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RESEARCH PAPER

Probability and intensity of climate adaptation through agricultural technologies in western zone of Tamil Nadu

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ABSTRACT

Climate change is already affecting millions of people and is increasing the risk of hunger and food insecurity, particularly in countries whose economies are highly dependent on climate sensitive sectors such as agriculture, fisheries and forestry. Climate variability has a direct, influence on the quantity and quality of agricultural production. In response to changing climate, adaptation is becoming an urgent priority because large reductions in negative impacts of climate change are feasible when adaptation is fully implemented Adaptation is the processes through which societies make themselves better able to cope with an uncertain future. Adapting to climate change entails taking the right measures to reduce the negative effects of climate change by making the appropriate adjustments and changes**.** This study estimates the extent of adoption of agricultural technologies to the climate variability. This study is based on primary survey and data collected from farmers' in Western Zone of Tamil Nadu. The study period was 2011-12 cropping season. The sample consisted of 180 farm households. Results from the study indicated that among the key determinants of climate adaptation were extension services, membership in farmers' association. The result also showed that temperature was highly significant and positive influence on the decision to adapt for climate change. Temperature influenced both farm households' decision to adopt and the extent of adoption. The co-efficient, of distance to market was negative and statistically significant, which implies longer distance, lesser the intensity of climate adaption. Access to credit was statistically significant and positive, implying high adaptation rates due to availability of credit facility. The study concluded that new agricultural technologies are very important in helping small holder farmers to continue to produce food in changing climate, but more complementary support is needed if these technologies are to be taken up by farmers on a large scale.

KEY WORDS : Climate variability, Technology adoption, Double hurdle approach

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Climate change is already affecting millions of people and is increasing the risk of hunger and food insecurity, particularly in countries whose economies are highly dependent on climate sensitive sectors such as agriculture, fisheries and forestry. Climate variability has a direct influence on the quantity and quality of agricultural production. Temperature, rainfall, humidity, sunshine (day length) are the important climatic elements that influence crop production. India is heavily dependent on the monsoon to meet its agricultural and water needs. Over 60 per cent of India's population still being agriculture dependent (either directly or indirectly), even a small impact of climate change on monsoons, erratic occurrences of floods and droughts would enormously contribute to vulnerability of people. Developing countries are the most vulnerable to climate change impacts because they have fewer resources to adapt: socially, technologically and financially.

In response to changing climate, adaptation is becoming an urgent priority because large reductions in negative

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impacts of climate change are feasible when adaptation is fully implemented. Adaptation is processes through which societies make themselves better able to cope with an uncertain future. Various adaptation options in agriculture have been suggested, but the development and diffusion of technologies are considered to be one of the most relevant options (UNFCCC, 2006; Below *et al.*, 2010; Lybbert and Sumner, 2010). In view of this, researchers are modifying and extending existing agricultural technologies to tolerate climate-related shocks. One of the principal challenges in developing these technologies is to ensure that they serve those in greatest need, typically the poorest and most vulnerable smallholders (UNFCCC, 2006). However, despite the increasing importance of the promotion of agricultural technologies for climate change adaptation, there has been little empirical research on the determinants of smallholder farmers' adoption of such technologies. Puddling and levelling, System of rice intensification for paddy, change in cropping pattern, change in variety, change in irrigation method, drought tolerant varieties, mulching, soil bunding, direct sowing, spraying of chemicals, summer ploughing etc., are the some of the adaptive measures in agriculture.

This study focuses on climate adaptation technologies practiced in Western Zone of Tamil Nadu. Determining the key factors affecting the adoption of climate-resilient technologies is highly relevant to policies focusing on climate change adaptation. By employing survey data from farm households and an econometric model that allows for a two-part adoption process, we examined the determinants of the decision to adopt and the extent of adopting technology in Western zones of Tamil Nadu.

METHODOLOGY

The study was carried out in western zone of Tamil Nadu. It is based on primary survey data collected from farmer's technology adoption in Western Zone. The survey was based on the 2011-12 cropping season. The sample consisted of 180 farm households.

Tools of analysis :

Adoption index :

An adoption index was constructed to quantify the adoption of such technologies :

$$\textbf{Adoption index} = \frac{\mathbf{A}}{\mathbf{P}} \times \mathbf{100}$$

where,

a = Number of practices adopted by respondents, and

p = Total number of practices recommended.

