with a proportion of 25.29 per cent and 25.01 per cent respectively.

The gross income was highest among paddy farmers with Rs.82632 per hectare and followed by Black gram and Groundnut with Rs.53161 per hectare and Rs.48523 per hectare respectively. The net income was also highest among paddy farmers with Rs.18384.66 per hectare and followed by Black gram and Groundnut with Rs.13651.42 per hectare and Rs.11522.82 per hectare respectively. The total cost of cultivation was also high for paddy farmers with Rs.64247.34 per hectare followed by Black gram and Groundnut with Rs. 39509.58 per hectare and Rs.37000.18 per hectare respectively. Thus, it could be inferred from the results that the Paddy was the most profitable among the dryland farms of Sivagangai district followed by Black gram and Groundnut crops.

Table 1: Total cost and return of principal crops (in Rs. /Ha).

Sr. No.	Particulars	Paddy	Groundnut	Black gram
1.	Fixed cost	16072.78	9358.58	14194.22
	In %	25.01	25.29	35.93
2.	Variable cost	48174.56	27641.60	25315.36
	In %	74.98	74.71	64.07
3.	Total cost of cultivation	64247.34	37000.18	39509.58
	In %	100.00	100.00	100.00
Gross income		**82632**	**48523**	**53161**
Net income		**18384.66**	**11522.82**	**13651.42**

B. Impact of climatic variables on net income of sample farmers

Sample farmers were grouped as high dryland, medium dryland and low dryland farmers and the impact of climatic variables on net income of sample farmers were analyzed using Ricardian model.

(i) Impact of climatic variables on net income of low dryland farmers in Sivagangai district. To measure the impact of climatic variables on net income of farmers, Ricardian cross-sectional model was used and the estimated results were given for low dryland farmers in Sivagangai district in Table 2. The coefficient of mean maximum temperature was negative and significant at five per cent level which indicated that increase in mean maximum temperature would decrease the net income of low dry land farmers. The squared maximum temperature was positive and significant which indicated that the quadratic curve formed a hill shape, which would result in increase in net income and prolonged further increase in temperature would cause a detrimental effect on net income of low dry land farmers. The coefficient of mean minimum temperature was negative and significant at five per cent level which indicated that increase in mean minimum temperature would decrease the net income of low dry land farmers.

Table 2: Estimated Ricardian income function for low dryland farmers.

Sr. No.	Particulars	Coefficients
1.	Intercept	45136.50
2.	Mean maximum temperature	-867.16*
3.	Mean minimum temperature	-384.35*
4.	Average rainfall	1416.61**
5.	Squared maximum temperature	6.48*
6.	Squared minimum temperature	-486.31
7.	Squared rainfall	-56.13*
8.	Education	356.18
9.	Farm experience	78.16*
10.	Family size	68.61*
11.	Extension contacts	-681.84

** significant at 1 per cent level; * significant at 5 per cent level; R^2 = 0.79; $\overline{R^2}$ = 0.75

The coefficient of average rainfall was positive and significant at one percent level which indicated that with increase in average rainfall, the net income of low dry land farmers would increase. The squared average rainfall was found to be negative and significant at five per cent level, indicating that the quadratic function was 'U' shaped. This showed that increased average rainfall would increase net income with diminishing marginal benefits up to inflection point, after which a further increase in average rainfall would have detrimental effect. The coefficient of farm experience and family size were positive and significant at five per cent levels with values of 78.16 and 68.61 respectively which implied that with increase in one year of farm experience would increase the net income by Rs. 78.16 of low dry land farmers and increase in one unit of family size would increase the net income by Rs. 68.61 of low dry land farmers.

(ii) Impact of climatic variables on net income of medium dryland farmers in Sivagangai district. To measure the impact of climatic variables on net income of farmers, Ricardian cross-sectional model was again used for medium dryland farmers and the estimated results for Sivagangai district were given in Table 3.

Table 3: Estimated Ricardian income function for medium dryland farmers.

