Assessment of Adaptive Capacity to Drought of Rainfed Rice Farmers in Maha Sarakham, Northeastern Thailand

Arika Bridhikitti[1*]

ABSTRACT: There is high confidence that Southeast Asia is seriously affected by climate changes, and poverty of farmers in this region is a major concern. This study aims to assess adaptive capacity to drought of rainfed rice farmers in the northeastern part of Thailand. The assessment was conducted through secondary data collection, field survey and interviews in four sub-districts across Kantarawichai District, Maha Sarakham, Thailand during the 2015−16 drought event. The results show the farmers' background economic status and rice cropping practices. Long-term rainfall record illustrated significant changes in rainfall magnitude and variability, trends and characteristics of the drought. The degree of adaptive capacity reveals that at the preparation and response phases, the farmers could be able to cope with the drought to some extents because of their high responsiveness to drought, high modularity, greatly addressing morality in decision making, and acknowledging social equity. After the drought, poor rice market system could significantly hamper the bounce-back ability of the farmers. Several adaptive options are suggested to build better adaptive capacity on future unprecedented drought.

Keywords: adaptive capacity, climate change, drought, rainfed rice, Southeast Asia

Introduction

Intergovernmental Panel on Climate Change (IPCC) expected that climate changes in the Southeast Asian region will be exacerbated in the future with increasing number of warm days, decreasing cool days and increasing interannual rainfall variability together with extreme rainfall events and cyclones (Stocker et al., 2013). IPCC has medium confidence that the climate change will cause declines in agricultural productivity, including rice, and it is highly confident that future extreme climate events will have an increasing impact on human health, security, livelihoods, and poverty across Asia (Field et al., 2014).

In the northeastern part of Thailand, increasing air temperature and longer summertime could drive greater demands for water and exacerbate conflicts between upstream and downstream users (Asia-Pacific Network for Global Change Research, 2008). Sangpenchan (2011) identified characteristics of farmer households in Thailand with high vulnerability to climate changes. Rice yields tend to decline due to heat stress during vegetation phase, low minimum temperature, and high moisture during harvest. Furthermore Thai rice farmers are having no alternative sources of income, living in low economic status and owning a small farm land. The poverty of rice farmers have been identified by the Asian

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[1] Climate Change and Adaptation Research Unit (CCARE), Faculty of Environment and Resource Studies, Mahasarakham University, Kantarawichai, Maha Sarakham 44150
[*] Corresponding author: arika.b@msu.ac.th

Development Bank (ADB) as the priority issues for food security in Thailand (ADB, 2012). ADB also specifies that Northeastern Thailand has the highest percentage of the poor and this is mainly found in rice-producing areas (ADB, 2012).

Maha Sarakham Province is in the middle of Northeastern Thailand, in which water shortage had often been reported (Feangjuada, 2007; Kerdsuk and Kerdsuk, 2009; Kom Chad Luek Newspaper, Feb. 19, 2016). Kerdsuk and Kerdsuk (2009) studied effects of climate change on risk and vulnerability of paddy farmer in the Chi Watershed and their result shows that 77.49% of the sampled farmers in Maha Sarakham, Khon Kaen and Roi Et were affected by drought. Kantarawichai District in Maha Sarakham was not only repeatedly experienced drought but also unacceptable water quality for agricultural and domestic uses owing to domestic discharges of wastewater and solid waste (Kom Chad Luek Newspaper, Feb. 19, 2016).

From the viewpoint of social service agencies, building the capacities can be achieved through changes in management process, and these adaptive levels should be assessed by considering proper determinants, reflecting a governance structure (Brooks and Adger, 2004). The third IPCC annual report provided recommendations of six determinants to assess characteristics of systems influencing human adaptive capacity, which are economic resources, technology, information/skills/management, infrastructure, institutions/networks and equity (Smit and Pilifosova, 2001). These determinants have been widely applied as guidelines for climate change adaptations in several organizations, including Ontario Centre for Climate Impacts and Adaptation Resources (OCCIAR, 2014) and International Institute for Sustainable Development, IISD (Swanson et al., 2007). The Institute for Social and Environment Transition (ISET) develops climate resilience framework, including characteristics reflect human adaptive capacity (Friend and MacClune, 2013), and are similar to those describing the IPCC's determinants. The characteristics are responsiveness, resourcefulness, equity in accessibility of essential resources, decision-making processes, information flows, diversity of tasks under a wide range of conditions, modularity of multiple pathways that can replace each other and safe failure from sudden shocks (Friend and MacClune, 2013).

