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Three-stage quantitative approach of understanding household adaptation decisions in rural Cambodia

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Abstract

Purpose – A better understanding of the processes that shape households' adaptation decisions is essential for developing pertinent policies locally, thereby enabling better adaptation across scales and multiple stakeholders. This paper aims to examine the determinants of household decisions to adapt, it is also possible to target factors that facilitate or constrain adaptation. This helps to identify key components of current adaptive capacity, which leads to important insights into households' competence to adapt in the future.

Design/methodology/approach – This paper takes a full-pledged approach examining factors and processes that shape households' climate adaptation decision-making in rural Cambodia at three levels: adaptation status, adaptation intensity and choices of adaptation strategy. The three-stage analyses are materialized by applying the double hurdle model and multivariate probit model, which provides a potential way to systematically assess household adaptation decision-making in rural settings.

Findings – Results show a high level of involvement in adaptation among local households who are facing multiple stressors including climatic risks. The findings suggest that perceived climate change influence

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households' decisions in both adaptation status and intensity. Access to financial credit, farmland size, water availability and physical asset holdings are identified as key factors promoting the adoption of more adaptation measures. To facilitate adaptation, collective effort and support at community level is important in providing knowledge based climate information dissemination and early warning systems. Public sector support and development aid programs should focus on positive triggers for targeted community and household adaptation.

Originality/value – The study, to the authors' best knowledge, is one of the first studies to investigate the determinants of local adaptation decision-making systematically in Cambodia. It also provides a comprehensive approach to improve understanding of adaptation decision-making processes by exploring how various capital assets are associated with different stages of adaptation decisions. The findings contribute to policy implications enlightening adaptation planning at multi-scales with knowledge of key factors, which enhance local adaptive capacity to reduce climate change vulnerability.

Keywords Adaptive capacity, Southeast Asia, Climate change, Rural livelihoods, Adaptation decision

Paper type Research paper

1. Introduction

It is generally acknowledged that the poor in developing countries are vulnerable to shocks and crisis with limited adaptive capacity; and climate change induced adverse impact is one of the many stressors they may face, due to higher dependence on climate-sensitive income sources (e.g. agricultural and natural resource-based) (Mertz *et al.*, 2009; Piya, 2019). The importance of using bottom-up approaches to examine socio-economic aspects of climate change at the local level has been highlighted by recent research to acknowledge context-specific vulnerability and capacity to adapt in a dynamic social-ecological system confronted with multiple drivers of change (Piya, 2019). Adaptation, defined as the adjustment in the system to a new or changing environment (i.e. climatic stimuli in the context of climate change) (Evers and Pathirana, 2018; Smit *et al.*, 2000; Smit and Wandel, 2006), not only can be planned and initiated by the government but also requires autonomous adjustments at the household and community level (Smit *et al.*, 2000).

Adaptive capacity is defined as the ability of a system to moderate the potentially adverse impacts of climate change and take advantage of arising opportunities (IPCC, 2007). Several conceptual frameworks have characterized its elements as related to a composite of socio-economic, technological, informational, institutional and psychological factors (Grothmann and Patt, 2005; Yohe and Tol, 2002). In the context of rural livelihoods, these factors are interpreted in a sustainable livelihood approach as portfolios of capital assets (i.e. natural, human, financial, social and physical) that households can build up to tackle risks, including climate risks (Li *et al.*, 2016; Piya, 2019; Scoones, 1998). Thus, adaptation to climate change and variability is regarded as an intrinsic part of households' overall risk management strategies in rural reality. A better understanding of the processes that shape households' adaptation decisions is essential for developing pertinent policies locally, thereby enabling better adaptation across scales and multiple stakeholders. By examining the determinants of household decisions to adapt, it is also possible to target factors that facilitate or constrain adaptation. This helps to identify key components of current adaptive capacity, which leads to important insights into households' competence to adapt in the future (Füssel and Klein, 2006).

Studies on socio-economic aspects of climate change has gained momentum in the past decade. There is limited empirical evidence concerning the determinants of households' adaptation decisions (Below *et al.*, 2012; Vincent, 2007). A few studies have examined what drives discrete choices of adaptation by investigating the factors that affect the option of whether to adapt (Deressa *et al.*, 2011; Maddison, 2007) or various but mutually exclusive adaptation choices (Bryan *et al.*, 2013; Deressa *et al.*, 2009; Gbetibouo *et al.*, 2010; Molua, 2009; Waibel *et al.*, 2018) or the probability of one household carrying out multiple adaptation measures (Piya *et al.*, 2013). Other studies have addressed what influences the depth of adaptation, i.e. how many adaptation practices were implemented by individual households (Below *et al.*, 2012; Esham and Garforth, 2012; Gong *et al.*, 2018). The majority of these studies focus on rural communities in Africa (Bryan *et al.*, 2013; Deressa *et al.*, 2009; Gbetibouo *et al.*, 2010), with a few in Asia (Gong *et al.*, 2018; Piya *et al.*, 2013; Wang *et al.*, 2010) and rarely in Southeast Asia (Waibel *et al.*, 2018).

In this study, we incorporated the above considerations and research gaps from previous studies and investigated three dimensions of household adaptation decisions in the case study of Cambodia, following Noltze *et al.* (2012) (Figure 1). These are:

(1) adaptation status, referred to as whether any adaptation has been undertaken by the household or not; if yes;

(2) adaptation intensity, defined as the extent (how many adaptation measures) to which adaptation has been performed; and

(3) adaptation strategy, referred to categories of specific adaptation measures undertaken by households that are classified into different themes of adaptation actions.