The respondents were classified as adopters if the adoption index was 50 or above. The recommended practices for crop production are given in the 'Package of practices' approved by the State Department of Agriculture in consultation with the Tamil Nadu Agricultural University. From this package of practices, technologies recommended for rainfall variability/water stress were identified to quantify adoption. The recommended technologies considered in the present study were system of rice intensification for paddy. Change in cropping pattern, change in variety, change in irrigation method, drought tolerant varieties, mulching, summer ploughing and agricultural allied activities like animal husbandry.

Probability and intensity of climate adaptation in agriculture: double hurdle model :

Adoption of agricultural technology generally involves a two-part decision making process: whether to adopt and then how much to adopt. These two decisions are made jointly or separately (Gebremedhin and Swinton, 2003). The Tobit model can be used in analyzing adaptation when the two decisions are made jointly. When the two decisions are made separately, an alternative model, the double hurdle, is more appropriate to use in analyzing the determinants of innovation adoption (Tambo and Abdoulaye, 2012).

This model was originally proposed by Cragg (1971), and its variants have recently been used in the study of agricultural technology adoption such as soil conservation (Gebremedhin and Swinton, 2003), improved crop variety (Shiferaw *et al*., 2008; Langyintuo and Mungoma 2008) and poultry breed (Teklewold *et al*., 2006). This model assumes that farm households must cross two hurdles in order to adopt technology. The first decision is to decide whether to adopt or not (probability of adoption) and the second decision is about the intensity of adoption which is conditional on the first decision. The model allows for the possibility that the probability and intensity of adoption have different explanatory variables and even variables appearing in both may have different effects (Asfaw *et al.*, 2010; Teklewold *et al.*, 2006). The double hurdle model is expressed as :

$$\left.\begin{array}{l} \mathbf{d^*} = \mathbf{z_i}\alpha + \varepsilon_i \\ \mathbf{d_i} = \mathbf{1\ if\ d_i^*} > \mathbf{0\ and\ 0\ if\ d_i^*} \leq \mathbf{0} \end{array}\right\} \text{First hurdle (decision to adopt)}$$

$$\left.\begin{array}{l} \mathbf{y^*} = \mathbf{x_i}\beta + u_i \\ \mathbf{y_i} = \mathbf{y_i^*\ if\ y_i^*} > \mathbf{0\ and\ d_i^*} > \mathbf{0} \\ \mathbf{y_i} = \mathbf{0\ otherwise} \end{array}\right\} \text{Second hurdle (intensity of adoption)}$$

where d_i*is a latent variable that describes household decision to adopt while d_i observed household decision to adopt and takes a value of 1 if the farmer adapts to climate change and 0 otherwise. y_i*is a latent variable describing the intensity of adoption and y_i is the observed response on intensity of technology adaptation as measured by technology adoption index. z and x are vectors of variables explaining the decision to adapt and intensity of use of technology, respectively, which are allowed to overlap. α and β are vectors of the parameters. e_i is an error term with mean 0 and variance 1. μ_i is also an error term with mean 0 and variance s. Based on the assumption of independence of the two error terms, the first and second hurdles were estimated by using the maximum likelihood method of probit and truncated regressions, respectively (Gebremedhin and Swinton, 2003; Teklewold *et al.*, 2006).

Choice of explanatory variables :

The study uses three broad classes of explanatory factors. These are household and farm characteristics institutional factors and farmers perception about the technology. Characteristics of the person responsible for farming decisions such as age (and its square) and educational level are expected to influence climate adaptation through technology. A higher level of education is expected to increase a farmer's ability to obtain, understand and utilize information relevant to adoption of technology. Older farmers may be more risk-averse and less likely to be flexible than younger farmers and thus have a lesser likelihood of adopting new technologies. Farm size is expected to influence technology adoption. Households with large farm size are considered more likely to be adopters because they will be more willing to use part of their land to cultivate new or untried varieties. On the other hand, households with smaller farm sizes may be more willing to adopt technologies that require intensive management (CIMMYT, 1993; Langyintuo and Mungoma, 2008).

Contacts with extension officers, group membership, credit accessibility and easy access to markets are institutional factors included in the adoption model. Extension services are key sources of information on new agricultural technologies in the study area. Frequent extension visits are expected to positively influence the adoption of technologies.