With vulnerability of the rainfed rice farmers in Kantarawichai Dsitrict, Maha Sarakham in the northeastern part of Thailand, this study aims to assess their adaptive capacity to drought through analysis of the climate resilience framework, adopted from ISET (Friend and MacClune, 2013). The result illustrates performance of the existing adaptive options, assisting the communities building their better ability to cope with future unprecedented drought.

Methodology

Studied area

Kantarawichai District was one of the seven districts in Maha Sarakham, often experienced severe drought since there are not many natural water resources (Feangjunda, 2007). Rice paddy accounted for approximately 89% of the total agricultural lands in this district and 13,908 households were relied on incomes from agricultural sectors (Kantarawichai District Office of Agriculture, 2018). Rice farming in this district is technological reliance and regulated by market economy and, causing high capital expenditure and financial instability (Nontree, 2000; Seti, 2005).

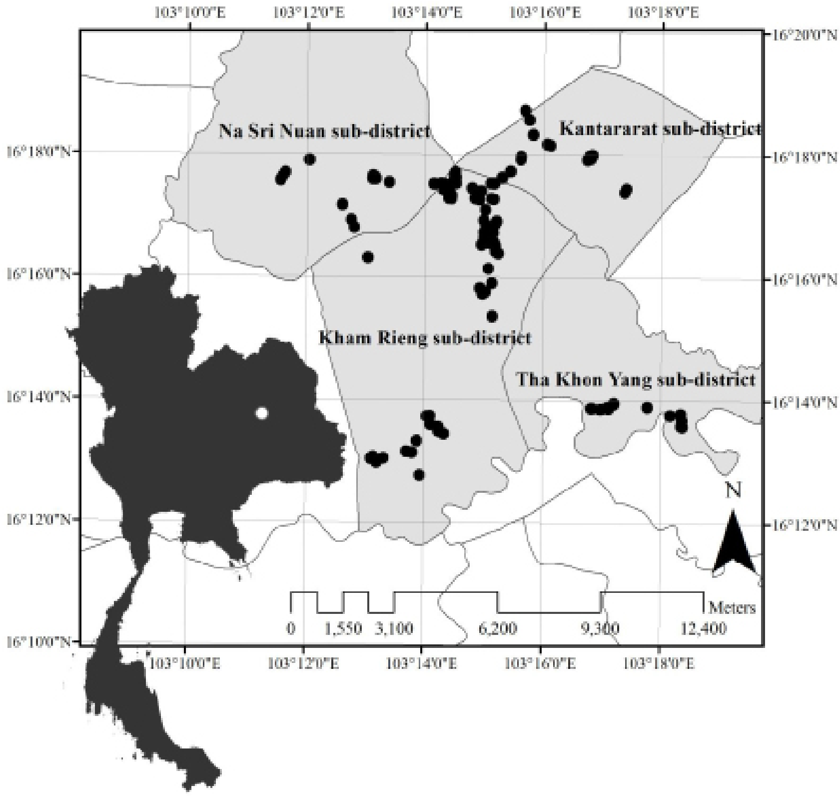

Figure 1 Rice fields' locations owned or rented by the 95 interviewed farmers in 4 sub-districts of Kantarawichai District, Maha Sarakham, Thailand.

The map of the studied rice fields is illustrated in Figure 1. These sampling sites are largely clustering in the villages in 4 sub-districts, which are: Kham Rieng, Tha Khon Yang, Kantararat and Na Sri Nuan in Kantarawichai District, Maha Sarakham, Thailand. These areas were purposively chosen from its prevailing rainfed agriculture, rapid urbanization partly due to impacts of Mahasarakham University Campuses (in Kham Rieng and Na Sri Nuan Sub-Districts), and ease of data accessibility through a road network.

Sample size

Ninety five farmer households, who owned or rented the studied rice fields, were interviewed and the data were statistically analyzed to infer their economic background and rice cultivation practices. This accounts for 0.68% of total agricultural households in Kantarawichai District and be responsible for approximately 90% confidence accordingly systematic random sampling using Taro Yamane formula (Yamane, 1973). Furthermore, twenty two informants, involving in agricultural administration, were interviewed to justify average weighing scores of significance levels for characteristics of high adaptive capacity. They include 1 deputy district chief (Kantarawichai District), 2 deputy sub-district agricultural officers (from Kham Rieng and Tha Khon Yang Sub-Districts), 5 community leaders and 14 senior and experiencing farmers, chosen among the interviewed farmers from the four districts.

