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Analyzing the Determinants of Farmers' Adaptation to Climate Change in the Chao Phraya River Basin

Kannika Thampanishvong

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Abstract

This study examines the factors that influence farm households' decisions to adapt to climate change in the Chao Phraya River Basin of Thailand. We also identify the methods used by farmers to adapt to flood and drought as well as the barriers to adaptation. Access to agricultural credit, the average rainfall during the rainy season, land tenure, number of members in the households and the socio-economic characteristics of household head are found to be the main drivers behind adaptation to severe flood. Results from our analysis indicate that access to credit, land ownership, vehicle ownership, household size and gender of household head influence farm households' adaptation to severe drought.

Key words: adaptation, flood, drought, determinants, Chao Phraya River Basin of Thailand

JEL classification: Q12, Q18, Q54

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Analyzing the Determinants of Farmers' Adaptation to Climate Change in the Chao Phraya River Basin

Kannika Thampanishvong[*]

1. Introduction

Agriculture has an important driver of Thailand's economy in the past. During 1960s and the early 1980s, there was a rapid agricultural growth based on utilization of underused land and labor as new lands were opened up for farming, facilitated by the existence of a forest frontier where squatting was tolerated. This absorbed growing labor to produce more of the main staples for both the domestic market and export. Later on, agriculture began to transform, as Thailand experienced rapid economic growth led by manufacturing; labor began to leave this sector and it became harder to open up new land. Agricultural sector thus becomes more mechanized and more capital intensive (Leturque and Wiggins, 2010). Despite undergoing a transformation, at present, Thailand is still among the major exporters of several agricultural commodities, such as rice and rubber; and the agricultural sector still employ around 38 percent of the Thai labor force. Despite its contribution to the Thai economy, this sector is challenged by many factors, of which the major ones are the climate-related disasters (Attavanich, 2012).

The major problems of climate change in Thailand are droughts and floods due to fluctuated rainfalls. Basing on the data from Department of Disaster Prevention and Mitigation and Ministry of Agriculture and Cooperatives during 1989-2010, Tadkaew and Kasem (2012) reported that a large amount of agricultural areas were damaged by flood and drought. Supnithadnaporn et al. (2011) argued that during 1989-2010, on average, 8.6 and 2.9 million rai of agricultural areas were damaged by flood and drought. The potential physical impact of climate change on major crops include the impact of uncertain rainfall at the beginning of rainy season on wet season rice; the impact of uncertain rainfall at the end of rainy season on second rice; the cassava's root damage due to heavy rain and the impact of water shortage on sugarcane. In general, extreme weather events such as flood and drought could affect crop productivity and give rise to crop yield losses.

Given these discouraging prospects, the identification of adaptation strategies is vital to support the crop yields. These adaptation strategies can help the farm households buffer against climate change and extreme weather events and

* Correspondence: Kannika Thampanishvong, Thailand Development Research Institute, 565 Ramkhamhaeng 39, Ramkhamhaeng Road, Wangthonglang, Bangkok 10310, Thailand, Tel: +66-2718-5460 ext 415, E-mail: kannika@tdri.or.th

play a crucial role in enhancing security and livelihood of farm households. There is, indeed, a large a growing literature that investigate the farmers' adaptation decision to climate change. By using econometric analysis of cross-sectional data, Di Falco et al. (2011) found that factors that influence Ethiopian farmers' adaptation to climate change include information on farming practices and on climate change. Moreover, households with access to credit are more likely to undertake adaptation strategies. Deressa et al. (2008) used the multinomial logit model to study the determinants of farmers' choice of adaptation methods. Their results show that wealth attributes of households, availability of information, agroecological features, social capital and temperature influence adaptation to climate change in the Nile Basin of Ethiopia. Piya et al. (2012) used the multivariate probit model to analyze the factors that influence the adoption of various adaptation practices of highly marginalized indigenous community in Nepal. The results from their analysis show that perception of rainfall change, size of landholding, status of land tenure, distance to motor road, access to productive credit, information, extension services and skill development training all influence households to adopt adaptation practices to climate change.

