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ADAPTING TO CLIMATE CHANGE THROUGH CROP CHOICE BY SMALL AND MEDIUM FARMERS IN SOUTHERN ZONE OF TAMIL NADU, INDIA

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ABSTRACT

Unpredictable changes in the climate can have a significant impact on crop yield in India in general and in particular in the climate vulnerable state of Tamil Nadu. This study evaluates how farmers in the Sothern Zone of Tamil Nadu adapt crop change as a technique to cope with uncertainty in crop yield. Three districts in the Sothern Zone, viz., Virudhunagar, Thoothukudi and Thriunelveli districts were adopted for this study. The sample size was equally distributed with 60 households randomly selected and who actively engage in agriculture. The results derived from the Multinomial Logit Model indicate that older farmers were more likely to choose sorghum, groundnut and less likely to choose maize, fruits and vegetables. Education had positive and significant influence on growing sorghum groundnut and chillies. Fruits and vegetables are more likely to chosen if farmer has large acreage. The climate variables seem to have neutral effect for sorghum and groundnut, hence farmers lend to choose theses crops for price stability. Farmers are most likely to prefer sorghum, cotton, maize and groundnut when income increases from other non-farm sources. When temperature increases by 1°C, farmers more often tend to choose pulses, sorghum, chilli and groundnut. If precipitation increases by 1 cm, farmers choose to cultivate pulses, maize, cotton, fruits and vegetable. Farmers adaptations may vary across agro climatic zones of Tamil Nadu. Hence local government policies and programs in agriculture should have a built in component to address the climate change issues.

Keywords: Adaptation, Crop choice, Climate change, Impacts, Multinomial Logit, Southern Zone, Tamil Nadu.

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INTRODUCTION

The impacts on agriculture due to climate change have received considerable attention in the developing world which is closely associated with food security and poverty and economic status of vast majority of the population (Kurukulasuriya and Rosenthal, 2003; Carraro and Sgobbi, 2008; Kameyama et al., 2008). Past studies using cross section data found how a farmer adapts to climate by changing crops (Seo and Mendelsohn, 2008). Policy responses to climate change include Mitigation and adaptation. Mitigation refers reduction of Green House Gases (GHGs) Because GHG emissions known to be a major contributor to change in the earth's climate which requires long term policy options. Adaptation strategies, on the other hand refers to local farmers ability to adapt to climate change in the short to medium term by crop change, crop choice, crop rotation, and crop diversification. While mitigation is seen largely as a *reactive policy* response to climate change whereas adaptation is a *proactive* strategy. Though GHG mitigation has dominated the climate policy widely thus far, alternate adaptation strategies are coming to the fore of late in order to formulate a more comprehensive policy response at social, technological, institutional and policy level (Singh et al., 2012). One of the crucial inputs needed for policy formulation on mitigation or adaptation is information on the potential impacts of climate change on various climate sensitive sectors.

Agriculture sector is most vulnerable to climate change and can inflict adverse economic impact on small farmers (Pearce et al., 1996; Tol 2002; Mendelsohn and Williams 2007). But the magnitude of such damage will depend on how effectively farmers adapt to the new climates (Mendelsohn 2000). Farmers can increase their net revenue through efficient adaptations strategies in short to medium time frame. Initial research indicates that farmers are likely to make many changes including changing irrigation, crop species choice, and livestock species choice (Kurukulasuriya and Mendelsohn 2007, 2008; Seo and Mendelsohn 2008a; 2008b).

These adaptations strategies are known to reduce the damages from climate change (Kurukulasuriya et al., 2006; Kurukulasuriya and Mendelsohn 2008; Seo and Mendelsohn 2008b). Further, there are additional measures that would require government and institutional coordination such as the development of irrigation potential and new breeds of animals and crop varieties to cope with high temperatures. These adaptations describe long-run behavior and do not capture some of the potential problems associated with short-term adaptation rates (Mendelsohn 2000; Kelly et al., 2005).