The geographic focus of the study is Cambodia. As one of the recipients of financial support from the least developed countries fund, Cambodia has begun to launch adaptation actions nation-wide (D'Agostino and Sovacool, 2011). The existing literature reports mostly on experiences from specific adaptation projects in Cambodia (D'Agostino and Sovacool, 2011; Ly *et al.*, 2012; Sovacool *et al.*, 2012), while little has been done to examine adaptation decisions and practices from local actors' perspective (Resurreccion *et al.*, 2008). This paper aims to conduct a systematic analysis on what factors influence households' adaptation decisions in rural Cambodia at three dimensions:

(1) adaptation status;

(2) adaptation intensity; and

(3) adaptation strategy (category).

The study, to our knowledge, is one of the first studies to investigate the determinants of local adaptation decision-making in Cambodia. It also provides a comprehensive approach to improve understanding of adaptation decision-making processes by exploring how

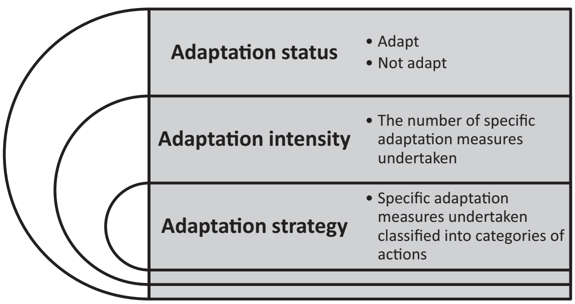

Figure 1.
Conceptual framework of household adaptation decisions in the study

various capital assets are associated with different stages of adaptation decisions. The findings contribute to policy implications by enlightening adaptation planning at multi-scales with knowledge of key factors, which enhance local adaptive capacity to reduce climate change vulnerability.

2. Material and methods

2.1 Study sites

Cambodia is anticipated to be severely affected by climate change, as agriculture is a major pillar of its economy. A decrease of 10-20 per cent in rice yields for the 2020s is projected without adaptation under climate change scenarios (Kim *et al.*, 2018). In this study, fieldwork was undertaken in 15 villages in three communes in Cambodia: Takaen in Kampot Province, Sangkae Satob in Kampong Speu Province and Tum Ring in Kampong Thom Province (Figure 1), which were initially selected in 2008 for the studies of the Poverty Environment Network (PEN, 2007). The studied communes cover a total land area of 70,082 hectares with a population of 23,460 (NCDD, 2010). The majority is Khmer; other ethnic minority groups include Souy and Khmer Muslim. Site selection criteria included:

- large areas, which have been deforested within the last 10-15 years (agricultural frontier); and
- the presence of some degree of reliance on environmental products at the household level.

The sites are all located in the lowlands, including the transition area between lowlands and mountains, and reflect the variations in rainfall patterns and other climatic characteristics.

More specifically, Takaen Commune is located in the coastal cardamom area. Annual rainfall is relatively high, ranging from 2,600 to 3,200 mm. Sangkae Satob Commune is located in the transition zone between the northern Cardamom mountain range and the lowlands of Tonle Sap Lake. The dry season is shorter than four months with low annual rainfall ranging between 800 and 1,400 mm. Tum Ring Commune is a lowland area in a remote part of Kampong Thom Province. The area experiences a relatively long and intensive dry season that lasts for more than four months. Annual rainfall ranges from 1,400 to 2,000 mm with an average of 1,700 mm (Ra *et al.*, 2011) (Figure 2).

Rural livelihoods in the study areas are a combination of subsistence and cash income-oriented activities with the transition to a more diversified livelihood portfolio. Agricultural production remains the most important component of local livelihoods. The collection of forest and other environmental products also contributes significantly to household income portfolio (Ra *et al.*, 2011). Seasonal and long-term migration and remittances are becoming important for livelihood strategies. Major climate risks in the study area are droughts and minor floods (Bylander, 2015; Nguyen *et al.*, 2009), which have a direct impact on rice and other crop productivity. In general, there are no irrigation systems at the study sites, and paddy fields located at higher elevations and away from water bodies are at increased risk of drought and dry spells.

2.2 Data collection

Participatory group discussions and structured household questionnaire surveys were used as primary data collection methods. Data collection and handling followed the procedures developed by the PEN (Angelsen *et al.*, 2011). A total of 600 households were randomly selected initially in 2008, with 200 households in each study site and 40 households in each of the 15 villages (corresponding to 10-30 per cent of households in each village). Of the originally

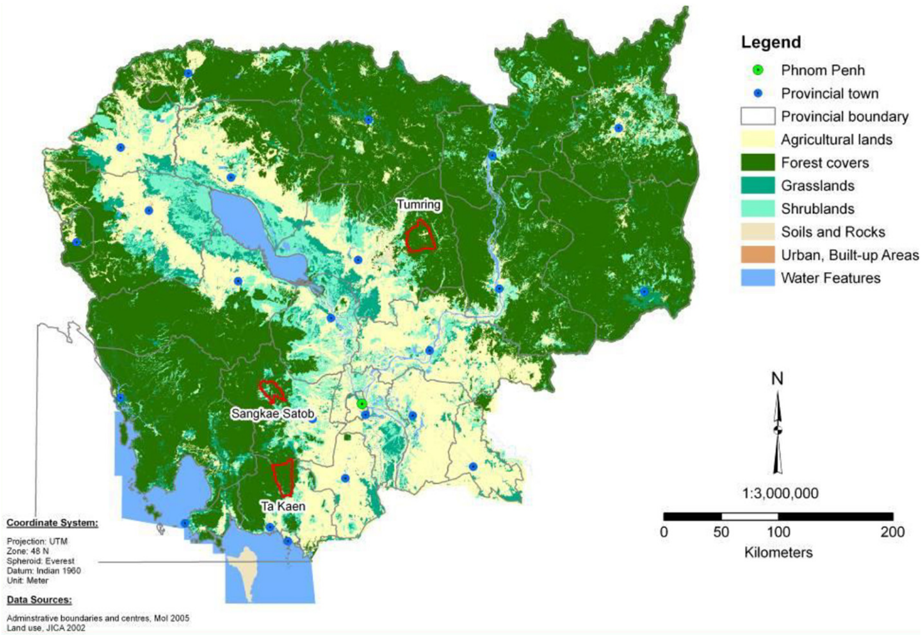

Figure 2.
Locations of selected study sites

selected 600 households, 586 households participated in the second wave of the structured household surveys in January of 2013, where the questions for this study on climate change perception and adaptation were incorporated (which was not part of the study in 2008).