While many studies in the literature look at the farm households' implementation of adaptation strategies in response to long-run changes in key climatic variables, such as temperature and rainfall, in this paper, we examine the driving forces behind farm households' decisions to adapt to extreme weather events, i.e. severe flood and drought. This paper aims to provide a micro perspective on the issue of farmers' adaptation to climate change. Specifically, we investigate the farm households' decision to adapt to flood and drought, i.e. implementation of a set of strategies such as changing crop varieties, changing crop calendar, water conservation strategies, etc. Though there exist a number of papers that identified the adaptation actions implemented in the agricultural sector, some of these studies look at adaptation from the macro perspective (Supnithadnaporn et al., 2011), while others look at the adaptation implemented at the community level (Chinvanno and Kerdsuk, 2013). To our best knowledge, this is the first study that attempts to identify factors that determine farm households' decision to adapt to climate-related disasters in the case of Chao Phraya River Basin of Thailand. The objective of this study is to guide policymakers on ways to promote adaptation.

Econometric results show that access to agricultural credit, the average rainfall during the rainy season, type of land tenure, number of members in the households and the socio-economic characteristics of household head, such as level of education and marital status, are found to be the main drivers behind adaptation to severe flood. Results from our analysis indicate that access to credit, land ownership, vehicle ownership, household size and gender of household head influence farmers' adaptation to severe drought.

This paper is organized as follows. Section 2 contains description of the study sites and the survey instruments. Section 3 is devoted to discuss the empirical methodology used to model adaptation to climate-related disasters. Section 4 presents the results from our empirical analysis, and section 5 contains concluding remarks and policy implications.

2. Description of study sites and survey instruments

2.1 Study areas

The Chao Phraya basin is the most important basin in Thailand. The Basin can be divided into 8 sub-basins based on the natural distribution of its river system. In the past, over 90 percent of the area of the Basin is either used for agriculture or covered with forest, with the proportions of these land uses being roughly equal. In recent years there has been encroachment and land conversion in the forest areas for agricultural purposes, while cultivated land near urban centers has been converted to residential or industrial use. Water availability is the key factor constraining future developments in agriculture in the Central Plain. The water quantity in the Basin governs the possible extension of second rice cropping or other field crops in the dry season.

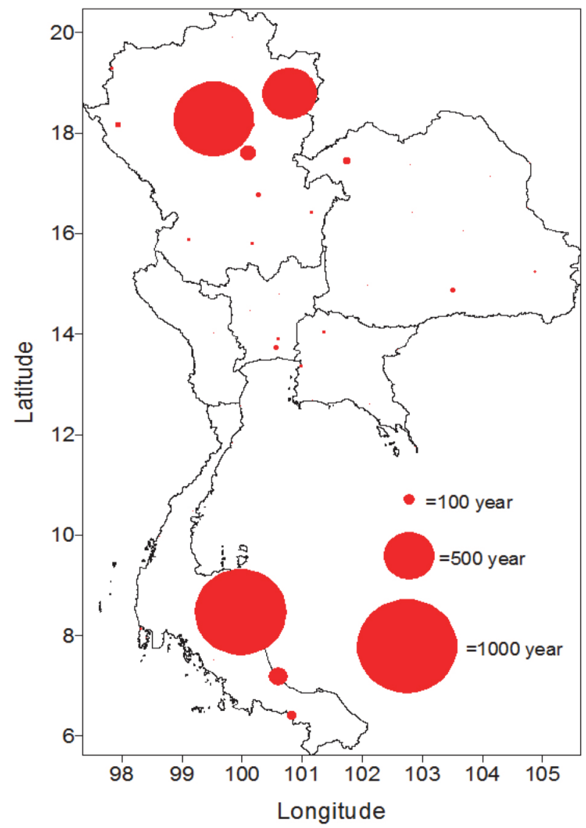
Floods and drought are a natural phenomenon in the Chao Phraya River Basin. Though residents have historically adapted their lifestyle to deal with annual flood events and the Government has constructed multi-purpose reservoirs and other flood control infrastructure, the extreme flooding and drought that took place in recent years increasingly challenge the management of the entire Basin, for example, the major flood of 2011 that set a new precedent in terms of scale and scope of the issues at hand (Figure 1). Two factors appear to be playing the role in explaining the unprecedented scale of the 2011 flood: the unusual increase in rainfall extreme events (Figure 2) and other non-meteorological factors such as changes in land use and reservoir operation policies.

