How do capital asset interactions affect livelihood sensitivity to climatic stresses? Insights from the northeastern floodplains of Bangladesh

Abstract

This paper offers a novel methodological approach for better understanding how different capital assets can be organized, transformed, and used in different combinations to reduce livelihood sensitivity to climatic stresses – an area that requires greater research attention in the context of adaptation policy. Research was conducted in the northeastern floodplain communities of Bangladesh, regarded as one of the most climate sensitive, resource poor, and highly understudied areas of the country. This wetland-dominated ecosystem is home to diverse resources user groups (e.g., farmer and fisher) who are subjected to regular seasonal flooding, excessive rainfall, drought, and flash floods. Working in 12 adjacent villages of two significant wetlands (Hakaluki *haor* and Tanguar *haor*), qualitative and quantitative data were collected through 15 focus groups (n=15), 35 key informant interviews, and 356 household surveys to better understand how community members adapt in response to their livelihood sensitivity to the climatic stresses. Results indicate that community members organize and transform capital assets in diverse way to escape climate-induced 'poverty traps'. Findings also reveal that interventions from external agencies (e.g., government, non-governmental organizations and market institutions) are an important key to livelihood sustainability for many households.

Keywords: Asset combination; Adaptive capacity; Livelihood strategies; Thresholds; Wetland systems.

1. Introduction

Sensitivity, a component of climate vulnerability, indicates the degree to which a system is either positively or negatively affected by climatic stresses (IPCC, 2012). In other words, it is the measurement or exploratory description of a system's stability under stress. However, since sensitivity depends on context-specific system properties and their responses to stresses, there is no 'rule of thumb' for describing it in different contexts (Ford et al., 2010). For example, rural smallholders in developing countries are considered to be among the most climate-sensitive livelihood groups since they depend on social-ecological systems for their living (Bele et al., 2013; Ford et al., 2014). While the livelihood activities of, and opportunities for, rural smallholders are governed by the availability and productivity of ecosystem resources and socio-economic processes (Bele et al., 2013; Etzold et al., 2014), climatic uncertainties directly impact the ecosystem and influence livelihood sustainability (Bunce et al., 2010; Eitzinger et al., 2014).

According to the sustainable rural livelihoods (SRL) framework, livelihood resources, which are derived from social-ecological systems, are grouped into five capital asset categories: financial, manufactured, human, social, and natural capital (Ellis, 2000; Reed, et al., 2006; Birkmann et al., 2013; Speranza, et al., 2014). These asset categories are widely used as the basis for sensitivity-measuring indicators (Binder, et al., 2013; Marshall, 2011) that operate on the underlying assumption that the degree of access to assets directly influences a household's sensitivity to various stresses (Barua et al., 2014). However, the selection of indicators is highly contextual (Birkmann, 2006; Polsky et al., 2007; Füssel, 2010). For example, three very different sets of indicators were used to conduct assessments of the sensitivity of river basin management in Taiwan, marine-fisheries-based livelihoods in Bangladesh, and water resource systems in the eastern Nile basin (Hamouda et al., 2009; Hung and Chen, 2013; Islam et al., 2014). Notably, the selection of indicator sets is often guided by indicator selection principles and is grounded either in the existing literature or derived from field studies (Adger et al., 2004; Birkmann, 2006).

Despite the theoretical rigor and methodological robustness of indicator-based analysis, some researchers remain skeptical about its usefulness. For example, Below et al. (2012) noted that indicator approaches provide normative arguments (e.g., which conditions are good and which are bad) but cannot offer context-specific conclusions when applied to assess a poorly-defined system. Moreover, O'Brien et al. (2007) suggested that context-specific sensitivity is an assimilation of political, institutional, social, and economic structures, many of which are external to the context. These findings are extended by Hinkel (2011) who identified this feature as a major challenge to defining the boundary of a system. In addition to these observations, we also note that the indicator-based approach often fails to reflect the theoretical background of individual (or groups of) indicators. For example, according to the SRL framework, capital assets are connected to each other in different ways (Fang et al., 2014). Notably, each of these assets has its own observed variables, and variables of one asset may interact with those of another. In this paper, we assume that livelihood sensitivity is governed by these overlapping interactions, but that it cannot be adequately captured by their independent assessment.