Data collection

Primary interviewing data: Constructed interviews were conducted from December 2015 to January 2016 during the end of the rice harvesting season in 2015-16 El Niño. The information collected from the interviews with the farmers includes economic background, rice cultivation practices and individual perceptions on characteristics of high adaptive capacities to climate change along with their significance levels for these characteristics, as described below:

- Economic background is collected by asking the farmers about sources of their household incomes and their economic status by considering debt-paying ability and total household revenue.

- Rice cultivating information includes yield, rice varieties, usages of chemicals, residue management, land-use allocation, and cropping calendar.

- Eight characteristics of high adaptive capacities to climate change are referred in this study and they are described below. When the characteristic was not found, the data was assigned to “0” and assigned to “1” for vice versa.

1. Responsiveness

1.1 Farmers are well prepared for drought and apply drought mitigation approach(es) for cropping rice

2. Modularity

2.1 There are accessible water resources in the dry season

2.2 Farmers have their alternative jobs during non-rice cropping season

3. Information accessibility

3.1 Farmers access drought early warning at the proper time

3.2 Farmers can access resourceful information concerning household drought management from local communities or state

4. Resourcefulness

4.1 Drought-affecting farmers can access helps in financial, technological and/or other elemental supports from local communities or state

5. Diversity

5.1 There are varieties of drought mitigation projects/activities, arranged by local communities or state

6. Social equity

6.1 Farmers with all genders, ages and social status can equally access helps from local communities or state

7. Decision-making processes

7.1 Local water management is somewhat effective

7.2 Local water management authorities work under righteousness and justice

8. Safe failure

8.1 There is an effective rice market management that helps farmers to quickly recovery from drought

Average weighing scores of significance levels for characteristics of high adaptive capacity were obtained from the 22 informants and its score ranging from 0 (realized as insignificant to farmers) to 10 (realized as highly significant to farmers).

Primary soil organic carbon (SOC) data: Soils taken from rice fields of the interviewed farmers were air–dried, sieved and then analyzed at MSU Environmental Laboratory for its organic carbon content following Walkley and Black (1934) method.

Secondary rainfall data: Long-term monthly rainfall data were used in this study to assess characteristics of 2015–16 drought. Data for January 1988 to December 2015 were collected at Kantarawichai Rain Gauge Station (station ID 01387003) and acquired from Kantarawichai District Administration Office.

Data analysis

Statistical analysis: The descriptive statistics on the data had been reported, which are arithmetic mean, medium and percentage. One-way analysis of variance (ANOVA) using F statistic was conducted to compare means among groups of the farmers with different economic levels and Least Significant Difference (LSD) was tested to identify those pairs of means exhibiting significant difference within 95% confidence ($P \leq 0.05$). Data were analyzed by using MATLAB R2017b.

Assessment of adaptive capacity of the farmers to drought: Degrees of adaptive capacity were estimated by multiplying each of the observed characteristics which reflected high adaptive capacity with their significance to farmers' livelihoods. The score of 4.9 (out of 10) or higher indicated high degree of adaptive capacity, whereas the score of 2.5 (out of 10) or lower indicated the low degree. Frequency of appearance of the observed characteristics from the structured interviews with the 95 farmer households, were normalized to 0 to 10 scale ("0" stands for not found and "10" stands for found in all observations). These characteristics reflect high adaptive capacity of the farmers. They are consisting of 1) responsiveness, 2) modularity of multiple pathways that can replace each other, 3) information accessibility, 4) resourcefulness,5) diversity of tasks under a wide range of conditions, 6) social equity in resource assessments, 7) decision making and 8) safe failure from sudden shocks.

Results and Discussion

2015-16 drought characteristics

With total annual rainfall of 925.6 mm, the 2015 rainfall in Kantarawichai District was less than the annual average rainfall (for years 1988 to 2015), which is 1,124 mm (see Figure 2A). As shown in Figure 2B, the 2015 rainfall anomalies were clearly below the normal levels in the early cropping season in April and May and in the ending season in August and September. The 2015-16 drought was associated with long-term El Niño-induced low water budget and high evapotransportation. United Nations delivered in December, 2015 the key messages that the 2015-16 El Niño signal is comparable to that of the greatest 1997-98 El Niño and it happened after several months of mild El Niño in 2014 (ESCAP and RIMES, 2015). With this ENSO pattern, the Asia and Pacific region would be seriously affected by drought from November 2015 to April 2016, and this would even more severe in certain locations, such as the central part and the northeastern part of Thailand (ESCAP and RIMES, 2015). Thai Meteorological Department also observed warmer air over Northeastern Thailand from March to December during the years 2014 and 2015, which was found to be higher than the mean level, as a result of the El Niño (TMD, 2016). Correspondingly, rainfall in Kantarawichai District was found unusually low between August (132 mm) and September (128 mm) 2015, the period of which rainfall is supposed to be at the peak of the year.