The structured questionnaire focussed on households' observations and perception of climate variability and extreme events, past experience of livelihood risks/shocks (especially climate risks and impacts on livelihoods) and adaptation behaviours and decisions, as well as five capital asset holdings and income sources. Experienced local research assistants and enumerators participated in pre-testing of the questionnaire and the survey process. Participatory group discussions were conducted prior to household surveys to gather contextual and qualitative information as inputs to detailed household survey questionnaire design (e.g. to identify localized adaptation measures). Two villages from each study site were selected for group discussions, reflecting diversified climate risks and livelihood strategies. Groups representing different genders and age and a diversity of livelihood strategies discussed the vulnerability and adaptation matrix, seasonal calendar and historical timelines in six of the villages using interactive flip chart tables and drawings facilitated by local research assistants.

2.3 Empirical models

Probit models and Heckman sample selection probit models have been used by previous studies to investigate the decision of households to adapt or not (Deressa *et al.*, 2011; Maddison, 2007). However, adaptation is not simply a yes or no decision, and binary models fail to consider the intensity of adaptation or the relationship between different measures (Noltze *et al.*, 2012; Piya *et al.*, 2013). Continuous models or count models were also used to analyse adaptation intensity (Below *et al.*, 2012; Esham and Garforth, 2012). In our study, we are interested in both decision stages: firstly, the decision to adapt or not, and secondly, the degree of intensity with which households undertake adaptation measures. Thus, this study uses a double hurdle model (Cragg, 1971), more specifically a Poisson count data hurdle model (Mullahy, 1986) to operationalize the two-stages of the decision-making process in the rural communities in Cambodia, and the approach has been applied in the context of agricultural technology adoption (Langyintuo and Mungoma, 2008; Noltze *et al.*, 2012; Tambo and Abdoulaye, 2012).

$$y_{i1}^{*} = x_i^{'}\alpha + \mu_i \tag{1}$$

$$y_{i2}^{*} = z_i^{'}\beta + \omega_i \tag{2}$$

Adopted from Noltze *et al.* (2012), equation (1) examines the binary decision to undertake any adaptation measures, whereas the number of adaption measures the household has practiced is represented by equation (2). y_{i1}^{*} and y_{i2}^{*} are the two latent variables of adaptation status (whether to adapt any) and intensity (how many measures undertaken). $x_i^{'}$ and $z_i^{'}$ are vectors of household characteristics and asset capital variables (Table I), which determine the adaptation decisions, and α and β are coefficients to be estimated. μ_i and ω_i represent the respective error terms, which are assumed to be independent and distributed as $\mu_i \sim$ N (0,1) and $\omega_i \sim N(0,\sigma^2)$. More specifically, the first decision stage regarding whether to adopt any adaptation measures ($y > 0$) is estimated by a binomial logistic regression model; while the second decision stage is based on a conditional distribution of the number of adaptation measures adopted, given $y > 0$ (Greene, 2008). The two-part likelihood function used in the model estimation is described in details in Jones (1989) and Noltze *et al.* (2012).

Further, this study uses a multivariate probit model (MVP) to analyse the determinants of individual adaptation strategy among the studied households in rural Cambodia. MVP enables modelling the probability of choosing more than one adaptation strategy option simultaneously, which overcomes the limitation of the multinomial logit model with strict assumption of independence of the irrelevant alternatives (Piya *et al.*, 2013). The same set of explanatory variables were used for the double hurdle model and the MPV model, which allows the investigation of how specific factors affect different decision stages and types of adaptation strategy.

$$Z_{ij} = X_i\beta + \varepsilon_i, \quad i = 1, \ldots, \quad n \tag{3}$$

Following Piya *et al.* (2013) and Tabet (2007), the MVP model is described as equation (3) above. Where $i = 1, \ldots,$ n are the individual household observations, $j = 1, \ldots,$ J are the available distinct binary adaptation responses; $Z_{ij} = (Z_{i1}, \ldots, Z_{iJ})'$ presents a J-variate normal vector of latent variables and X_i is a matrix of covariates composed of explanatory variables, which influence a household's decision regarding adaptation choices; $\beta = \left(\beta_1^{'}, \ldots, \beta_J^{'}\right)$ is a matrix of unknown regression coefficients, ε_i is a vector of residual error distributed as multivariate normal distribution with zero means and unitary variance; $\varepsilon_i \sim N(0,\sum)$ where $\sum$ is the variance-covariance matrix.

$$Y_{ij} = \left\{ \begin{matrix} 1 & if\ Z_{ij} > 0; \\ 0 & otherwise \end{matrix} \right\} \quad i = 1, \ldots, n \quad and \quad j = 1, \ldots, \quad J. \tag{4}$$

Let $Y_{ij} = (Y_{i1}, \ldots, Y_{iJ})$ denote the J-dimensional vector of observed binary responses taking values {0, 1} on the i-th household. The relationship between Z_{ij} and Y_{ij} is described in equation (4). For further information on the model specification (i.e. likelihood function and correlation matrix), see Piya *et al.* (2013) and Cappellari and Jenkins (2003).