The Thai Government responded to the big flood in 2011 by launching both urgent measures after the flood receded as well as the long-term response in terms of the flood management master plan. Our focus in this section is on the long term response to extreme events – both flood and drought – by implementing adaptation strategies which help create higher resilience to future occurrence of extreme events.

2.2 Survey data

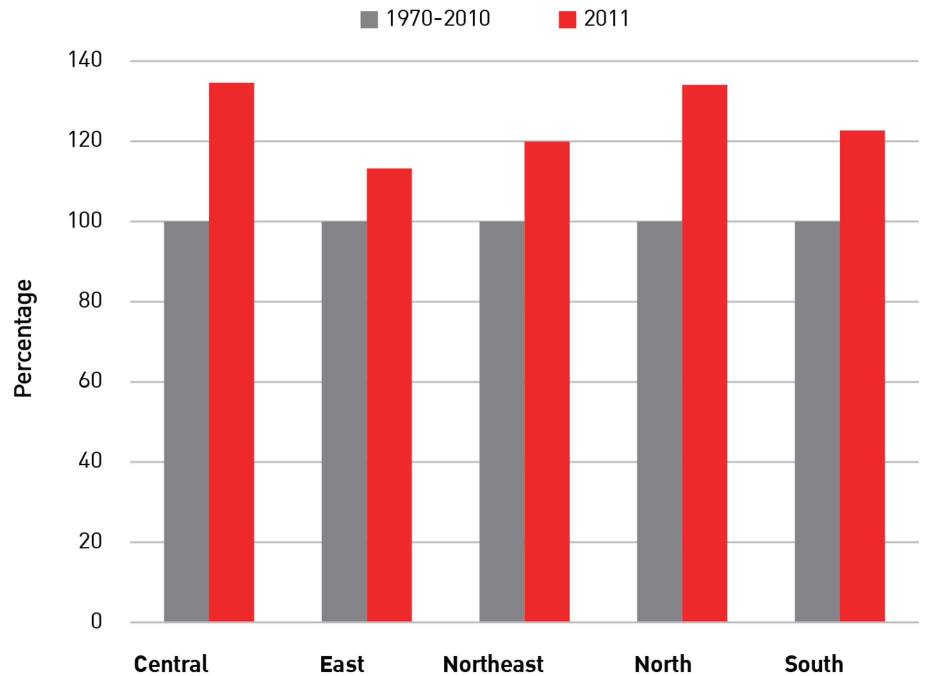
To identify factors that determine farm households' decision to adapt to flood and drought, we conducted the farm household survey in six Central provinces in the Chao Phraya basin, namely Pitsanulok, Nakhon Sawan, Uthai Thani, Lop Buri, Suphan Buri and Ayutthaya. In overall, 815 households from 80 sub-districts ("tambols") took part in the survey, comprising of 484 households from the 52 tambols in the flood-prone areas and 331 farm households from the 28 tambols in drought-zone areas. Figure 3 shows the survey villages in the Chao Phraya Basin of Thailand. The cross-sectional household survey was conducted during October-November 2013. The sample districts were purposely selected according to the drought and flood severity indices constructed by the Department of Disaster Prevention and Mitigation (DDPM). Moreover, additional districts were purposely selected as these districts contain areas to be designated as flood retention under the flood management master plan of the Thai Government. Then, in each of the selected district, two sub-districts or tambols were randomly selected. To ensure that there is greater degree of variety in the survey data, we impose a condition that two sub-districts to be selected must not be adjacent to each other. (Table 1)

Figure 1: 2011 Flood in Chao Phraya Basin (return periods of annual rainfall amount)



Source: Limsakul (2013).