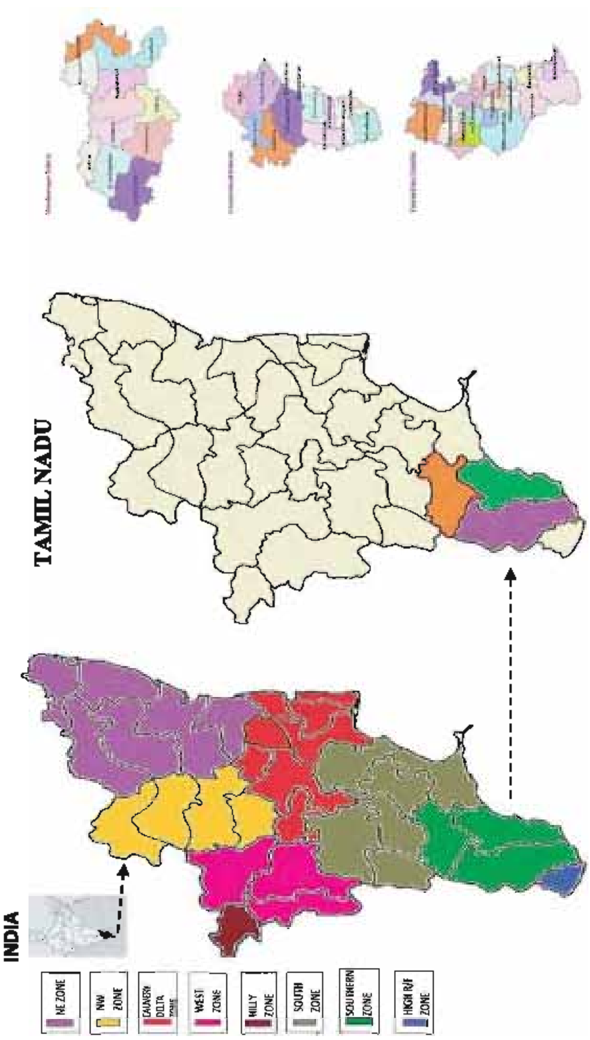
Moreover, small farmers lack resources to adequately protect themselves or adapt rapidly to the changed circumstance, and more importantly the local weather conditions. The mitigation and adaptation to climate change are necessary to ensure food and energy security, which are the pre-requisites for sustainable economic development. Against this background, this study attempts to evaluate how small and medium farmers cope with adaptation strategies with respect to climate change.

METHODS OF DATA ANALYSIS

Description of Data

The Southern Zone in Tamil Nadu is one of the most vulnerable zones to climate change (Figure-1). Therefore, the study conducted surveys at the farm level from three Southern zone districts: Virudhunagar, Thoothukudi and Thriunelveli. These districts comprise of 11, 12, and 19 blocks respectively. From each district one block was selected based on the maximum percent of area under monsoon dependent agriculture. Accordingly, Aruppukottai, Vilathikulam and Kuruvikulam blocks were selected from Virudhunagar, Thoothukudi and Thriunelveli districts. We randomly selected 60 farmers from each districts, totalling of 180 sample participants. The detailed survey was conducted during the period of December 2011 to March 2012.

FIGURE1. STUDY AREA - SOUTHERN ZONE



Source: Indian Meteorological Department (2011) available at: www.imdchennai.gov.in

Climate data were collected from Department of Statistics, Government of Tamil Nadu. Monthly climate data were averaged to construct crop growing season climate data. In the southern zone, crop growing climate data is the average of monsoon (June, July, August and September) and post monsoon periods (October, November and December) respectively.

Theory

Adapting to climate change through crop choice: Adaptation measures help farmers guard against losses due to variations in temperatures and precipitation. The analyses presented in this study identified the important determinants of adaptation. The analytical approaches that are commonly used in an adaptation decision studies involves Multinomial Logit (MNL) and Multinomial Probit (MNP) models. Both the MNL and MNP are important for analyzing farmer's adaptation decisions as these are usually made jointly. These approaches are also appropriate for evaluating alternative combination of adaption strategies, including individual strategies (Hausman and Wise, 1978; Wu and Babcock, 1998). This study used a multinomial logit model to analyse the determinants of farmers' adaptation strategies.