Variable	Expected sign	Description	Capital assets	Mean	SD
Age of HH head	+	Age of household head in years	Human capital	44.90	11.99
Age^2 (of HH head)	−	Age (of household head) squared	Human capital	2159	1149
HH size	+	Number of household members	Human capital	5.14	1.76
Female-headed HH	−	Household is female headed: 0 = male; 1 = female	Human capital	0.18	0.39
Education of HH head	+	Number of years in school completed by the household head	Human capital	3.43	3.17
Health status (sickness)	−	Number of family members who are in bad health	Human capital	0.33	0.98
Perception of climate change	+	Household perceived changes of extreme climate events (i.e. flood, drought)	Human capital	0.96	0.21
Past experience with drought	+	The average loss of paddy production during drought year (in percentage) compared with normal production year	Human capital	0.24	0.28
Farmland area	±	Area of cultivated farmland (hectares)	Natural capital	1.14	1.34
Access to water	+	Amount of water available to household farmland: 1 = low availability or too much water; 2 = moderate; 3 = good for agricultural production	Natural capital	2.09	0.80
Physical assets	+	The current value of all physical assets owned by the household (in million Riel local currency)	Physical capital	4.87	7.82
Access to market	−	Distance to the nearest main road (in kilometers)	Physical capital	0.11	0.62
Access to credit	+	Number of financial sources household able to access (i.e. formal banks and government programs/village development fund, self-organized saving groups, informal credit from relatives or friends)	Financial capital	2.04	0.67
Trust	+	General trust among people living in the village/community: 1 = no; 2 = partly; 3 = yes	Social capital	2.47	0.55
Sangke Satob	±	Household located in Sangke Satob commune: 1 = Yes; 0 = otherwise	Social, natural, physical capital	0.34	0.48
Tum Ring	±	Household located in Tum Ring commune: 1 = Yes; 0 = otherwise	Social, natural, physical capital	0.32	0.47

Table I. Explanatory variables selected for the empirical models

2.4 Model variables

In the first decision stage – adaptation status, we use the dummy variable (Yes/No), which indicates whether households have taken any adaptation measures. Adaptation intensity is calculated using the simple unweighted sum of adaptation measures households have adopted. We assume that each adaptation measure is equally important depending on the location where it is implemented. All the adaptation measures are then categorized into five broader adaptation strategy categories (Figure 3) as the dependent variables for the MPV model.

The choice of explanatory variables was based on the literature review and results from participatory group discussions (Table I). Mixed results have been reported in the literature

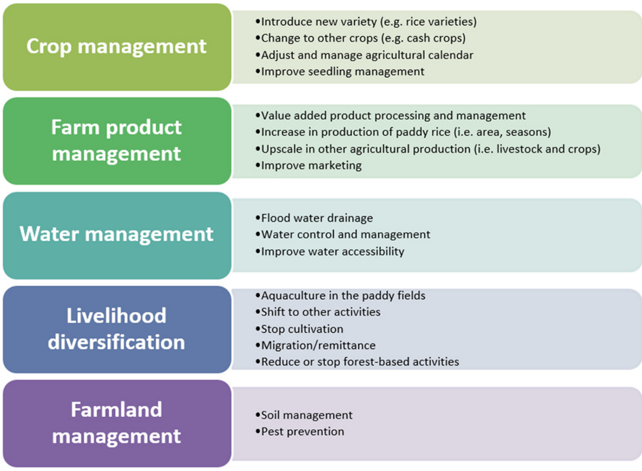

Figure 3.
Categorization of adaptation measures into five adaptation strategies

regarding the impacts of age on adaptation, showing both increased and decreased propensity to conduct different adaptation measures (Deressa *et al.*, 2009; Hassan and Nhemachena, 2008; Piya *et al.*, 2013). In this study, we expect that older households are more likely to adapt as they are more experienced in farming. However, we also hypothesize that intention to adapt drops above a certain age threshold given that households have more limited energy and ability to implement adaptation or that they have less need to adapt given reduced consumption. Thus, age-squared is included in the model. The literature also shows varying relations between household size and the uptake of adaptation measures. For instance, larger families were found more likely to carry out soil and water conservation practices (Bryan *et al.*, 2013) and labour intensive measures such as multiple cropping (Hassan and Nhemachena, 2008). In this study, we expect that households with more family members will be more inclined to adapt and conduct strategies that require a larger pool of labour supply such as livelihood diversification. Moreover, the literature has well-documented gender-specific adaptation measures on account of the differential access of men and women to assets, education, credit and information, which is very much decided by the specific context where adaptation occurs (Below *et al.*, 2012; Bryan *et al.*, 2013; Deressa *et al.*, 2009). In this study, we also expect major variances in adaptation decisions, intensity and types of strategies with regard to gender, and less adaptation practiced by female-headed households. Education is another important factor in promoting adaptation and the adoption of agricultural technology (Maddison, 2007; Tambo and Abdoulaye, 2012). We hypothesize a positive impact of education on adaptation as more schooling may enhance households' capabilities to approach, interpret and make use of information pertinent to adaptation. The health conditions of households have seldom been considered when elaborating adaptation decisions in the current literature. In this study, we incorporate this variable (i.e. number of family members who are in bad health) in the analysis and hypothesize that it negatively affects adaptation as it not only reduces the effective labour supply, but also that households may be forced to divert part of their time and money to care for members in need.