This paper goes beyond widely used indicator-based measurements and offers a methodological approach that aims to addresses three key livelihood sensitivity-related questions: i) To what extent are capital assets connected to each other? ii) What is the nature of their interconnectivity? and iii) How do the interactive associations of capital assets contribute to reducing climate sensitivity? Thus, this study contributes to filling a research gap that limits our understanding of how resources can be better invested to reduce livelihood sensitivity to climate change (Ribot, 2014).

2. Conceptual background

2.1 Characterizing capital assets

Rural development literature suggests that capital assets enhance the ability of smallholders to sustain their livelihoods, while climate adaptation studies identify them as buffers against risk and uncertainty (Devereux, 2001; Cinner et al., 2013; Speranza et al., 2014). However, the characterization of capital assets in relation to climate sensitivity is dynamic and complex. Although overlooked in much of the adaptation literature, development economics and resilience theories provide two necessary concepts that can assist with better describing these relations: poverty and rigidity traps.

Development economics describes a poverty trap as self-reinforcing, persistent poverty that occurs because of three conditions (Maru et al., 2012). The first condition is the *threshold effect*, which suggests that poverty persists because one or more capital assets remain under a critical level, consequently slowing development growth. The second condition, *institutional dysfunction*, may arise due to socially-embedded power asymmetries, the political exclusion of marginalized sects of society, and economic inequality. The third condition, *neighborhood effect*, results from socio-economic inequalities that separate society into several sub-groups based on economic status. This condition describes a socio-economic situation wherein affluent groups are able to afford better opportunities, whereas less affluent groups cannot; the result is that poorer groups tend to inherit their economic status, which is passed down from generation to generation.

As described in Holling (2001) and Moore and Westley (2011), resilience theory suggests that a community becomes stuck in a poverty trap as a consequence of poor potential (i.e., assets), poor connectivity (i.e., network and institutional connectivity), and poor resilience (i.e., the capacity to consume external shocks like climatic stresses). For example, Maru et al. (2012) and Crona and Bodin (2010) suggest that indigenous communities often fall into poverty traps because of economic and social inequity resulting from insufficient and unorganized capital assets, and that this situation of limited resources leads to unfocused and myopic innovations.

Although discussed primarily in resilience theory, a rigidity trap is considered a consequence of high levels of potential, over connectivity among institutional actors, and high resilience (Carpenter and Brock, 2008). When a system falls into a rigidity trap, an innovation vacuum is created, which can lead to lower diversity and change within the community (Allison and Hobbs, 2004; Carpenter and Brock, 2008; Holling, 2001). For example, Amekawa (2011) argued that households with higher levels of capital asset endowment for agricultural activities tend to show poor innovation when it comes to generating non-agricultural livelihood activities. Despite this, Maru et al. (2012) concluded that, between the poles of the poverty and rigidity trap, there is an optimal range of potential, connectivity, and resilience that supports the development of innovation, self-organization, and flexibility to reduce sensitivity. However, while the identification of this range is critical, it is often very difficult. For example, it is unclear what level of assets constitutes the threshold of this range, which assets can be categorized as having 'low' or 'high' potential, or what level of connectivity indicates functioning institutions.

Both development economics and resilience concepts consider such traps from different perspectives, yet together they propose that homogeneity in asset ownership across a community (a development economics perspective) and functional connectivity among them (a resilience perspective) are necessary for escaping traps and generating and sustaining multiple livelihood activities (Moore and Westley, 2011; Maru et al., 2012). Both concepts also emphasize the capital assets required to sustain a livelihood through generating necessary feedbacks when stresses occur

(Haider et al., 2018). Here, the SRL framework focuses on three potential relationships among assets. First, assets may be sequentially related, which means that one capital asset ensures the availability of others and vice versa. For example, Barua et al. (2014) noted that the loss of human capital increases the susceptibility of natural capital loss, while households with higher levels of financial capital can bear the cost of innovation by experimenting with new technologies and learning new skills (van den Berg, 2010). Second, one asset may be substitutable for another. For example, Tacoli (2009) and Etzold et al., (2014) point out that, in the absence of sufficient natural capital, the climate-stressed rural poor in Bangladesh adopt migration—which requires a high degree of social capital—as a livelihood strategy. Third, a combination or cluster of different assets sustains livelihood activities. For example, Deressa et al. (2009) noted how Ethiopian farmers depend on all five capital assets in order to adapt, while Dorward et al. (2009) concluded that capital assets are used in specific combinations for generating different livelihood strategies.