Members of farmer associations may have better access to information, credit and inputs and are, therefore, more likely to adopt technology than non-members. Farmers with access to credit will have the financial resources needed to purchase inputs, hence, are expected to adapt the technology more readily. Market accessibility is controlled for by distance to closest input market. Farmers located far from input markets are expected to be less likely to adapt new technologies available in markets because they incur transaction costs which in turn increase the cost of the technologies (Salasya *et al.,* 2007).

Studies have shown that farmers' subjective perceptions of the characteristics of an innovation influence adoption decisions (Adesina and Zinnah, 1993; Langyintuo and Mungoma, 2008). It is expected that farmers' positive perception yields will influence adoption of the technology. Farmers are likely to adopt an agricultural technology when they are easily available; therefore, it is anticipated that farmers' perception about technology will have a positive influence on its adoption. Farmers' awareness of changes in climate attributes is important in the adaptation decision-making process (Maddison, 2007). It is expected that farmers who have heard or read about climate change and its negative consequences are likely to take up adaptation measures such as adopting agricultural technologies. Table 1 presents the descriptive statistics of the variables in the empirical models.

Table 1 : Descriptive summary of variables used in estimations

Variables	Mean	Standard deviation
Dependent variables		
Adoption	0.53	0.50
Intensity	0.31	0.16
Household and farm characteristics		
Age	50.92	11.09
Age squared	2714.72	1162.98
Education	9.37	4.20
Net income	66955.89	17406.21
Farm size	10.00	11.45
Institutional factors		
Distance to market for agricultural inputs	4.96	3.30
Extension contact	16.20	4.58
Credit	0.48	0.50
Membership	0.46	0.50
Perception of technology		
Yield potential	0.46	0.50
Climate change awareness	0.55	0.50
Temperature	26.53	2.40
Rainfall (mm)	27.91	9.86
Temperature square	709.82	119.46
Rainfall square	875.66	766.75

Garrett ranking technique :

Ranking is an expression of the respondent's priority about their thoughts and feelings. To rank the constraints or problems faced by the farmers in technology adoption, Garrett's ranking, were used. The order of the merit assigned by the respondents were converted into ranks using the formula.

As a first step, the per cent position of each rank was found out by the following formula :

Per cent position = $[100(R_{ij} - 0.5)]/N_i$

where,

R_{ij} = Rank given for i^{th} items by the j^{th} individual

N_j = Number of items ranked by j^{th} individual

The per cent position of each rank, thus, obtained was then converted into scores by referring to the table given by

Garrett. The respondents were requested to rank the opinions/reasons relevant to them according to the degree of importance. The ranks given by each of the respondents was converted into scores. Then for each reason, the scores of individual respondents were added together and divided by the total number of respondents. These mean scores for all the reasons were arranged in the descending order and ranks were given. By this method, the accuracy in determining the preference was obtained.

ANALYSIS AND DISCUSSION

The results obtained from the present investigation are presented below :

Climate change adaption index :

The State Department of Agriculture and the Tamil Nadu Agricultural University have released the package of practices for different crops. These practices include among other recommendations, technologies to cope up with deficit rainfall or water stress. Examples of such technologies are system of rice intensification for paddy crop, change in cropping pattern, change in variety, drought tolerant crops, drip irrigation, irrigation through bore well, mulching, summer ploughing, and allied agricultural activities like Animal husbandry.

The various adaptation strategies being used by farmers in response to changing climatic are presented in Table 2. Analyzing adaptations made by all respondents revealed that improved irrigation technologies are the most important adaptation measure in response to climatic variability. To cope with climate variability farmers have developed a wide range of management practices such as cropping pattern, change in variety, mulching and summer ploughing. The abrupt climate fluctuations such as drought had made the farmers to rise in drought tolerant crops and varieties in dry season. Some the respondent farmers adopted other agricultural allied activities like dairy. Adaptation to climate change through these technologies was quantified by constructing a technology adoption index and results are furnished in Table 3. Majority of the farmers had a technology adoption index of less than 50 per cent, while 38 per cent of the farmers had technology adoption index more than, 71 per cent.