Several studies have found that households' perceptions of climate change (changes in long-term temperature, precipitation and climate variability such as drought) and its related impacts are positive and significant determinants of adaptation decision-making

(Comoé and Siegrist, 2013; Deressa *et al.*, 2011; Deressa *et al.*, 2009; Esham and Garforth, 2012). As drought and flood have been reported as the most frequent and concerned extreme climatic events in the study areas (95.6 per cent of the interviewed households observed irregular flood and drought patterns in recent years), this study focuses on investigating the perception and awareness of the frequency and magnitude of changes regarding these two climatic events. We expect that households, which notice such changes in climate will tend to adapt and with greater intensity with diverse measures to prevent losses or to take advantage of opportunities. We further study the impact of past experience with climate risks on adaptation behaviour measured in terms of crop harvest losses to previous droughts. Theoretical models have underlined past personal experience as an important catalyst of adaptation (Grothmann and Patt, 2005). In this study, we assume that households, which have had bad experiences with climate change events in the past will tend to undertake adaptation using various measures.

The literature has demonstrated mixed effects of farmland area on adaptation, depending on the type of adaptation measures being explored. Households with larger size of farmland were found more likely to change crop varieties, conduct soil and water conservation measures and plant trees (Bryan *et al.*, 2013; Piya *et al.*, 2013; Waibel *et al.*, 2018), while those with less farmland appeared to be supportive of adopting multiple crop or crop-livestock systems with irrigation (Hassan and Nhemachena, 2008). We hypothesize that the farmland area is positively associated with propensity to adapt and adaptation intensity, which increases the probability of uptake of all adaptation strategies except for livelihood diversification. Furthermore, we consider the effect of access to water on adaptation decisions. Bryan *et al.* (2013) found that access to irrigation enables changing crop type. In this study, we expect that improved access to water stimulates adaptation, in particular strategies managing crops, water and farmland. The literature also suggests that the availability of machinery drives adaptation (Below *et al.*, 2012). In this study, we assume that households, which are richer in physical capital including production machinery (e.g. tractors) and telecommunication devices (e.g. mobile phones), relate positively to various adaptation decision-making processes.

Various studies have noted the significance of access to market in facilitating adaptation of a diverse nature, given the essential role of the market for information gathering and sharing (Below *et al.*, 2012; Hassan and Nhemachena, 2008; Maddison, 2007; Tambo and Abdoulaye, 2012). In this study, access to market is controlled by the distance to the nearest main road. It is expected that households located further away from the main road are less likely to adapt. Similarly, the indispensable role played by access to credit in boosting adaptation in a variety of ways is well documented in the literature (Below *et al.*, 2012; Deressa *et al.*, 2009; Hassan and Nhemachena, 2008; Piya *et al.*, 2013). We hypothesize that households with more sources to accumulate financial capital at their disposal are better able to purchase inputs and invest in costly strategies if needed, and therefore, more likely to adapt with an expanded range of strategies including those in this study. It has been established that different forms of social capital (e.g. social networks, informal institutions) act as key stimulants of adaptation by providing critical conduits to transfer finances and information(Adger, 2003; Wolf *et al.*, 2010), as well as forming common collaborative frameworks. In this paper, we used the level of trust among households as a proxy for social capital, and assume that it is positively associated with different types of adaptation decision-making.

As adaptation is highly context-specific (Smit and Wandel, 2006), we included location dummies to capture the heterogeneity in biophysical and socio-economic conditions across communities, and expect that adaptation decisions vary significantly among households residing in different geographical zones, as reported in other studies (Deressa *et al.*, 2009; Hassan and Nhemachena, 2008; Piya *et al.*, 2013; Tambo and Abdoulaye, 2012).

3. Results

3.1 Descriptive statistics

Over 80 per cent of the household survey respondents observed a decrease in total annual rainfall and irregular shifts in rainfall patterns during recent years. Local communities often associate the increased climate risks with loss of forests due to logging, agricultural land conversion and large-scale economic land concessions. The results show that the majority of households have undertaken a variety of adaptation strategies in the study area (Table II). The number of households, which reported no adaptation measures accounted for only five per cent of the sample. On average, households undertook over three adaptation measures (*mean* = 3.17, *sd.* = 2.04, *range* = 0-12) out of a total of 18 diversified local practices. Among the five groups of adaptation strategies, crop management practices, such as adjusting crop varieties and types, improving seedlings and shifting planting dates, were most commonly practised by households (81 per cent). Measures constituting key components of farmland management, such as enhancing soil fertility and pest control, were also widely used (53 per cent). Other groups of strategies included managing agricultural products, which was aimed primarily at strategic processing and marketing (e.g. crop and livestock products) (37 per cent), diversifying livelihoods that focussed on using other natural resources (e.g. fish ponds) and engaging in non-farm activities (e.g. small businesses and migration for remittance) (23 per cent), water resource management strategies, which consist of water and flood control (e.g. drainage), as well as improving access to water for agriculture (e.g. pumps) (20 per cent).

The main groups of adaptation practices adopted by households varied across the three study sites. Households in Takaen and Sangke Satob were more similar in terms of adaptation patterns, except for the frequency of practicing water management. The application of water management was more prevailing in Takaen than in Sangke Satob. While crop management remained the most prevalent group of measures adopted by households in Tum Ring, like in the other two provinces, product management was another key adaptation category, which was ranked second in terms of frequency.