2.2 Capital assets and livelihood diversities

Chambers (1989) and Amekawa (2011) have suggested that rural smallholders do not invest all their assets in a single livelihood practice; rather, they distribute them among multiple activities to reduce the risk of investment failure. Therefore, rural communities construct a portfolio of practices, which Cinner and Bodin (2010) define as a livelihood landscape. Livelihood opportunities are dependent on a household's 'bundle of rights' in relation to the assets (Ribot and Peluso, 2003), although access rights are often challenged by the poverty that results from social exclusion, skewed market access, powerlessness, and exclusion from policy processes (Goulden et al. 2013; Ribot, 2014). Thus, it has been argued that the impact of climatic uncertainties is compounded by socio-political and socio-economic entities, which in turn creates a group of people who are highly sensitive to climatic stresses (Kelly and Adger, 2000; Scoones, 2009). As a result, the exclusion of socio-political and socio-economic entities from the description of climate sensitivity is conceptually difficult.

2.3 Measuring livelihood sensitivity

Although an explicit connection exists between climatic and non-climatic entities (McDowell and Hess, 2012), Cinner et al. (2012) were able to offer a livelihood sensitivity measurement technique that is solely based on natural resources dependency. This technique is based on the concept that sensitivity results from over-dependency on natural resources, which then leads to poverty or rigidity traps; however, Cinner et al. (2012) suggest that these traps can potentially be escaped via livelihood activities that are not dependent on natural resources (Cinner et al., 2013; Fang et al., 2014). Despite the risks of stresses, rural smallholders continue to engage in climate-sensitive livelihood activities for three main reasons: i) the lack of alternative livelihood sources and inadequate skillsets that prevent participation in non-natural-resource-dependent activities (Bhandari, 2013); ii) a cultural and historical connection to the natural resources (Daskon and Binns, 2009); and iii) concerns about food security that are rooted in the tendency for natural-resource-dependent households to be more food secure than wage earners because of unstable food market mechanisms in many developing countries (Knueppel et al., 2010). In contrast, crop failure due to climatic stress is a probabilistic phenomenon that depends on timing and frequency. Hence, based on the ideas of Cinner et al. (2012), we have developed a household-level climate sensitivity measurement technique that incorporates the probability of crop failure and non-natural-resource-dependent livelihood diversities (for more detail see Section 4.2.2).

3. Study setting: Northeastern floodplain of Bangladesh

The northeastern floodplain of Bangladesh is a wetland-dominated ecosystem that is characterized by natural depressions locally known as *haors* (MPHA, 2012). These depressions are usually flooded during the rainy season from June to September before drying up during the winter. However, some water remains in ditches (known as *beels*) that are non-uniformly distributed across the *haors* (MPHA, 2012). During the dry season, most of the wetland areas serve as agricultural land while the *beels* serve as a habitat for diverse fish resources. Thus, these wetlands provide multiple livelihood opportunities for the natural-resource-dependent communities of the adjacent villages (Salam et al., 1994). However, these wetlands are highly susceptible to different climatic stresses like flash floods, seasonal flooding, excessive rainfall, and drought (Nowreen et al., 2015). Flash floods generally occur between mid-March and mid-April, which is the harvesting period of the area's major agricultural crop, *Boro*, or winter rice. Prolonged regular flooding and excessive rainfall affect both monsoon rice and fishing, while long term drought affects the early growth of *Boro* rice. The Hakaluki and Tanguar *haors* are considered to be the two most important wetland systems in this area due to their richness in biodiversity and natural resources.

3.1 Hakaluki *haor*

The Hakaluki *haor* is the largest freshwater wetland in Bangladesh, and it has been designated as an Ecologically Critical Area under the Environment Conservation Act (1995). This *haor* is located between 24º35′ to 24º44′ north and 92º00′ to 92º08′ east, and covers an area of 41,614 ha with a permanent inundation area (e.g., *beels*) of 4,635 ha (Choudhury and Nishat, 2005). It stands in between two districts, including Sylhet and Maulavibazar of Sylhet division. In addition, there are 5 sub-districts around the *haor* which include Golapganj and Fenchuganj of Sylhet district, and the Kulaura, Juri, and Baralekha sub-districts of Maulavibazar. In total, 11 unions (cluster of villages and the smallest administrative unit of Bangladesh government) of these five sub-districts are located around the *haor*.