The advantage of using a MNL model is its computational simplicity in calculating the choice probabilities that are expressible in analytical form (Tse, 1987). This model provides a convenient closed form underlying choice probabilities, with no need for multivariate integration, making it simple to compute choice situations by many alternatives. The main limitation of this model is that the independence of irrelevant alternatives (IIA) property, which states that the ratio of the probabilities of choosing any two alternatives is independent of the attributes of any other alternative in the choice set (Hausman and McFadden 1984; Tse, 1987).

The MNL model for adaptation choice specifies the relationship between the probability choosing a crop j (j=1, 2…) and set of explanatory variables X (Greene, 2003). The study assumed that each farmer faces a set of discrete, mutually exclusive choices of adaption measures. Following the standard assumption of many agro-economic studies, profit π is a function of climate variables as well as socioeconomic characteristics of farmers (Schlenker et al., 2006). Assuming the net revenue of i^{th} farmer choosing a j^{th} crop and is written as,

$$\pi_{ij} = V_j (K_i, S_i) + \square_j (K_i, S_i) \qquad \text{.........................(1)}$$

Where K is a vector of exogenous characteristics of the farm and S is a vector of characteristics of the farmer. The vector K includes climate variables; and S includes the relevant socio-economic and demographic information. The profit that the farmer obtains from choosing jth crop as shown in (1) is thus decomposed into:

a) A part labeled $V_j (K_i, S_i)$ comprising some known parameters, and,

b) An unknown part $\square_j (K_i, S_i)$ that is treated as a random error.

The farmer will choose the crop that gives him the highest profit. When farmers select multiple crops, the crop choice is defined as the single crop with the greatest net revenue. Alternatively, this study could have examined all combinations of crops that farmers select (Seo and Mendelsohn, 2008). However, the number of combinations is large and becomes difficult to model. In this connection, this study focused on single crop (the crop that yields the highest net revenue). The choices are consequently mutually exclusive and exhaustive, i.e. the farmer must pick only one crop from available crops.

Defining Z= (K, S), the farmer will choose jth crop over all other crops k if:

$$\pi_j^*(Z_i) > \pi_K^*(Z_i) \, for \, \forall K \neq j.[or \;\; if \;\; \varepsilon_k(Z_i) - \varepsilon_j(Z_i) < V_j(Z_i) - V_K(Z_i) \, for \;\; K \neq j] \ldots \quad (2)$$

More succinctly, his problem is:

$$\underset{j}{\arg.\max} \left[\pi_1^*(Z_i), \pi_2^*(Z_i)........\pi_j^*(Z_i)\right] \qquad .... (3)$$

The probability p_{ij} for the jth crop to be chosen by ith farmer is then given as

$$p_{ij} = pr\,(\varepsilon_k(Z_i) - \varepsilon_j(Z_i) \leq [V_j - V_k])\ \forall\, k \neq j \qquad ....(4)$$

Assume that ε is impudently Gumbel distributed and the profit function can be written linearly in its parameters: $V_k(Z_i) = Z_{ik}\gamma_k$ where Z_{ij} is a vector of observed variables relating to alternative j. With this specification, the probabilities become

$$p_{ij} = \frac{e^{Z_{ij}\gamma_j}}{\sum_{k=1}^{j} e^{Z_{ik}\gamma_k}} \qquad ....(5)$$

This shows the probability that ith farmer will choose the jth crop among k alternatives (McFadden, 1973; Train, 2003). The parameters can be estimated by the Maximum Likelihood Method, using an iterative non-linear optimization technique such as the Newton-Raphson Method. These estimates are Consistent and Asymptotically Normal (CAN) under standard regularity conditions (McFadden, 1999).

The dependent variable as a probability that farmer will choose the jth crop among k alternatives Viz., 1.Pulses 2.Sorghum 3.Cotton 4.Maize 5.Groundnut 6.Chilli, 7.Fruits and Vegetables. These are major crops in the selected blocks and the farmer will choose the crop that gives the highest profit.