3.2. Results from the logit-Poisson hurdle model

Before going into the discussion of determinants of adaptation, we tested the specifications of the logit-Poisson hurdle model against its alternatives to justify its use. First, the Poisson model was compared to the negative binomial regressions model (Long and Freese, 2001). We found no over-dispersion of the data based on the insignificant

Table II. Adaptation strategies adopted by households in the study area

Adaptation measures	Takaen (*n* = 200)	Sangke satob (*n* = 201)	Tum ring (*n* = 185)	Total (*n* = 586)
Crop management	173 (87)	167 (83)	135 (73)	475 (81)
Water management	20 (10)	54 (27)	43 (23)	117 (20)
Farm products management	62 (31)	73 (36)	81 (44)	216 (37)
Livelihood diversification	55 (28)	40 (20)	38 (21)	133 (23)
Farmland management	137 (68)	118 (59)	56 (30)	311 (53)

Note: Percentage of households adopting a specific type of adaptation presented in parenthesis coefficient estimated, which reflected unobserved heterogeneity among observations. This suggests that the Poisson model was in favour. We proceeded to test the two-stage decision model against the single Poisson regression. To do so, we used a likelihood- ratio (LR) test (Greene, 2008), considering that the Poisson model is nested in the double hurdle model given its generalized specification. The result was highly significant ($LR\ \chi^2$ (17) = 43.83, p = 0.0004), thereby rejecting the null hypothesis that the Poisson model was appropriate.

Table III presents the results from the double hurdle model exploring the factors that influence the two-stage household adaptation decisions: whether to adopt any adaptation measures and, if so, how many. Perceived climate change (i.e. drought and flood) and improved access to water for farmland have positive and significant effects on both adaptation decision stages. At the first decision stage, the positive effect of age and a negative effect of age squared show that the probability of adaptation increases with age of household heads; however, when household heads reach a certain age, the effect of age lessens. Other factors that influence the first stage of decision-making include health status and access to market and services. The results show that the poor health of family members may constrain households to adapt; this was expected as participation in different kinds of adaptation is most likely to be labour intensive. Proximity to a main road with better access to market and other services facilitates household adaptation. Regarding the intensity of adaptation, households with more farmland are more likely to adopt a larger number of adaptation measures. We also found that physical asset accumulation and better access to credit have a positive effect on household adaptation intensity. Households with higher crop sensitivity (loss of productivity) because of drought undertake more adaptation measures.

	Decision to adapt		Intensity to adapt	
Variable	Coefficients	p-value	Coefficients	p-value
Sangke Satob (1/0)	−0.838	0.334	0.076	0.179
Tum Ring (1/0)	−2.321***	0.007	0.202**	0.018
Female headed HH (1/0)	−0.473	0.332	−0.103	0.165
Age of HH head (year)	0.267**	0.033	−0.007	0.622
Age^2 (of HH head)	−0.002*	0.056	0.000	0.578
HH size (persons)	0.148	0.261	0.004	0.817
Education of HH head (year)	0.095	0.251	0.000	0.987
No. of sick persons (persons)	−0.209*	0.067	−0.022	0.496
Farmland area (ha)	0.255	0.693	0.052***	0.002
Farmland access to water	0.844**	0.001	0.230***	0.000
Distance to main road (km)	−0.460*	0.051	0.037	0.265
Physical assets (million Riel)	−0.008	0.582	0.006***	0.008
Trust among community	−0.418	0.355	0.040	0.480
Access to credit	−0.473	0.193	0.092**	0.025
Perception of climate change	1.263**	0.037	0.503**	0.021
Past experience with drought	1.868	0.252	0.364***	0.000
Constant	−3.819	0.148	−0.224	0.615
Number of observations	586			
Wald χ^2 (16)	83.41			
p-value	0.0000***			
Log pseudo-likelihood	−1,121.8267			

Notes: HH means household; ***; **; * Significant at 1, 5 and 10 % level, respectively

Table III. Parameter estimates of the logit-Poisson hurdle model

3.3. Results from the multivariate probit model model

The validation of adopting the MVP model – assessing all equations simultaneously instead of the independent assessment of individual equations – was suggested in the significant result of the LR test (χ^2 (10) = 45.05, p = 0.0000). The estimated correlation coefficients (ρkj) among various groups of adaptations were highly significant for 7 out of 10 combinations. The positive signs implied that the adoptions of these multifaceted adaptation strategies are complementary, indicating households often chose more than one adaptation strategy.

Table IV shows the results from the MVP model examining the determinants of households' choices of adaptation strategies, and we found that adoptions of different adaptation strategies are not significantly influenced by the same set of variables. Similar to the two-stage decision-making, better access to water for farmland often provides an incentive to households to adopt crop management, farm product management and farmland management adaptation strategies. The higher extent of crop productivity loss due to drought seems to have a significant positive effect on adopting strategies such as farm product management, water management and farmland management. Farmland size is positively associated with the adoption of crop management and farm product management strategies, while physical asset accumulation seems to facilitate farm products and water management strategies.

While there are factors supportive of several types of adaptations, other factors were found to facilitate only one specific type of adaptation. Human capital and household characteristics seem to only affect the choice of livelihood diversification strategy. Senior male-headed households with a higher education are more likely to diversify or shift to other livelihood alternatives (e.g. running a small business, a migrant worker for remittance), while bad health of family members becomes a barrier to this type of adaptation strategy. Interestingly, households adopting the livelihood diversification strategy often own fewer physical assets, probably because less physical capital is required and they liquidate these assets to invest in non-farm activities. Notably, perception of climate change seems to only influence adaptation of crop management. Trust among people in the community shows a positive and significant effect on undertaking crop management strategies, which underlines the fact that communication and information sharing networks may facilitate the most practiced crop management measures.

