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Farm-Level Adaptation to Climate Change and Impacts on Household Food Security: Evidence from the Dry Zone of Sri Lanka

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Abstract: Climate change can have detrimental impacts on rural agricultural households. Farmers all over Sri Lanka are seen adopting numerous strategies to face the impacts of climate change. Climate change poses considerable challenges to all four dimensions of food security. Therefore, this study aims to explore climate related factors affecting the level of household food security of rural farmers. The study was conducted with 110 farmer families in the district of Anuradhapura. Data were collected through a structured questionnaire-based survey over a period of four months along with field observations. An ordered logistic regression was carried out in order to find out the influence of climate change adaptation and other related factors at farm-level on the household food security. Household food insecurity access scale was used to categorize the sample into different levels of food security. Results show that farmers who adopted climate change strategies are more food secure compared to those who did not adapt. Exposure to climate change and strong social networks also have a positive influence in leading these households to a higher level of food security. Certain socio-demographic factors such as the farmer's level of education and being a male-headed household were also positively associated with food security. The study therefore emphasizes the importance of stronger policies that can enhance farmer adaptation strategies through better accessibility to endowments such as alternative livelihoods, stronger social networks, awareness and better education for agricultural households.

Keyword: Climate change, Farm-level adaptation, Food security, Household

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Introduction

Climate change is an inevitable phenomenon that is being experienced globally in various forms and will continue for deca des even with immediate implementation of mitigation strategies. Developing countries are more vulnerable to climate change due to the already stressed marginal production and scarcity of capital on development and dissemination of adaptation measures (Fischer *et al*., 2005). The impacts of global climate change experienced at farm level in developing countries may lead to increase in poverty levels among rural communities due to effects on agricultural productivity.

In Sri Lanka, about 40% of households are agricultural which covers 4,399,404 acres in total land extent. Drought and irregular rains both in *Yala* (43%) and *Maha* (52%) season every so often inflict detrimental effects on households in the dry zone (Northern, Eastern, North Western province, Hambantota, and Anuradhapura districts) (Department of Census and Statistics, 2017). Among the 2.3 million agricultural operators, 22% and 14% operators cultivate paddy during Maha and Yala seasons which shows clearly uneven distribution due to unavailability of water (Department of Census and Statistics, 2014).

The impact of climate change on Sri Lankan agriculture has been researched particularly on principal crops such as paddy, tea and coconut (De Costa, 2000; De Silva *et al*., 2007; Peiris *et al*., 2004; Wijeratne *et al*., 2007) while some have attempted to quantify the impacts in terms of yield loss and economic loss (Diyawadana *et al*., 2016; Fernando *et al*., 2007; Kalim, 2015; Seo *et al*., 2005; Wijeratne *et al*., 2007). The findings show that climate change impacts on the agricultural sector in Sri Lanka can be significantly reduced through appropriate adaptation strategies. Further, according to Esham and Garforth (2013), farmers perceive the ongoing climatic changes based on their experiences and take measures to address climate change and variability in five main categories i.e. crop management, land management, irrigation management, income diversification, and rituals.

Climate change has abundant impacts on food security. Food security refers to a situation that exists when all people at all times have physical, social, and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (FAO, 2006). Later the definition was conventionally subdivided into four main components i.e. (a) food availability: physical presence of food, (b) food access: ability of acquisition through production or purchase, (c) food utilization: the appropriate nutritional content of the food and the ability of the body to use it effectively and (d) stability: all four above dimension should be enduring without any fluctuations over time (FAO, 2011).

It is important to explore each of these aspects of food security in the context of climate change as well. Climate change will impact food availability, access, and utilization through many pathways. Climate induced changes in agricultural productivity will likely affect the incomes earned and the food prices faced by poor households that consequently effect on food security. Further the health impacts associated with climate change could hamper the ability of individuals to utilize food effectively in particular the methods used to understand them. Food security is more than just food production, and that some of the most important effects of climate on food security could be through its effects on food prices, incomes as well as the health of the poor (Hertel *et al*., 2010).