Figure 2: Annual rainfall amount

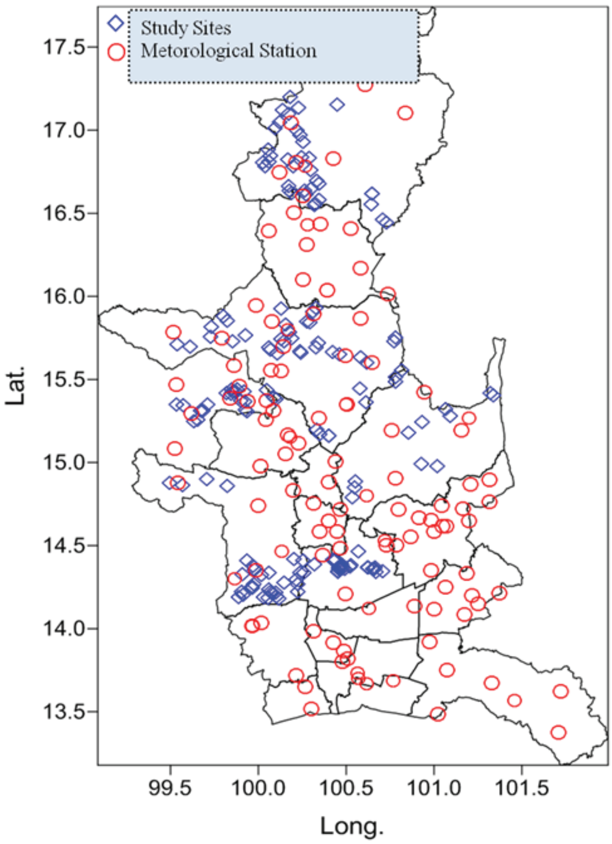


Source: Thailand Development Research Institute.

Table 1: Description of study sites and survey instrument

	Number of tambols			Number of Villages			Number of farm households		
Region/Province	**Floods**	**Droughts**	**Total**	**Floods**	**Droughts**	**Total**	**Floods**	**Droughts**	**Total**
Lower North									
- Pitsanulok	14	4	18	30	7	37	154	42	196
- Nokhon Sawan	12	7	19	23	14	37	123	89	212
- Uthai Thani	2	9	11	3	18	21	14	98	112
Central Plains									
- Lop Buri	2	5	7	3	11	14	21	68	89
- Suphan Buri	11	3	14	25	7	32	90	34	124
- Ayutthaya	11	0	11	27	0	27	82	0	82
Total	**52**	**28**	**80**	**111**	**57**	**168**	**484**	**331**	**815**

Figure 3: Survey villages in the Chao Phraya Basin of Thailand



The data collected comprises of seven main parts, namely household characteristics, agricultural land utilization and land tenure, agriculture and livestock production, perceptions of climate change, incidence of severe flood, incidence of severe drought and perception of Government's flood management projects.

3. Empirical methodology

3.1 Analytical framework

The decision of the farm household whether or not to adapt to climate change is, in the literature, considered under the utility maximization framework (Norris and Batie 1987; Deressa et al. 2008). Under such framework, it is assumed that the farm household will adopt a new farm technology (i.e. adaptation strategy) only if the perceived utility or profit from using the new technology is greater than the old method. The utility of farm household is specified as:

$$U_{ij} = \boldsymbol{\beta}_j \boldsymbol{x}_i + \varepsilon_j \text{ and } U_{ik} = \boldsymbol{\beta}_k \boldsymbol{x}_i + \varepsilon_k, \quad (1)$$

where U_{ij} and U_{ik} are the perceived utility of farm household i from adopting strategy j and k, respectively; $\boldsymbol{x}$ is the vector of explanatory variables that influence the perceived desirability of the strategy; $\boldsymbol{\beta}$ is the vector of coefficients to be estimated; ε_j and ε_k are identically and independently distributed error terms. If farm household i chooses strategy j instead of k, it implies that the perceived utility derived from j is greater than k or can be expressed as:

$$U_{ij} > U_{ik}, k \neq j \quad (2)$$

According to Deressa et al. (2008), the utility derived from adaptation strategy cannot be observed, but the actions of farm households are observed through the choices they make. In what follows, we use the latent variable to transform equation (2) and use the probit model in the analysis. Details of the probit regression model can be found in the next subsection.

3.2 Estimation model

Provided that what we are examining is the probability of adaptation in response to extreme flood and drought, then y could be 1 if the farm household adapts and 0 otherwise. Given the binary response, one could consider the binary response model, with the following response probability:

$$P(y = 1|\boldsymbol{x}) = P(y = 1|x_1, x_2, \dots, x_n), \quad (3)$$

where $\boldsymbol{x}$ denotes the full set of explanatory variables, including farm household characteristics (age, education, gender and marital status of household head), and other factors that affect adaptation decision, including climate variables, access to credit, and land tenure.