Sr. No.	Particulars	Coefficients
1.	Intercept	21651.38*
2.	Mean maximum temperature	-1346.46*
3.	Mean minimum temperature	-86.41
4.	Average rainfall	3465.46**
5.	Squared maximum temperature	7.45*
6.	Squared minimum temperature	-432.51
7.	Squared rainfall	-0.78*
8.	Education	163.76*
9.	Farm experience	58.34*
10.	Family size	64.13
11.	Extension contacts	786.43*

** significant at 1 per cent level; * significant at 5 per cent level; R^2 = 0.74; $\overline{R^2}$ = 0.70; N = 70

The coefficient of mean maximum temperature was negative and significant at five per cent level and the squared maximum temperature was positive and significant which followed as interpreted for low dry land farmers. The coefficient of average rainfall was positive and the squared average rainfall was found to be negative which followed as interpreted for low dry land farmers. The coefficient of education, farm experience and extension contact were positive and significant and hence positively influenced the net income of medium dry land farmers.

(iii) Impact of climatic variables on net income of high dryland farmers in Sivagangai district. To measure the impact of climatic variables on net income of farmers, Ricardian cross-sectional model was further used and the estimated results were given for high dryland farmers in Sivagangai district in Table 4.

Table 4: Estimated Ricardian income function for high dryland farmers.

Sr. No.	Particulars	Coefficients
1.	Intercept	68513.16
2.	Mean maximum temperature	-8643.13**
3.	Mean minimum temperature	-13546.78*
4.	Average rainfall	3078.85*
5.	Squared maximum temperature	8.16*
6.	Squared minimum temperature	5.23
7.	Squared rainfall	0.07
8.	Education	103.48*
9.	Farm experience	168.81
10.	Family size	31.53
11.	Extension contacts	406.81*

** significant at 1 per cent level; * significant at 5 per cent level; R^2 = 0.76; $\overline{R^2}$ = 0.71 ; N = 70

The coefficient of mean maximum temperature was negative and the squared maximum temperature was positive and significant which followed as interpreted for low and medium dry land farmers. The coefficient of mean minimum temperature was negative and significant at five per cent level which negatively influenced the net income of high dry land farmers. The coefficient of average rainfall was positive and significant at one percent level which positively influenced the net income of the high dry land farmers would increase. The coefficient of education and extension contact were positive and significant at five per cent levels which positively influenced the net income of high dry land farmers.

(iv) Marginal impacts of significant climatic variables over net income. The marginal impacts of significant climatic variables over net income for high dryland, medium dryland and low dryland farmers are furnished in the Table 5.

Table 5: Marginal impacts of significant climatic variables over net income.

Sr. No.	Farm type	Mean maximum temperature	Mean minimum temperature	Average rainfall
1.	Low Dryland	-867.16*	-384.35*	1416.61**
2.	Medium Dryland	-1346.46*	-	3465.46**
3.	High Dryland	-8643.13**	-13546.78*	3078.85*

** significant at 1 per cent level; * significant at 5 per cent level

It could be observed from the table that the maximum temperature had a detrimental effect on the net income of farmers with one degree increase in maximum temperature would decrease the net income of low, medium and high dryland farmers by Rs.867.16, Rs. 1346.46 and Rs. 8643.13 respectively. Thus, the effect was varied with the intensity of dry land. Likewise, the minimum temperature had a detrimental effect on the net income of farmers with one degree increase in maximum temperature would decrease the net income of low and high dryland farmers by Rs. 384.35 and Rs. 13546.78 respectively. Here also, the effect was varied with intensity of dry land. An increase in the average rainfall by one mm would increase the net income of low, medium and high dryland farmers by Rs.1416.61, Rs.3465.46 and Rs.3078.85 respectively. Here, in the case of average rainfall, the increase effect showed a different picture with medium dry land farmers responding more as against high dry land farmers.

Similar study done by Nhemachena *et al.* (2010) concluded that warmer and drier climates adversely affect net farm revenues. Gonalez and Velasco (2008) showed that the highest land values were in areas with moderate temperature and precipitation. Kurukulasuriya and Mendelsohn (2008); Seo and Mendelsohn (2008) employed the Ricardian model and proved that climate change affect net farm income. More specifically, Deressa and Hassan (2009) and Thappar and Joshi (2010) estimated that with Ricardian model, as temperature decreases and rainfall increases, the net income increases. The present study is in line with the findings of the last two authors.