Contextualizing to Sri Lanka, the climate change adaptation strategies can be either traditional (e.g. threshing floor) or modern (e.g. drought resistance crop varieties). Changing planting dates (early Planting), appropriate irrigation system (micro irrigation), switch the use of land from food to cash crop, changes in livestock management (maintain few cattle around homestead), apply traditional weather forecasting methods, communal collective actions (praying together to god/blessings) are the strategies that stand out among all.

With this background, it is important to identify the relationship between climate change and food security with respect to the farmer openness to the adaptation strategies at farm level. Thus, the purpose of the present study is to explore the influence of climate change adaptation at farm-level on the household food security. Specifically, the objectives of the study are: 1) to measure the degree household adaptation to climate change 2) to determine the relationship between food security and climate change adaptation in the farmer households and; 3) to make recommendations on effective interventions of government bodies and local farmer communities in the face of climate change.

Agriculture, Climate Change and Food Security in Sri Lanka

Agriculture is a vital sector in the Sri Lankan economy due to its significantly large contribution to the Gross Domestic Product and foreign exchange earnings. Agriculture plays a central role in ensuring food security. It could be seen that livelihood strategies of the most food insecure households in Sri Lanka are based on agriculture. Increasing impacts of climate change have threatened the agriculture sector thereby largely affecting the food security. Climatic changes such as increasing temperature, rainfall, floods as well as prolonged period of droughts have had detrimental effects on the staple food; rice as well as other crops. Unless climate challenges are met with proper adaptation and mitigation measures, agricultural production in the future is at stake resulting in serious challenges for the rising population.

Climate change directly affects the availability as well as the stability dimensions of food security. Farmers around the world seem to use certain strategies as measures of adapting to climate change such as planting of short duration crop varieties, altering input use and fertilizer rates, diversification of income through other activities such as livestock raising.

The United Nations Food and Agriculture Organization ranks Sri Lanka at the 84th of Global Hunger Index and 64th in the Global Food Security Index which shows that Sri Lanka is doing poorly in terms of food security compared to other South Asian countries. Food security is directly dependent on the agriculture sector. Therefore, climatic changes can have adverse effects on the country's level of food security. Hence, this study aims to explore the relationship between the level of climate change adaptation and the household food security.

Food security is a multi-dimensional concept. Household food security can be explained in terms of four dimensions; 1) food availability, 2) food accessibility, 3) utilization and 4) stability (FAO, 2011). World Food Summit (2000) defined the concept of food security at household, national and global level as a state achieved when all people, at all times, have physical and economic access to adequate, nutritious and safe food to meet their dietary wants and food likes for an active and healthy life (FAO, 2006).

Methodology

Data

Anuradhapura district in the dry zone is largely affected by drought and irregular patterns of rainfall. Agricultural production in the dry zone, particularly paddy is very much dependent of rainfall and availability of irrigation water. Thus, climatic changes can pose severe impacts of household food insecurity (Ministry of Environment, 2011). Anuradhapura district therefore was selected to collect data.

A pilot study was carried out with ten paddy farmer households selected from Thulana Grama-Niladhari (GN) Division in Rambawa Divisional Secretariat (DS) division. Ten farmer households were interviewed in order to gather the information. Initial questionnaire was revised using the gathered information. Sampling framework consisted of n=110 farmer households collected from five GN divisions in the Anuradhapura District. A stratified sampling technique was used to select the sample of farmers. The questionnaire was administered among the households. Pilot questionnaire was revised before eth actual survey.

The survey gathered information regarding household demographics; food availability; characteristics of the household; food consumption; dietary diversity; agricultural production; income and expenditure of the household. It posed several questions pertaining to how climate change was

sensed such as stress factors, exposure to climate change, shocks, coping and climate change adaptation strategies affecting the household.

Conceptual Framework

Variable Identification

This study categorized the level of food security of a household using the Household Food Insecurity Access Scale (HFIAS). This categorical variable was in turn used as the dependent variable while indices such as climate change adaptation index social network index and other socio demographic factors were used as the independent variables together with other socio-demographic factors.

USAID's Food and Nutrition Technical Assistance (FANTA) program identified a set of questions to measure the household food security. This set of questions named as the Household Food Insecurity Access Scale (HFIAS) is widely used around the world to measure the level of food security, categorize household food security and distinguish food secure house from food insecure households (Bilinsky, 2007). The set of questions represents different dimensions of food security, availability, accessibility, utilization and stability. These questions were included in the questionnaire together with other questions to explore the status and factors affecting food security at household level.