The independent variables are expected to have association with the level of climate change adaption. the following are the independent variables used in the model: crop growing season average temperature (^{0}c), crop growing season precipitation (cm), square root of crop growing season temperature (^{0}c), square root of crop growing season precipitation (cm), age (number of years), years of education (number of years), years of education (number of years), household size (number of adult members in the household), farm size (hectare), dummy, takes the value of 1 if owned and 0 otherwise, price of selected crops (groundnut, maize, black gram, cotton, fruits and vegetables), annual non-farm income, were selected based on available literature.

RESULTS AND DISCUSSION

Many studies predicted reduction in the yields of specific crops in warmer temperature due to drought (Reilly et al., 1996; McCarthy et al., 2001). These studies assume farmers making no changes in crops and predict large losses in net revenue due to climate change. But some studies noted that farmers substitute new crops that will perform better in the new climate/changed climate (Adams et al., 1999; Mendelsohn et al., 1994, Kurukulasuriya et al., 2006). Hence an attempt was made in this section to explore how farmers would make crop choices to adapt to changes in exogenous factors such as temperature, rainfall and socio-economic variables along with the endogenous factors using a multinomial logit model.

The probability of choosing each crop was assumed to be a function of seasonal temperature and seasonal precipitation during the cultivation period. Other explanatory both demographics and socio- economic variables such as farmer age, education, household size, prices, livestock ownership and non-farm income were included to strength the model predictability. The choice of pulses has been left out of the regression as the base case. The estimated value of positive and significant coefficients implies that the probability of choosing each crop increases as the corresponding explanatory variable increases. Response of farmer's crop choice with respect to new climate is presented in table 1.

Table 1A. Multinomial Logit Model for Crop Choice

Particulars	Sorghum		Cotton		Maize	
	Coef.	Std. Er	Coef.	Std. Er	Coef.	Std. Er
On-Season temperature	-0.418	2.954	-11.334**	5.343	-2.408	6.459
On- Season Precipitation	-0.551**	0.264	0.879**	0.401	0.396	0.332
On-Season temperature^2	0.035	0.052	0.203**	0.093	0.064	0.112
On- Season Precipitation^2	0.000**	0.000	-0.001**	0.000	0.000	0.000
Age of Household	0.067*	0.039	-0.059	0.049	-0.122**	0.057
Education	0.160*	0.099	0.216	0.168	0.073	0.127
Family Size	-0.131	0.264	0.491	0.412	0.031	0.361
Land holdings	-0.021	0.151	0.361	0.265	-0.054	0.216
Livestock Ownership	0.497**	0.201	16.781	12.326	1.732*	0.904
Maize Price	0.009	0.158	0.483**	0.238	0.098	0.208
Sorghum Price	0.346***	0.115	0.301*	0.163	-0.137	0.134

Cotton Price	0.257	0.187	-0.028	0.318	0.978**	0.338
Groundnut Price	0.068	0.128	0.274	0.182	0.012	0.171
Chilli price	0.183	0.123	0.137	0.187	0.106	0.165
Black Gram Price	-0.406*	0.219	-1.192***	0.318	-0.883***	0.238
Mango Price	0.021	0.110	0.170	0.171	0.040	0.161
Tomato Price	0.178	0.131	0.240	0.167	0.208	0.153
Non-farm Income	0.000*	0.000	0.000***	0.000	0.000**	0.000
Constant	151.346	94.990	-173.264	127.253	-145.058	134.492