4. Discussion

The analyses provide some insights into households' adaptation strategies and their determinants in rural Cambodia. The findings suggest a high level of adaptation involvement among local households with three adaptation measures undertaken on average. This may be explained by the way in which adaptations were addressed and elicited. Indeed, rural households always have to adapt under various situations and risks, and often undertake measures as part of traditional farming practices without regarding them as "adaptation" (Nyong *et al.*, 2007). Given the context of rural livelihoods faced with multiple drivers of change including climate change, adaptation measures adopted by the households in the study area are not necessarily limited to those solely initiated in response to climate change risks, unlike other research (Deressa *et al.*, 2011). In fact, households' adaptation are often conducted to fulfil multiple objectives as an essential part of the overall risk management, which holds particularly true for rural households, who are constantly confronted with diversified stressors (O'Brien and Leichenko, 2000). For instance, some of the adaptation measures reported in our study are mainly climate-related, such as flood water control; while others, such

Table IV. Parameter estimates of the MVP model

Variable	Crop management Coefficients	*p*-value	Farm products management Coefficients	*p*-value	Water management Coefficient	*p*-value	Livelihood diversification Coefficient	*p*-value	Farmland management Coefficient	*p*-value
Sangke Satob (1/0)	−0.083	0.631	0.169	0.214	0.721***	0.000	−0.212	0.150	−0.255*	0.059
Tum Ring (1/0)	0.092	0.611	0.617***	0.000	0.831***	0.000	−0.318*	0.060	−0.812***	0.000
Female headed HH (1/0)	0.234	0.174	−0.027	0.855	−0.076	0.655	−0.398***	0.016	−0.191	0.206
Age of HH head (year)	−0.001	0.897	0.003	0.465	0.003	0.602	0.009*	0.056	−0.006	0.235
HH size (persons)	0.006	0.865	−0.021	0.496	0.039	0.297	−0.002	0.960	0.041	0.188
Education of HH head (year)	−0.007	0.750	−0.006	0.711	−0.007	0.752	0.053***	0.006	0.006	0.743
No. of sick persons (persons)	−0.037	0.558	0.055	0.368	−0.086	0.284	−0.251**	0.044	−0.088	0.136
Farmland area (ha)	0.385***	0.000	0.089**	0.046	0.026	0.579	−0.051	0.386	0.086	0.186
Farmland access to water	0.392***	0.000	0.108	0.154	0.305***	0.000	0.096	0.226	0.220***	0.002
Distance to main road (km)	−0.083	0.396	0.024	0.812	−0.111	0.150	0.038	0.697	−0.053	0.651
Physical assets (million Riel)	0.006	0.516	0.015*	0.050	0.015**	0.044	−0.024**	0.046	0.001	0.880
Trust among community	0.245**	0.037	−0.125	0.208	−0.056	0.632	−0.057	0.596	0.005	0.960
Access to credit	−0.091	0.374	0.190**	0.025	0.235**	0.031	−0.073	0.387	0.108	0.214
Perception of climate change	1.141***	0.000	0.415	0.161	0.661	0.148	−0.244	0.384	0.189	0.506
Past experience with drought	0.014	0.958	0.395*	0.050	0.664***	0.002	0.147	0.529	0.374*	0.068
Constant	−1.755***	0.003	−1.602***	0.002	−3.608***	0.000	−0.613	0.263	−0.559	0.272

(*continued*)

Table IV.

Correlation coefficients	Coefficient	p-level
ρ_{21}	0.171*	0.037
ρ_{31}	0.111	0.237
ρ_{41}	−0.139	0.102
ρ_{51}	0.026	0.750
ρ_{32}	0.208***	0.006
ρ_{42}	0.182**	0.016
ρ_{52}	0.144**	0.040
ρ_{43}	0.280***	0.001
ρ_{53}	0.216***	0.005
ρ_{54}	0.189**	0.011
Number of observations	586	
Draws	100	
Wald χ^2 (75)	400.33	
p-value	0.000***	
Log pseudolikelihood	−1,493.5462	

Notes: Likelihood ratio test of $\rho_{21} = \rho_{31} = \rho_{41} = \rho_{51} = \rho_{32} = \rho_{42} = \rho_{52} = \rho_{43} = \rho_{53} = \rho_{54} = 0$, χ^2 (10) = 45.0472 and p-value = 0.0000; ***; **; * Significant at 1, 5 and 10 % level, respectively. HH means household as changing crop variety and type, are generally beneficial in terms of increasing productivity and profitability, in the meantime reducing risks from different sources (i.e. climate and market).

In this study, we have demonstrated that perceived climate change drives households' adaptation behaviour. An awareness of climate change is regarded as an important factor or even a prerequisite for adaptation, which is highlighted by quite a few theoretical and empirical studies (Deressa *et al.*, 2011; Maddison, 2007). The results from our study; particularly the positive association found between perceived climate change and adaptation decisions provide further evidence that households, which are aware of climate change adapt more readily in a variety of ways. Thus, enhancing awareness of climate change and adaptation among households through capacity building and information dissemination can be an effective approach to promote adaptation. Our study also found that past experience with climatic risks plays a significant role in motivating adaptation; households, which bore heavier crop losses during previous droughts are more likely to adapt with greater intensity and use strategies aimed at protecting (e.g. water and farmland management) or expanding crop production. This finds support in other studies (Koerth *et al.*, 2013; Weinstein, 1989), where personal experience with past damages was found to be a key predictor of self-protective actions against natural hazards. In the study areas where households have poor access to climate information and weak adaptation capacity, knowledge-based information and early warning mechanisms are important for effective community-based and household-level adaptation. Herein, some potential incentive packages are necessary with the support of the private sector (such as the public-private partnership with telecommunication firms) to use mobile technology for weather forecasts, early flood and drought warnings (similar to market information network for farmers via mobile phones or fund transfers via mobile network).