HFIAS set of questions first poses an occurrence question. For example, "whether the condition of one of the four food security dimensions happened at all in the past four weeks". The respondents are given an option of yes or no as the answer. For example, whether in the past four weeks, have you had to worry that your household would not have enough food? If the respondent answers "yes" to an occurrence question, a frequency is then presented to determine whether the condition happened rarely (once or twice), sometimes (three to ten times) or often (more than ten times) in the past four weeks (Coates *et al*., 2007). A score, herein termed as HFIAS score was calculated from the set of statements. This score was used as the measure of the degree of food insecurity. The HFIAS score variable is calculated for each household by summing the codes for each occurrence question (Coates *et al*., 2007).

The four levels were categories according to the scores given for each question in the questionnaire (Table 1). According to this categorization, each household will be placed in one category.

1 = Food Secure
2 = Mildly Food Insecure
3 = Moderately Food Insecure
4 = Severely Food Insecure

HFIA category = 1 if [(Q1a=0 or Q1a=1) and Q2=0 and Q3=0 and Q4=0 and Q5=0 and Q6=0 and Q7=0 and Q8=0 and Q9=0]

HFIA category = 2 if [(Q1a=2 or Q1a=3 or Q2a=1or Q2a=2 or Q2a=3 or Q3a=1 or Q4a=1) and Q5=0 and Q6=0 and Q7=0 and Q8=0 and Q9=0]

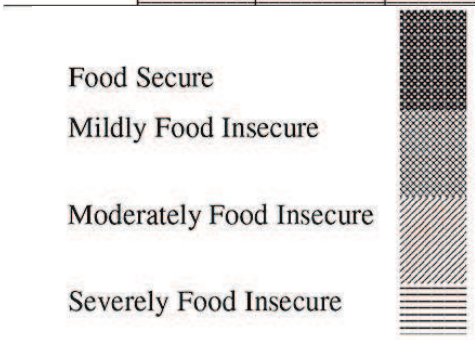
HFIA category = 3 if [(Q3a=2 or Q3a=3 or Q4a=2 or Q4a=3 or Q5a=1 or Q5a=2 or Q6a=1 or Q6a=2) and Q7=0 and Q8=0 and Q9=0]

HFIA category = 4 if [Q5a=3 or Q6a=3 or Q7a=1 or Q7a=2 or Q7a=3 or Q8a=1 or Q8a=2 or Q8a=3 or Q9a=1 or Q9a=2 or Q9a=3]

Households were then categorized in to four levels of food insecurity; food secure, mild, moderately and severely food insecure (Coates *et al*., 2007) (Table 1).

Table 1: Food security level categorization

Questions	Frequency		
	Rarely 1	Sometimes 2	Often 3
1a			
2a			
3a			
4a			
5a			
6a			
7a			
8a			
9a			



A food secure household experiences none of the food insecurity conditions (Table 1). A mildly food insecure household worries about not having enough food sometimes or often, is usually unable to eat preferred foods, and/or eats a more monotonous diet than desired. But it does not cut back on quantity. A moderately food insecure household sacrifices quality of the meal more frequently, by eating a monotonous diet or undesirable foods sometimes or often and has started to cut back on quantity by reducing size of meals or number of meals, rarely or sometimes. A severely food insecure household has a tendency to cut back on meal size or number of meals often, and usually experience running out of food, going to bed hungry most of the days.

Factors that could affect the level of food security were explored using logit regression. These factors included degree of climate change adaptation, exposure to climate change and social network of the respondents. A set of statements reflecting each factor was included in the questionnaire and each statement was presented with a five-point Likert scale ranging from strongly agree (+1) to strongly disagree (+5). An index was calculated for each factor using the responses given for the statements on the Likert scale

Data Analysis

The relationship between the degree of household food security and the influencing factors was analysed using an Ordered

Logit model. The three indices used as independent variables were; climate change adaptation, exposure to climate change and social network. Separate indices computed were used as variables in the model. Responses given to the statements reflecting the factors were recorded on a Likert scale ranging from "strongly disagree" (+1) to "strongly agree" (+5). Responses were analyzed for their construct validity by performing a Confirmatory Factor Analysis (CFA) (Nakamura *et al.*, 2001; Shavell, 1987 and Hair *et al*., 2006). The scores given by respondents to each factor i.e. 'climate change adaptation' were used to derive an index for the respective factor. This was done by taking the aggregate of the scores given by a respondent to each factor on the 5-point Likert scale and dividing it by the Maximum Potential Score (Jayasinghe-Mudalige and Udugama, 2014). In effect, the magnitude of the Index obtained for each factor for every household signals the perceptions and the true behaviour of the households in question. Therefore, this can be used as a proxy to represent those factors in the econometric model (Henson and Traill, 2000).