Table 1B. Multinomial Logit Model for Crop Choice

Particulars	Groundnut		Chilli		Fruits and Vegetables	
	Coef.	Std.Err	Coef.	Std.Err	Coef.	Std.Err
On-Season temperature	11.306	7.089	19.040	22.623	-66.494***	22.472
On- Season Precipitation	-1.27**	0.641	-0.599	0.578	0.131	0.514
On-Season temperature^2	-0.208	0.130	-0.47**	0.234	1.165***	0.393
On- Season Precipitatio^2	0.001**	0.000	0.000	0.000	0.000	0.000
Age of Household	0.33***	0.124	-0.118	0.115	-0.337*	0.189
Education	0.45**	0.229	0.21**	0.097	0.304	0.336
Family Size	-0.399	0.536	-0.35**	0.157	-0.759**	0.318
Land holdings	-0.513	0.530	-0.171	0.650	1.493**	0.616
Livestock Ownership	2.345	3.831	-1.353	5.003	-4.850	3.131
Maize Price	-1.021**	0.481	-0.443	0.416	0.183	0.615
Sorghum Price	0.047	0.226	0.047	0.323	-0.707**	0.345
Cotton Price	-0.022	0.524	0.533	0.548	0.140	0.526
Groundnut Price	3.45***	1.031	2.51***	0.841	2.311***	0.721
Chilli price	-0.322	0.371	0.668	0.751	0.149	0.340
Black Gram Price	-1.26***	0.441	-1.07***	0.343	-0.95***	0.344
Mango Price	0.389	0.294	1.26***	0.464	0.087	0.404
Tomato Price	-0.087	0.349	0.524	0.550	-0.300	0.413
Non-farm Income	0.00***	0.000	0.000	0.000	0.000	0.000
Constant	196.331	216.19	-154.60	402.03	786.15***	299.197

Note: Number of observation =180, LR chi2 (108) = 461.56, Prob > chi2 = 0.0000, Log likelihood = 107.804.

The likelihood of a farmer choosing sorghum and groundnut increases as the age of the farmer increase and less likely to choose maize, fruits and vegetables. Education has positive and significant influence on growing sorghum, groundnut and chillies. Farm holders with large family size are less likely to choose chillies, fruits and vegetables. Large farm holders are more likely to choose fruits and vegetables. The livestock ownership positively influences the probability of selecting sorghum and maize. As expected, farmers often prefer sorghum and groundnut as these crops have less volatility in market price movement. The cross-price effects are though significant the results are not conclusive. When non-farm income increases, farmers prefer sorghum, cotton, maize and groundnut for cultivation. The reasons might range from being less labor intensive, to tolerance to climate change and also need of lower investments as compared to other crops.

Marginal Effects of Climate Change on Crop Choice

Table 2 shows the baseline value and marginal effects of temperature and precipitation evaluated at the mean. The major crops that farmers selected in the southern zones were pulses (27 %), sorghum (19%), maize (16%), cotton (13%), groundnut (12%), chilli (7%), and fruits and vegetables (6%). Altogether 72% of the total crop revenue was generated from these seven crops.

Table 2. Baseline Value and Marginal Effects of Climate Change on Crop Choice

Crop	Pulses (%)	Sorghum (%)	Maize (%)	Cotton (%)	Groundnut (%)	Chilli (%)	Fruits and Vegetable (%)
Baseline (%)	27	19	16	13	12	7	6
*Temperature ^{o}C	0.32	.026	-.11	-0.23	0.02	0.05	-0.01
*Precipitation (cm /season)	0.051	-0.12	0.01	0.06	-.01	-0.03	0.01

Note: * Marginal effects of climate change on crops.

As temperature increases by $1^{o}C$, farmers less often tend to choose maize, cotton, fruits and vegetables but prefer pulses, sorghum, chilli and groundnut more often. If precipitation increases by 1 cm, farmers more likely to choose pulses, maize, cotton, fruits and vegetables. On the other hand, if climate change caused precipitation to fall, farmers would prefer sorghum, chilli and groundnut.

CONCLUSION

Agriculture is a main stay in many part of rural India. Therefore any climate induced impacts on agriculture will contribute to poverty, malnutrition and unemployment. Based on this study we recommended that the crop insurance scheme should be properly planned and executed to reduce the financial losses of farmers in the vulnerable regions to mitigate uncertainty and risk associated with yield loss due to climate change. Moreover adaptations may vary across agro-climatic zones of Tamil Nadu depending on climatic vulnerability. Hence, government policies should ensure that farmers have better access to affordable or subsidized inputs and credit to increase their ability and flexibility to change production strategies in response to the new climate conditions. If the climate impacts in agriculture are not mitigated, farmers ultimately may turn to move outside the agriculture sector, including rural-urban migration or finding wage employment, etc. Hence, all the development programmes in agriculture should have a built in component to address the issues to climate change. Further, investments in new technologies and crop varieties that are tolerant to stresses need to be given priority.

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