To avoid the limitation of the linear probability model, we consider a class of binary response model

$$P(y = 1|\boldsymbol{x}) = H(\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k) = H(\beta_0 + \boldsymbol{x\beta}), \quad (4)$$

where *H(.)* is a function such that $H: x \mapsto [0,1], \forall x \in \mathbb{R}$. Though various nonlinear functions have been suggested for the function *H* to make sure that the probabilities are between zero and one, in this paper, we consider the probit model. Under the probit model, it is assumed that the function *H(.)* follows a normal (cumulative) distribution,

$$H(x) = \Phi(x) = \int_{-\infty}^{x} \phi(z)dz,$$

where $\phi(z)$ is the normal density function:

$$\phi(z) = \frac{1}{\sqrt{2\pi}} exp(-z^2/2)$$

The probit model can be derived from the latent variable model. Let y^* be the latent variable, determined by:

$$y^* = \beta_0 + \boldsymbol{x\beta} + e, y = \mathbb{I}[y^* > 0], \quad (5)$$

where $\mathbb{I}[\cdot]$ is an indicator function which takes on the value one if the event in brackets is true and zero otherwise. Thus, y is one if $y^* > 0$ and y is zero if $y^* \leq 0$. It is assumed that e is independent of $\boldsymbol{x}$ and that e has the standard normal distribution. The response probability for y can be derived as follows:

$$P(y = 1|\boldsymbol{x}) = P(y^* > 0|\boldsymbol{x}) = P(e > -(\beta_0 + \boldsymbol{x\beta})|\boldsymbol{x})$$
$$= 1 - H[-(\beta_0 + \boldsymbol{x\beta})] = H(-(\beta_0 + \boldsymbol{x\beta}))$$

To estimate the limited dependent variable model, maximum likelihood method is indispensable.

4. Empirical results and discussion

The results from the estimation of probit model of determinants of adaptation decision in response to the 2011 flood and the 2012 drought are presented in Tables 2 and 3 respectively. In each case, different model specifications are considered.

The results of the probit model estimation (column (2)) presented in Table 2 suggest that farm households with access to agricultural credits are found to be more likely to adopt adaptation strategies in response to 2011 flood. This result highlights that farm households may need financial resources to adapt. Access to affordable credit increases the farm households' financial resources and their ability to meet transaction costs associated with the adaptation strategies they might want to adopt. According to Nhemachena and Hassan (2007), with higher financial resources through the agricultural credit, farm households are able to purchase new crop varieties, new technology or important inputs that would be more suitable for the climatic conditions.

The results of our analysis also show that land ownership matters. Farm households who do not own their farm land have less propensity to invest in adaptation strategies compared to with ownership. The key implication of this result is that

Table 2: Results of probit analysis of determinants of adaptation to the 2011 flood

Dependent Variable **Adaptation 1/0**	(1)	(2)	(3)	(4)
Farm household and head characteristics				
household size	-0.0575**	-0.0520**	-0.0832*	-0.0646*
	(0.0257)	(0.0242)	(0.0484)	(0.0373)
d_male	-0.1844	-0.0460	0.1791	0.1239
	(0.2209)	(0.2219)	(0.2651)	(0.2320)
age	0.0227	0.0213	0.0098	0.0194
	(0.0182)	(0.0169)	(0.0171)	(0.0205)
age-squared	-0.0002	-0.0002*	0.0002	-0.0003*
	(0.0001)	(0.0001)	(0.0002)	(0.0002)
d_single		0.4542*	0.9562*	0.9805**
		(0.2615)	(0.5071)	(0.5011)
d_at least secondary education	0.2185***	0.1911***	0.2752*	0.2746*
	(0.0792)	(0.0618)	(0.1629)	(0.1472)
d_access to agricultural credit		0.1869*	0.0592	0.1203
		(0.1064)	(0.1444)	(0.1009)
d_total agricultural credit	-0.0000019***			
	(0.0000009)			
d_public land			-0.7426***	-0.5541***
			(0.0833)	(0.0914)
Assets				
possession of agricultural tools	1.0174***			
	(0.2670)			
d_household non-farm income				-0.0383
				(0.2799)
2011 Flood				
crop damage			0.5913**	0.4766*
			(0.2402)	(0.2714)
debt suspension			-0.0173	
			(0.2726)	
Climatic factors				
average wet season rainfall				0.0005*
				(0.0002)
average night temperature			0.4202*	
			(0.2169)	
perception that average rainfall increase			0.0797	0.1214
			(0.1620)	(0.1265)
constant	-1.2299***	-0.9813**	-11.3511**	-1.1858**
	(0.4689)	(0.3981)	(5.6501)	(0.5487)
number of observation	446	454	267	283
Log Pseudolikelihood	-250.1545	-258.2076	-150.4620	-160.8436
Pseudo R-squared	0.0293	0.0190	0.0770	0.0607