SPSS (Statistical Package for the Social Sciences) software was used to carry out the analysis. For further analysis, farmers who practice adaptive measure are called "adaptive farmer" while those who are termed "non-adaptive" farmers. Both adaptive and non-adaptive farmers were categories in to four categories in according to the HFIAS scale (Bilinsky *et al*., 2007). The regression model can be specified as below;

$$FSH = \beta_0 + \beta_1(CAI) + \beta_2(ECI) + \beta_3(SNI) + \beta_4(EDL) + \beta_5(GND) + \beta_6(HHI) + \beta_7(LHT) + \beta_8(Age) + \varepsilon_i$$

Where, dependent variable is the category of household food security (FSH) and the independent variables are; Social Network Index (SNI), Climate Change Adaptation Index (CAI), Exposure to Climate Change Index (ECI), Educational Level of the household head (EDL), Gender (GND), Household Income (HHI) and Type of Livelihood (LHT). The variables, CAI, ECI, SNI were included as indices.

Variables CAI, ECI and SNI were index values ranging from 0 to 1 where as gender, level of education, household income and age were included in the model as dummy variables. Indices were computed from responses on the scale.

Results and Discussion

Descriptive Statistics

Majority of the respondents in the sample were male (86%) and were in the age category, 40 - 60 years (63%). Nearly 47 % of the farmers had secondary education. Majority of the farmer households earned more than Rs. 60,000 per month. The sample consisted of 68% farmers who practiced climate change adaptation strategies. If a farmer practices more than eight strategies, the particular households was considered as an "adaptive" household.

Where the type of adaptive strategies is of concern, ninety-five percent of the farmers were seen to adapt traditional techniques and practices for climate change such forecasting, pest and disease management etc. (Figure 2). It is also common to use traditional and indigenous knowledge such as collective praying, performing rituals for gods' blessings etc. The next most popular strategy of the respondents was to change planting time and the use more resistant crop varieties.

Use of effective irrigation techniques such as micro irrigation, and water harvesting techniques were also a popular adaptation strategy (64 %). An Ordered logit model was used to investigate factors affecting the level of household food security. Table1 Shows that Climate Change Adaptation Index (CAI), Exposure to climate change index (ECI), Social Network Index (SNI), gender and education level showed a significant impact on the level of household food security among the paddy farmers in the district.

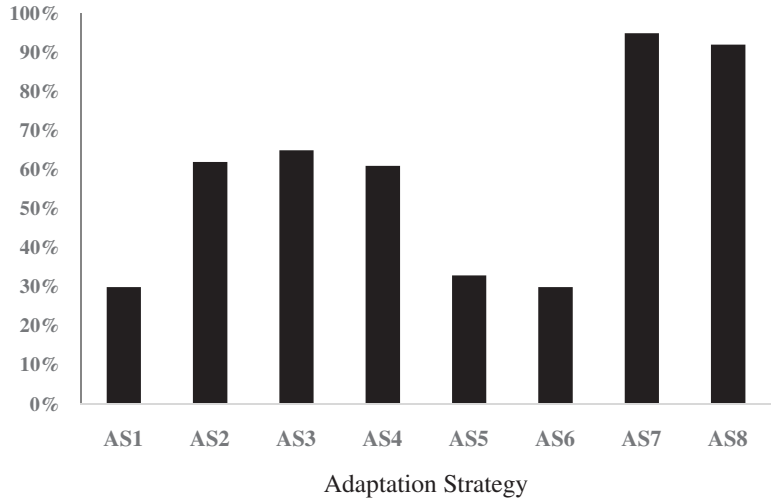


Figure 2: Adaptation strategies practiced by farmers

Note: AS1-Improved crop varieties, AS2-Crop diversification, AS3-Altered planting dates, AS4-Efficient irrigation techniques, AS5-Land management practices, AS6-Altered livestock management, AS7-Traditional forecasting and pest management, AS8-Communal collective action