Table 2 : Adoptions of technology to climate variability by respondents (n=180)

Adaptation	Respondents	
	Number	Percent
SRI	72	40.00
Change in cropping pattern	168	93.33
Change in variety	142	78.88
Drought tolerant crops	125	69.44
Drip irrigation	158	87.77
Bore well	170	94.44
Mulching	84	46.66
Summer ploughing	120	66.66
Dairy	165	91.66

Table 3 : Distribution of technology adoption index

Distribution of TAI (%)	Number of farmers
< 50	85 (47.22)
51-70	26 (14.44)
>71	69 (38.33)

Note: Figures in parenthesis percentage to the total

Determinants of adaptation to climate change in agriculture:

A likelihood ratio test was done and to find out which of the two models (Tobit or double hurdle) best fit the data set. The likelihood ratio statistic was 325.92 which far exceeds the Chi-square critical value of 30.58 at 1% level of significance and thus rejects the use of the Tobit model in favour of the double hurdle model specification. This result suggests that farm households make technology adoption decisions sequentially by first deciding whether to adopt and then deciding how much to adopt, hence, using a Tobit specification implies a misrepresentation of households adoption behaviour. Comparison of the results of the two models in Table 4 also shows that the double hurdle model better explains the adoption decisions. Consequently, the discussions on the determinants of technology adoption are based on the double hurdle model result.

The probit regression results are furnished in Table 4. It shows that farmers' climate adaptation decision is influenced by a wide range of factors. Farmers' perceptions about technology and climate change-related variables are important determinants of climate adaptation. The statistically significant and negative coefficient of age indicates that the older farmers are less likely to adapt through technology. Most of the farmers are credit constrained and hence, off-farm income and the wealth status of household were important in financing adaptation through technologies. The implication of this result is that the technology is less accessible to resource-poor farmers because of financial and resource constraints that inhibit their ability to purchase the technology and its complementary inputs. This suggests that more efforts are needed to assist resource-poor farmers so as to increase the probability of climate adaptation by these groups of farmers.

Among the institutional factors included in the model, extension visits and membership of association significantly influenced the probability of climate adaptation. As expected, extension visits used as a proxy for access to agricultural information has a positive effect on adaptation. The result implies that repeated visits by extension officers are important in influencing climate adaptation. Extension support enhances the promotion of climate adaptation technologies through the provision of advice, information and technical support to farmers. Membership of association has a positive influence on climate adaptation. Other variables like institutional factors, access to credit and distance to market had the expected positive co-efficients but are not statistically significant.

The growing concern to include farmers' perception of technological attributes in adoption models is justified by this study as farmers' perception of yield potential is statistically significant. These attributes are positively related to the adoption decision. The high significance level for yield potential shows that yield of technology is of extreme importance to farmers. Climate change awareness, and this is positively influences the decision to adopt technologies but not statistically significant. One major climate variable of interest was temperature and this had significant and positive influence on the decision to adapt for climate change. Temperature squared significantly influenced the adoption of technology. The results suggest that there is a non-linear relationship between temperature and technology adoption. It implies that increasing temperature that there is an increased probability of technology adoption. With increased incidence of extreme climatic events like temperature, farmers are being educated on climate change and possible adaptation options through discussions in the media and contact with researchers and extension officers. This result shows that the education of farmers on climate change is having positive impacts on adaptation through technologies options.

Determinants of the intensity of adaptation to climate change in agriculture :

The result of the second stage of the model on the intensity of technology adoption is also shown in Table 4. The result showed that after deciding to adopt the technology, most of the factors were no longer critical in determining the intensity of adoption.

The result obtained in the first hurdle, farm income was not significant but farm income of household (proxy for capacity to invest) that are important in the adaptation decision significantly influenced the extent of adaptation. The coefficient of distance to market was negative and statistically significant, implying that longer the distance to market, the smaller the intensity of adaptation. Access to the credit was positive and statistically significant, implying