Nevertheless, rice yield in the studied area did not substantially decline in the drought year of 2015 (~2.52 ton ha^{1}) even though farmers used lower amount of chemical fertilizers (see Table 1). This finding suggests that the anomaly rainfall may not significantly limit rice growing and warm temperature could even play a positive role in rice growth.

Economic background of the rice farmer households

Since rice can be cultivated once a year in the rainy season, many rice farmers needed to find an alternative job for their family income. Liese (2014) referred to the study conducted

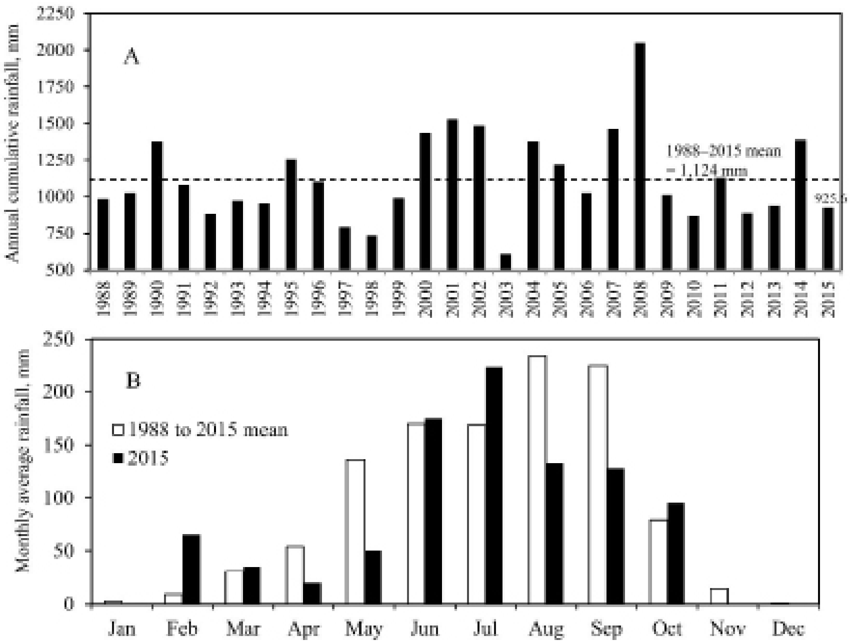

Figure 2 1988–2015 annual cumulative rainfall (A) and monthly average rainfall (B) at Kantarawichai rain gauge station.

by Sakondhavat, (2012) in year 2009 with farmer households in the northeastern part of Thailand and found that 77.3% of their revenues were from non-farm works. In this study, the key alternative careers for those included government employee (24.8%), labor (22%), minimart/store owner (15.6%) and fruit/vegetation farmer (14.7%). Fifty percent of the studied farmers had total monthly income per household member ranging from 1,658 Baht to 4,778 Baht, or with an average of 4,296 Baht. Their monthly income is below the provincial average of 21,644 Baht (for year 2013) per household (NSO, 2016). Nonetheless, rice yield in the 2015 drought year slightly increased to approximately 2.52 ton ha^{-1} (typical yield of 2.37 ton ha^{-1}); however, their household income slightly declined to 4,118 Baht month^{-1} capita^{-1} on average since the rice price in the market went down.

Table 1 shows that the majority of the farmer households (65%) had a cropland of their own and they were burdened with accounts payable and limited revenue. There are a significant number of poor households with cumulative debt (18%) who did not own land at all. This group of poor farmers grew rice over the average area of 1.9 ha which is significantly ($P < 0.05$) lower than those with the higher income (6.67 ha) who have enough assets to share with others. Nevertheless, the poor farmers produced the highest amount of rice yield (3.06 ton ha^{-1}). This finding suggests that farmers' economics is highly relating to size of cropping land.