Results show that household food security is significantly influenced by the level of adaptation to climate change. This implies that adaptation to climatic risks increase the potential to reduce the climate change induced damages whereby increasing the household benefits such as sustained income and food consumption. It was observed that household food security can be characterized as a function of household exposure to climate change as well. This index considered temperature rise, heavy rain and drought conditions in the area. Thus, a higher index value signals a higher exposure risk. Results show that, as the risk of exposure increases, the

households are more likely to fall into a lower category of food security.

Social networks in these areas have a strong impact on the household food security. The network with family, friends and other organizations such as welfare societies seem to support the households via different initiatives in order to make the households more resilient. Some of these programs include seed exchange programs, seed banks, financial assistance and collective management strategies. Literature suggests that strong social networks have a huge influence on the rural households in developing countries (Deressa *et al*., 2009; Chen *et al*., 2014; Hillig and Connell, 2018). Results show that stronger the social network of the households is, the less likely they are to move to a lower food security category.

Table 2: Parameter Estimation of Ordered Logit model

Variable	Coefficient	SE	P Value
FSH			
FSH 1	-49.944	3.212	0.000**
FSH 2	-46.889	3.101	0.000**
FSH 3	-44.887	3.050	0.000**
CAI	-9.103	2.832	0.001**
ECI	-11.366	3.346	0.001**
SNI	-3.848	1.607	0.017**
EDL Dummies			
Primary Education	19.594	0.631	0.000**
Secondary Education	19.594	0.565	0.000**
HHI Dummies			
Less than Rs.20000	-1.228	1.482	0.223
Rs. (20001-40000)	-0.974	2.060	0.151
Rs. (40001-60000)	-0.673	1.393	0.238
LHT	0.163	0.089	0.765
GND	1.052	3.619	0.050**
Age Dummies			
(25-40)	0.482	0.540	0.462
(40-60)	-0.405	0.651	0.420

SE: Standard Error

*Note: ** Significant at p<0.05*

The socio-demographic factors also seem to influence the level of food security. Education showed a positive significant effect showing that compared to very low level of education, farmers with relatively higher level of education seem to be on a relatively higher level of food security. Although this was not expected, it was observed that most farmers with higher level of education are engaged in off farm activities and do not follow significant strategies to avoid climate change. For farmers with below secondary or no education, farming is the only livelihood strategy and thus they mainly engage with farming practices to obtain enough income for their food and other necessities. Another factor that contributes to a resilient household was the gender of the household head. Compared to female-headed households, male-headed households showed a more secure status in terms of food.

Conclusion

This paper examines the influence of climate change adaptation as well as a range of other related factors affecting the level food security of farmer households in Sri Lanka. Farmers around the country in general and in the district of Anuradhapura are seen to be adopting a variety of adaptation practices to counter the adverse impact of climate change. The study was conducted to explore the relationship between food security and climate change and other factors affecting the degree of food security in these households. Results show that the farmers who adapted climate change strategies were more likely to be food secure compared to those who did not. Furthermore, it was shown that climate change exposure was also a determinant of food security. Having a stronger social network strengthens the ability of a households' adaptive capacity thereby increasing the possibility of being food secure. Social networks also have a direct impact on food security as well. Results also show that socio demographic factors such as education can also influence the level of food security over most other factors.

Therefore, this study suggests policies to promote the adoption and practice of climate change adaptation strategies among rural farmers also as a mean of ensuring food security. It is imperative to increase the awareness about the importance of adaptation to climate changes, food security as well as the interrelationships. As the results revealed, education plays a vital factor in increasing the adaptive capacity as well as food security. Therefore, the government policies should pay more attention to awareness and education on the four dimensions of food security.

Another policy consideration could be to increase the capacity of adaptation, both in terms of climate change as well as food security challenges. Awareness and investment on coping strategies is key for these rural households. As the results show, strengthening the social networks

as well as provision of alternative livelihood strategies could also minimise the risk of food insecurity.

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