Table 4 : Determinants of climate change adaptation

Variables	Double hurdle model				Tobit model	
	Probit (first hurdle)		Truncated regression (second hurdle)		Tobit	
	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error
Age	-0.2180***	0.0790	0.0044	0.0097	-0.1306***	0.0490
Age square	0.0020	0.0008	-0.00002	9.16E-05	0.0012	0.0005
Education	-0.0010	0.0257	0.0011	0.0034	-0.0011	0.0177
Farm income	-5.33E-06	6.06E-06	1.34E-06***	7.93E-07	-3.2E-06	4.07E-06
Farm size	0.0102	0.0093	-0.0015	0.0012	0.0066	0.0063
Distance to market	0.0055	0.0329	-0.0149***	0.0043	0.0016	0.0221
Extension contact	0.0401***	0.0222	-0.0001	0.0029	0.0285***	0.0151
Access to credit	0.2354	0.2020	0.0501***	0.0267	0.1505	0.1380
Membership in farmers' associations	0.3769***	0.2053	0.0241	0.0278	0.2562***	0.1400
Yield potential of climate adaption technologies	0.0110**	0.2074	0.0396	0.0269	0.0275	0.1425
Climate change awareness	0.2131	0.2115	-0.0212	0.0276	0.1326	0.1426
Temperature	1.3120***	0.7150	0.0021***	0.0953	-0.8642***	0.4749
Rainfall	-0.0066	0.0440	7.38E-06	0.0019	0.0022	0.0304
Temperature^2	0.0261***	0.0144	0.0074	0.0059	0.0172***	0.0096
Rainfall^2	2.94E-05	0.0006	-0.0001	7.66E-05	-6.9E-05	0.0004
Constant	21.3129***	9.1640	-0.0938	1.2069	13.7432	5.9998
Log likelihood	-113.0455		96.8433		-179.1647	
Pseudo R^2	0.0919				0.0573	
Prob>Chi^2	0.0866		0.0073		0.0897	
Number of observation	180		179		180	

Note: *** and ** indicate significance of values at P= 0.01 and 0.05, respectively that access to the credit increases, extent of adaptation. Temperature was the only variable that was statistically significant in both the hurdles. This results suggest that farm households may decide to adapt technology with high intensity with increasing temperature.

Constraints to climate change adaptation in agriculture :

The non-adopters cited lack of finance, lack of knowledge about technology, high cost of adaptation, lack of technical skill, inadequate size of land holdings and inadequate training and demonstration as the reasons for not adopting the technology (Table 5).

Table 5 : Constraints to climate change adaptation in agriculture

Reasons	Respondents	
	Mean score	Rank
Lack of finance	69.47	I
Lack of knowledge about technology	60.57	II
High cost of adaptation	54.17	III
Inadequate size of land holdings for the adaptation	42.18	IV
Lack of technical skill	38.10	V
Inadequate training and demonstration	32.33	VI

The sample respondents were asked to rank the possible constraints for climate adaptation. The details of probable constraints were given to the respondents and were requested to rank them. This was converted into score and ranked through Garret ranking technique and the details are furnished in Table 5. Lack of finance (Mean score 69.47) was the prime constraint climate adaptation followed by lack of knowledge about technology, high cost of adaptation, inadequate size of land holdings, lack of technical skill, and inadequate training and demonstration were the major constraints in climate adaptation.

Conclusion :

This study focused on climate adaptation among rural farmers, in western zone of Tamil Nadu. Generally farm households make climate adaptation decisions sequentially by deciding whether or not to adopt and then to what extent (intensity of adoption). Among the institutional factors, extension visits and membership in farmers' association significantly influenced the probability of climate adaptation through technology. The analysis highlighted that access to information about climate change was a key determinant in the adaption to climate change. Membership in farmers' associations had a positive influence on climate adaptation. The high significance level for yield potential of climate adaptation technologies shows that yield increase due to adaptation technologies was an important factor in adaption decisions. Temperature had significant and positive influence on the decision to adapt for climate change. Temperature squared significantly influenced adaptation. This shows a non-linear relationship between temperature and climate adaptation. Thus extension contact and membership in farmers' association and climate change awareness were pivotal factors in climate adaptation decisions. Temperature influenced both farm households' decision to adapt and the extent of adaption. The coefficient, distance to market was negative and statistically significant, which implies longer the distance, lesser the intensity of climate adaptation. Access to credit is statistically significant and positive implying high adaptation rates due to availability of credit facility.

The results suggest that new agricultural technologies are very important in helping smallholder farmers to continue to produce food in a changing climate, but more complementary support is needed if these technologies are to be taken up by farmers on a large scale. Necessary interventions include improving access to information popularising the available adaptation technologies, timely access to the technologies and improving access to credit, particularly for the resource-poor farm households.

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