The majority of farmer households in the studied area had 96.1% (median) of their lands for rice cultivation and 3.0% for housing. Only a few of them had their lands for water retention, gardening, livestock farming as well as for other purposes. Public water availability was a very sensitive issue to the farmers. Some of the

Table 1 Self-classifications of the farmer households' economic status and their chemical fertilizer used, rice yield, cropping area, soil organic carbon content (SOC) and total household income in year 2015

	Economic levels	Number of observation	Number of household member	Chemical Fertilizer application (kg ha^{-1}) Normal year	Chemical Fertilizer application (kg ha^{-1}) 2015	Rice yield (ton ha^{-1})	Paddy area (ha)	SOC (%)	Total household revenue (Baht month^{-1} capita^{-1})
1	Rent land, cumulative debt, limited revenue	12	4.17	221	214	3.06	1.90[a]	1.00[a]	2,726.39
2	Own land, accounts payable and limited revenue	62	4.18	241	218	2.37	2.24[ab]	0.87[ab]	3,986.78
3	Own land, less debt than revenue and reasonable revenue	18	3.50	171	172	1.94	3.26[ab]	0.74[b]	5,426.06
4	Able to help others	3	4.00	160	67	2.31	6.67[b]	1.17[ab]	7,054.63
		ANOVA-Test	NS	NS	NS	NS	**	**	NS

Means followed by the same letter at the same column were not significantly different than the LSD at $P \leq 0.05$
** Significant at $P \leq 0.01$, NS = Not Statistically Significant

land became useless during the dry season. Nevertheless, farmers usually grow edible vegetables for household consumption within the housing area of approximately 672 m^2, and some can be sold in the local market.

Rice cultivation in the drought year

Oryza sativa L. is commonly known as the most predominant of the Southeast Asian rice species, which is composed of many different varieties. Three rice varieties were popularly grown in this area, namely RD6 (~46.6% in normal year), RD15 (~20.2%) and Khao Dawk Mali 105 (~31.3%). The different proportions of rice varieties between the normal year and the drought year in 2015 were not substantial. Since these rice varieties are photosensitive, they can grow only one time a year, and the harvested date can be predictable, which is usually in mid-November. Both RD15 and Khao Dawk Mali 105 are fragrance jasmine rice, which have comparatively high selling price and are in high-market demand. These varieties are drought-resistant and be able to grow in acidic or saline soils. However, they are susceptible to strong wind during the harvesting stage and they are not well resistible to the outbreaks of typical rice diseases and pests.

The fertilizers supplied in the drought year declined due to poor economic status of the farmers (see Table 1). Rice yields in this year varied from field to field, which 50% of the observations were ranging from 1.71 ton ha^{-1} to 2.77 ton ha^{-1}. The yields were in the typical ranges of Khao Dawk Mali 105 from the northeastern part of Thailand, which were 1.54 ton ha^{-1} (for only P and K added) to 1.99 ton ha^{-1} (for all-nutrient dressing) (Wade et al., 1999a). These yields are below the typical international average of rain-fed lowland rice (3.29 ton ha^{-1}, Wade et al., 1999b).

Table 2 Summary of nine characteristics of high adaptive capacity for the farmers

Phase of disaster management	Characteristics of high adaptive capacity		Significance to farmers' livelihoods (0-10)*	Actual Appearance (0-10)**	Adaptive capacity (0-10)***
Preparation	Responsiveness	Farmers are well-prepared for drought and apply drought mitigation approach(es) for cropping rice	7.01	7.80	**5.47**
	Modularity	-There are accessible water resources in the dry season	7.88	4.71	3.71
		-Farmers have their alternative jobs during non-rice cropping season	7.52	8.62	**6.48**
	Information	-Farmers access drought early warning at the proper time	8.16	2.29	1.87
		-Farmers can access resourceful information concerning household drought management from local communities or state	8.05	4.50	3.62
Response	Resourcefulness	Drought-affecting farmers can access helps in financial, technological and/ or other elemental supports from local communities or state	7.43	4.68	3.48
	Diversity	There are varieties of drought mitigation projects/activities, arranged by local communities or state	7.39	5.29	3.91
	Social equity	Farmers with all genders, ages and social status can equally access to all kinds of assistances from local communities or state	7.43	7.49	**5.57**
	Decision making	-Local water management is somewhat effective	8.67	2.75	2.39
		-Local water management authorities work under righteousness and justice	7.89	7.97	**6.29**
Recovery	Safe Failure	There is an effective rice market management that helps farmers to quickly recovery from drought	8.25	0.37	0.31

* using average weighing scores (from 0-insignificant to 10-highly significant) judged by the 22 stakeholders

** using normalized frequency of appearances of the nine adaptive characteristics (0-No/Not found and 1-Yes/Found) obtained from the 95 farmers into 0 to 10 data range