C. Factors influencing climate smart technology adoption

The climate smart technologies included technologies of mulching, press mud application, zero tillage, biological pest control and construction of farm ponds. The factors influencing these climate smart technologies are furnished in Table 6.

Table 6: Factors influencing climate smart technology adoption.

S. No.	Variables	Coefficient	t-value	Total elasticity
1.	Farm size	0.132*	1.13	0.117
2.	Education	0.064**	5.22	0.058
3.	Extension contacts	0.065**	1.12	0.011
4.	Age of household head	-0.672	-0.01	-0.072
5.	Experience	-0.108**	-2.64	-0.039
6.	Family size	0.128*	2.65	0.023
7.	Constant	-0.108	-2.45	
8.	Sigma	402.65		
9.	Log-likelihood	33.23		

** significant at 1 per cent level; * significant at 5 per cent level

From the Table 6, it could be inferred that the farm size of the sample farmers was positive and significant at five per cent level with a coefficient value of 0.132. This showed that with increase in farm size of farmers, the cost spent for climate smart technology adoption increases. Similarly, family size, education and extension contact were found to be having positive impact on the climate smart technology adoption and significant at one per cent level. The result was in line with the findings of Laxmi *et al.* (2007) who reported significant and positive impact of extension contact towards adoption of technology. Similarly Etwire *et al.* (2013) *identified* that sex, age, farm size, access to formal agricultural extension, agro ecology and noticing of unpredictable temperatures were the factors influencing farmers' adoption of a climate related strategies.

On the other hand, farm experience showed a negative coefficient and significant at one per cent level. This showed that the adoption of climate smart technology decreased with increase in farm experience of farmers as they become aged, they less resort to climate smart technology adoption. This was substantiated by showing farmer age having negative coefficient. Thus, with increased age of farmers, they were not willing to spend for conservation technologies while young farmers take the risk by introducing new technologies. The result was in line with the findings of Omolehin, *et al*. (2020) who reported that among the farmers in Nigeria, the age of farmers and farming experience had negative impact on the adoption of technologies.

SUMMARY AND CONCLUSION

The study was taken up in Sivagangai district of Tamil Nadu, India with a sample size of 210 farmers. The study revealed that Paddy was the most profitable among the dryland farms of Sivagangai District followed by Black gram and Groundnut crops. The maximum and minimum temperature had a detrimental effect on the net income of farmers and the effect was varied with intensity of dry land. In the case of average rainfall, the increase effect showed a different picture with medium dry land farmers responding more as against high dry land farmers. Farm size, family size, education and extension contact were found to be having positive impact on the climate smart technology adoption while the farm experience had a negative impact on the climate smart technology adoption.

The increase in maximum temperature showed to reduce net income of farmers among small, medium and large farms. Hence to reduce maximum temperature, social forestry should be encouraged. Government should provide free tree samplings and encourage farmers to adopt to location specific drought tolerant varieties to mitigate climate change. Ricardian analyses on small, medium and large farmers revealed that climatic variables had significant and differential influence on net income of farmers. Also, the intensity of climate change especially the maximum temperature is affecting the net income of farmers of the district. Hence the Government should plan for climate contingencies and adaptation strategies to mitigate the harmful effects of climate change in the district. Education and extension contact were found to be having positive impact on the climate resilient technology adoption. Hence adult literacy programs should be conducted by the Government to promote climate resilient technologies. Also, frequent extension contacts should be undertaken by Agriculture Department to promote climate resilient technologies.

FUTURE SCOPE

Future researches on vulnerability and resilience to climate change, sustainability of dry land farms and livelihood security of dry land farmers could be conducted for the development of dry land farming in Tamil Nadu, India. Optimal farm plans could also be further developed with Minimisation of Total Absolute Deviation (MOTAD) model for the dry land farmers in Tamil Nadu, India to enhance their income with risk.

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