*, **, *** *Statistically significant at 10%, 5% and 1% respectively; data are clustered by province and the robust standard errors are shown in the parentheses.*

Table 3: Results of probit analysis of determinants of adaptation to the 2012 drought

Dependent Variable **Adaptation 1/0**	(1)	(2)	(3)
Farm household and head characteristics			
Proportion of member engaging in farm	0.4147**	0.3629***	0.4251**
	(0.1659)	(0.1230)	(0.1971)
d_male	-0.5145***	-0.4558***	-0.5383***
	(0.1541)	(0.1677)	(0.1595)
age	0.1131*	0.1097*	0.1002
	(0.0670)	(0.0631)	(0.0722)
age-squared	-0.0011*	-0.0011*	-0.0010
	(0.0006)	(0.0006)	(0.0006)
d_single	-0.1388	-0.1168	-0.1448
	(0.1892)	(0.1882)	(0.1745)
d_at least secondary education	0.2881	0.2593	0.2409
	(0.2750)	(0.2558)	(0.2765)
d_access to agricultural credit	-0.3966**	-0.3167*	-0.4346**
	(0.1747)	(0.1838)	(0.1733)
d_public land	0.7104***		0.6085***
	(0.1597)		(0.1716)
Assets			
possession of vehicle	0.3373***	0.4364***	0.3605**
	(0.1316)	(0.1602)	(0.1605)
Climatic factors			
average rainfall			-0.0015
			(0.0011)
average temperature			-0.3826*
			(0.1982)
perception that average rainfall increase		-0.0252	
		(0.2386)	
constant	-2.9246	-2.8924	10.9641
	(1.8569)	(1.8008)	(7.6622)
number of observation	128	127	128
Log Pseudolikelihood	-73.6772	-73.3219	-73.2420
Pseudo R-squared	0.0536	0.0431	0.0592

*, **, *** *Statistically significant at 10%, 5% and 1% respectively; data are clustered by province and the robust standard errors are shown in the parentheses.*

secure tenure arrangement is an important factor that influence or facilitate investment in long-term adaptation by farmers. Land ownership provides a positive incentive for farmers to invest in their farms, including investment in adaptation and changes the agricultural practices.

Increasing average annual night temperature increases the probability of farm households adopting adaptation strategies in response to the 2011 flood (column (3)). This is along the line of Nhemachena and Hassan (2007), which found that increasing warming could result in higher evapotranspiration rates and water shortage that require farmer responses; for instance, changes in crop varieties and variation in planting dates. Increasing the mean precipitation or rainfall during the rainy season increases the probability of adaptation by farm households as more extreme rainfall could raise the possibility of flooding.

Farm households who were adversely affected by the 2011 flood in term of high crop damages are more likely to take up adaptation strategies. We also found that some socio-economic characteristics of the household and household's head matter. The households with well-educated and single head are more likely to adopt adaptation strategies. According to Norris and Batie (1987), higher level of education is found to be associated with access to information on improved technology and higher productivity. As argued in Deressa et al. (2008), evidence from various sources indicates that there is a positive relationship between the education level of the household head and the adoption of improved technologies (Igoden et al. 1990; Lin 1991) and adaptation to climate change (Maddison 2006).

Last but not least, farm households with access to agricultural tools and machinery (such as harvester, large tractor) have higher possibility of taking up adaptation strategies. With access to farming technology, farmers are able to vary their crop calendar, change crop varieties, switch to new crop, etc. Moreover, ownership agricultural tools represent wealth. According to Knowler and Bradshaw (2007), the adoption of agricultural technologies requires sufficient financial wellbeing.

The estimation results presented in Table 3 show that possession of assets is associated with adaptation to extreme drought event. Having access to vehicles reflects the financial status of the households, and we found that vehicle ownership facilitates investment in long-term adaptation to drought. Unlike flood, lack of land ownership does not deter the households from taking up adaptation strategies. As shown in Table 3 (columns (1) and (3)), farm households that grow rice in the public land have higher propensity to invest in drought adaptation strategies compared to other types of land ownership.