*** $\frac{(1)\times(2)}{10}$, the score ranging from 0-not applied and not realized as significant to farmers to 10-frequently applied and realized as significant to farmers

Adaptive capacity of the farmers to drought

Results in Table 2 show that at the pre-drought stage, the farmers have high responsiveness to drought (5.47) and high modularity due to multiple sources of household income (6.48). These characteristics of the farmer community indicate self-abilities of the farmers and farmer communities to cope with drought problems. High capability of farmers to quickly responding to climate change is also found in Nepal, but it does not warrant long-term resilience to future impacts of climate change (Manandhar et al., 2011). To improve the adaptive capacity at the pre-stage, the farmers needed a better accessibility to water resources in the dry season (3.71) and resourceful information concerning household drought management (3.62). Furthermore, accessibility to drought early warning (1.87) was poorly performed and urgently required improvement.

During the drought period in response phase, adaptive capacity for the farmers and farmer communities was at moderate level. Though greatly addressing morality in decision making (6.29), the farmers were addressing ineffective decision making on water management (2.39). Social equity in accessing essential resources (5.57) was highly addressed. Related sectors should further develop effective programs/projects/activities related to drought mitigation, and invite more farmers to take part in (3.91). Furthermore, the farmers needed better accessibility of financial, technological and/or elemental supports (3.48). Similar conclusion has been made by Bastakoti (2014), who studied adaptations of the farmers in Kalasin Province in Northeastern Thailand and they suggest roles of local administrators to increase the farmers' adaptive capacity. The key roles include initiating adaptation measures using local resources and catalyzing adaptation practices by providing technical and material supports (Bastakoti et al., 2014).

The market rice system does not always reflect low rice productivity during droughts, but demands, associated with national rice stock. Most farmers viewed that the rice market system was somehow unsupportive or even discouraging, during the critical time. Apart from farmers, rice millers are also affected by climate uncertainty, together with rice demands (Thongrattana et al. 2009). With very low score on the effective market rice system (0.31), this characteristic could significantly hamper the bounce-back ability of the farmer, and solutions to fill the gap are urgently required.

Conclusion

The results obtained from the census survey showed that many farmer households had alternative sources of income. Their average household income (4,296 Baht per month), however, had been below the provincial mean. Although the 2015–16 regional drought was discernible in forms of lesser rainfall in rainy season, decline in rice yield was not considerable, and even more rice in some cases, despite of declines in fertilizer supply in overall. Nonetheless, their household income slightly declined since the rice price in the market went down.

The degrees of adaptive capacity, estimated from the observed characteristics reflecting high adaptive capacity and their significance to farmers' livelihoods, revealed that at the preparation and response phases, the farmers were well adopt to the drought to some extents. They had high responsiveness to drought, high modularity due to multiple sources of household income, greatly addressing morality in decision making and acknowledging social equity. However, they still needed a better accessibility to water resources in the dry season and also required an early drought warning as well as effective decision making on water management. All responsible sectors should consider developing varieties of effective drought mitigation programs/projects/activities and provide additional resourceful information concerning household drought management, together with financial, technological and/or elemental supports. After the drought in recovery phase, poor rice market system could significantly hamper the bounce-back ability of the farmers.

Suggestions

To buildup adaptive ability of the rice farmers in Kantarawichai District, Maha Sarakham in coping with drought, several adaptive options are proposed below:

1. Building engagement of smallholders in policy making and governance to gain more understanding on local vulnerability and minimize communication barriers. This option is also highly recommended by Wright et al. (2014) for Bangladesh, Mozambique, Uganda and India, where is under risks for food production.

2. Developing early warning systems providing inclusive weather predictions and adaptive options accordingly. Smit and Skinner (2002) pointed out that agriculture is generally well adapted to long-term climate variation but not to irregular or extreme conditions. They, therefore, suggest climatic simulation and inclusive weather forecast as the tools for long-term and short-term decision-making, respectively (Smit and Skinner, 2002). In case of the Kantarawichai District, climatic simulation could provide quantitative risk on unprecedented drought in the future and raising public awareness on the risk.

3. Strengthening farmer cooperative programs to gain power of negotiation in rice market. Smit and Skinner (2002) proposed modifying crop insurance programs for economic stabilization under climate risk based on Canadian situation. Furthermore, they also propose the concept on changing compensation to risk sharing. These options of Smit and Skinner (2002) could be useful to the farmers in some extent.

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