According to our finding, farmland size does not seem to be significantly associated with the decision to adapt, but households with large size of farmland tend to undertake more adaptation measures, especially those related to crop management practices and agricultural product processing and marketing. An associated issue is that insecure land tenure may become a barrier to farmers allocating land or making investments in certain adaptation measures, such as water management infrastructure, as pointed out by many studies (Maddison, 2007; Piya *et al.*, 2013). Farmland access to water is found to be a critical factor in our study, which influences adaptation status and intensity decisions, as well as adaptation strategy choices regarding farmland, water and crop management. This complies with other findings about the significant impact of access to irrigation on adaptation (Bryan *et al.*, 2013). In the studied communities, crop production is mainly rain-fed agriculture and irrigation systems are not available. Appropriate water management facilities and technologies should, therefore, be promoted and enhanced to facilitate the adoption of agriculture-related adaptation options in the study area.

Households located closer to the main road and with better access to market and services are found most likely to adapt in our study, which is largely in line with other studies (Below *et al.*, 2012; Deressa *et al.*, 2011; Maddison, 2007). However, proximity to the main road is not significantly associated with adaptation intensity or any adaptation strategy choices. Possible reasons for this could be weak infrastructure and a lack of facilities in general in the study areas. This indicates that poor access to inputs, technologies and information, together with high transaction and opportunity costs, constitute critical entry barriers to further participation in adaptation (Hassan and Nhemachena, 2008; Piya *et al.*, 2013). Our findings also suggest that household physical assets serve as a significant contributor to adaptation intensity and promote the adoption of water and agricultural product management strategies, while its impact is negatively significant on the adoption of livelihood diversification strategy (e.g. small business, migratory work for remittance). Possible explanations may lie in that diversification has a lower demand for these assets or that these assets could actually be transformed into financial capital for investment in other non-farm activities.

There exists ample empirical evidence for credit availability as an influential factor in facilitating local adaptation (Below *et al.*, 2012; Bryan *et al.*, 2013; Deressa *et al.*, 2011; Hassan and Nhemachena, 2008; Piya *et al.*, 2013; Tambo and Abdoulaye, 2012), and it is further substantiated through our study that better credit accessibility enables households to undertake more adaptation measures, especially in water management and farm product management strategies in the local communities. To facilitate adaptation, investments and support could be directed to microcredit schemes, a social fund for community-based adaptation and weather-based insurance.

Our study suggests that male-headed, well-educated households and household members who are in good health are more likely to adapt by means of livelihood diversification. The result echoes the findings of other studies (Bryan *et al.*, 2013), where men – because of their stronger financial situation and better access to information/resource use – tended to adopt certain adaptation strategies (e.g. change animal feed). The result also confirms the positive effect of education on varied adaptation behaviours disclosed by others (Deressa *et al.*, 2009; Tambo and Abdoulaye, 2012). The analyses indicate that continuous investment in education and medical care systems, as well as measures that empower women should be emphasized as a key policy option in the study area to strengthen households' adaptive capacity. Furthermore, we found that trust among households is one of the key motivators for implementing crop management strategies in the study area. This may be because of that trust serves as the basis for social networking and information sharing about farming practices and crops among community members. Our study coincides with other studies, which highlight the essential role of social capital in the uptake of adaptation (Comoé and Siegrist, 2013; Esham and Garforth, 2012). Consequently, policies, which aim to reinforce community institutions and bonds are considered an effective means to facilitate adaptation to climate risks.

The significant coefficients of location dummies indicate that households living in different geographical settings used local-specific adaptation approaches, which was also found in other studies (Bryan *et al.*, 2013; Deressa *et al.*, 2009; Piya *et al.*, 2013). This implies that no one-size-fits-all adaptation strategy could be used across all communities. The formulation of adaptation strategies needs to be tailored to the local context and accommodate the specific needs and constraints of targeted communities (Bryan *et al.*, 2009). It is important to understand the fundamental process and drivers regarding adaptation at the community and household levels.

The three-stage analytical approach applied in our study provides a potential way to systematically assess household adaptation decision-making in other rural settings. However, site-specific selection of variables is needed to allow for the incorporation of local and contextual considerations. The method of using the unweighted sum of adaptation measures may not be a good reflection of the relative importance and contribution of different options towards enhanced adaptive capacity. This could be further refined in future research using objective weighting schemes derived from e.g. principal component analysis (Li *et al.*, 2016). Moreover, this study did not investigate the effectiveness or the associated costs and benefits of particular adaptation options, which points to future research in this area.

5. Conclusion

This study took a systematic approach to exploring the determinants of household adaptation decision-making from three dimensions, namely, adaptation status, adaptation intensity and choices of adaptation strategy. Key capital assets that determine household adaptation behaviours, which were identified through the double hurdle model and MVP model analyses, correspond well with the hypothesized results and existing empirical studies, and contribute to the literature with new angles and in-depth results at various adaptation decision-making stages. This paper provides an analysis of households' own autonomous adaptation measures practiced at present, although the speed and magnitude of climate-induced changes may seriously challenge their adaptive capacity in the future. Considering the significant influence of households' climate change perceptions on adaptation, actions should be taken to promote channels of climate information dissemination and sharing (e.g. through dialogues) at the village and sub-district levels. In this study, potential interventions derived from influential factors for adaptation decisions include improvement of rural infrastructure and services (i.e. education, healthcare, market facilities), the strengthening of local institutions and social capital, development and promotion of water management facilities and technologies, as well as micro-credit and insurance mechanisms. More importantly, adaptation strategies and actions should be tailored to the local context and mainstreamed into existing community development policy and planning process, involving multi-stakeholders.

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