When it comes to adaptation to drought, we find that households with higher proportion of members engaging in farm activities are more likely to respond to drought by adopting adaptation strategies. According to Deressa et al. (2008), households with more members assisting in the farming activities are associated with higher labor endowment, which would enable a household to

accomplish various agricultural tasks. Croppenstedt et al. (2003) argue that households with a larger pool of labor are more likely to adopt agricultural technology and use it more intensively because they have fewer labor shortages at peak times; thus, it is hypothesized that households with large families are more likely to adapt to drought.

Our results show that gender of the household head also matters. According to Table 3, households with male head have lower probability of uptaking the drought adaptation strategies. The effect of gender of household head on the adaptation decision in the previous studies is mixed. While Asfaw and Admassie (2004) and Tenge De Graffe and Hella (2004) found that male-headed households are more likely to get information about new technologies and undertake risky businesses than female-headed households, Nhemachena and Hassan (2007) finds contrary results, arguing that female-headed households are more likely to take up climate change adaptation methods. Thus, the adoptions of new technologies or adaptation methods appear to be rather context specific

Though some previous studies found that the availability of credit eases the cash constraints of

the farm households and facilitates the purchases of inputs such as fertilizer, improved crop varieties, and irrigation facilities (Yirga, 2007; Pattanayak et al., 2003), the results in Table 3 show that there is a negative relationship between the adaptation decision and the access to credit. This is consistent with the findings of Ndambiri et al. (2012) which also found that access to credit is inversely related to farmers' adaptation to climate change. The reason they gave for this result is that the adoption of an agricultural technology may demand the use of owned or borrowed funds. Since such an investment in technology adoption may be hampered by lack of borrowing capacity (El-Osta and Morehart, 1999), this may negatively end up affecting any perception of the farmers or even the taking up of adaptation measures.

Next, we consider the impact of current climatic variables on the probability of adaptation in response to the 2012 drought. Our results show that the average rainfall plays no role in determining the probability of adaptation. The estimated coefficient of the average rainfall variable is negative indicating that lower amount of precipitation is associated with higher probability of uptaking of drought adaptation strategies but it is not statistically significant. Ndambiri et al. (2012) found a negative relationship between change in precipitation and farmers' adaptation. The possible reason for this negative relationship is that increased precipitation in a water scarce area is unlikely to constrain farm production and, therefore, unlikely to promote the need to adapt to the changing climate.

Unlike rainfall, higher temperature over the survey period appears to work in the opposite direction with regard to the likelihood of adoption of adaptation techniques. Our results show that higher average temperature reduces the probability of adaptation.

5. Concluding remarks and policy implications

The results from the study show that the age, gender, education, and marital status of the household head, household size, wealth, access to credit, land ownership, precipitation and temperature are crucial determinants of farm households'

adaptation to extreme weather events such as flood and drought in the Chao Phraya Basin of Thailand though the factors that determine adaptation decision in response to flood and drought differ. A number of different policy implications arise from these analyses of the factors that influence farmers' adaptation decisions.

First, the policy makers should step in to facilitate the availability of credit to farm households, particularly those that want to adapt in response to extreme flood. Availability of credit eases the cash constraints and allows farm households to acquire inputs (such as improved crop varieties) and new farming technology. Second, to facilitate greater adoption of the adaptation strategies, information on new crop varieties, farming technology and farming practices should be provided to farm households as lack of knowledge and information is reported as one of the barriers to adaptation. Third, given that market access is a factor that influences adoption of agricultural technologies since markets provide an important platform for farmers to gather and share information according to previous studies (Maddison, 2006), some steps should be taken to improve farmers' access to market.

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สถาบันวิจัยเพื่อการพัฒนาประเทศไทย (ทีดีอาร์ไอ)
565 ซอยรามคำแหง 39 เขตวังทองหลาง กรุงเทพ 10310

Thailand Development Research Institute (TDRI)
565, Soi Ramkhamhaeng 39 Wangthonglang,
Bangkok 10310 Thailand
Tel. 02-718-5460
Fax. 02-718-5461-2
Website: http://tdri.or.th