The communities living in the villages surrounding the *haor* mostly depend on agriculture and fishing for their livelihood. *Boro*, or winter rice, is the major agricultural crop in the area, although multiple rotations of rice are also cultivated. In contrast, fishing is practiced throughout the year. However, obtaining fishing rights, which are categorized as either common or open, can be a complicated matter. Open fishing rights are granted to all community members, and these rights authorize residents to fish in rivers and canals only. Conversely, common fishing rights are only granted to community members who belong to fishermen's organizations, and these rights allow them to fish in the *beels* during winter (Rahman et al., 2015). Again, non-natural-resource-dependent activities like wage and day labor are also common. Notably, most villages in this area have access to drivable roads that are connected to sub-district level towns, which provides community members with more opportunities to participate in externally available livelihood activities.

3.2 Tanguar *haor*

Tanguar *haor* has also been designated as an Ecologically Critical Area by the government of Bangladesh. Moreover, this wetland is one of two Ramsar sites in Bangladesh because of its high biodiversity value. It is located between 25°05' to 25°12' north and 91°01' to 91°07' east, and covers an area of around 9,527 ha. India's Meghalayan foothills are located on the northern boundary of the wetland, and this area falls under the jurisdictions of Tahirpur and Dharmapasha sub-districts of the Sunamganj district. The adjacent villages are distributed among four unions: Uttar Sripur and Dakshin Sripur, which are located in the Tahirpur sub-district; and Uttar Badepasha and Dakshin Badepasha, which are part of the Dharmapasha sub-district.

Winter rice cultivation is the main agricultural practice in this wetland, and multiple rotations of rice are absent. However, fishing is more extensive in this wetland than in Hakaluki because of the government's wetland co-management project. In addition, non-natural-resource-dependent livelihood activities are common in this area (e.g., day labour, small business). Other livelihood activities like wage-based employment are uncommon due to generally low levels of education among community members and insufficient networks linking villages to nearby urban areas. Travel by boat is the only mode of transportation during monsoon season, and drivable roads are almost non-existent. Thus, this wetland is more remote than Hakaluki *haor*.

4. Methods

We adopted a comparative case study research approach using a mixed-method data collection strategy. Case study research is a common practice used for context-specific data collection and analysis (Ford et al., 2010). However, these studies do not ensure generalizability; rather, they support in-depth, locally-based climate sensitivity analysis (Gerring, 2004). Moreover, this approach provides opportunities to deal with a large number of variables. This mixed-method data collection strategy involves both qualitative and quantitative data to facilitate triangulation and maximize reliability (Bergman, 2011).

4.1 Data collection

We used five criteria in selecting the twelve case study villages from the two study areas: i) the selected village should be on the bank of the *haor*; ii) one village should be selected from each union; iii) villages with a recent history of experiencing climatic stresses should be selected; iv) villages having common boundaries and similar stress histories should be avoided; and v) the village's community should depend on wetland resources for their livelihood activities to some degree. Eight villages from Hakaluki and four villages from Tanguar *haor* were subsequently selected in close consultation with local government representatives (e.g., local government chairman and members), local leaders, and key community informants.

We surveyed randomly selected households to collect quantitative data. At least 25% of the total households from each village were surveyed, with the average size of Hakaluki *haor* villages ranging between 100-150 households, and the average size of Tanguar *haor* villages ranging between 70-100 households. Thus, a total of 354 households were surveyed (236 households from Hakaluki *haor* and 118 households from Tanguar *haor*). We interviewed the head of each household; if they were absent, we interviewed the most senior present adult household member instead. We asked 29 household capital asset-related questions using a pretested, semi-structured questionnaire (Table 1). These questions were initially selected from the Bangladesh Climate Change Adaptation Survey Round I questionnaire, which were then cross-checked in the field for contextual adjustment prior to final data collection. Before asking these questions, we listed the livelihood activities performed by the household members, and identified the household's major livelihood activities based on the self-reported income contribution of each activity. We also asked respondents to discuss how climate stresses had impacted their major livelihood activity during the past 10 years. We identified this time range to ensure that responses were both experience-based and could be reliably recalled, recognizing that the various climatic stresses are not experienced regularly, although they are becoming more frequent in each of the study areas [see also Shahid (2011) and Nowreen et al. (2015)].

(Table 1)

Qualitative data were collected through focus group discussions (FGD) and key informant interviews (Freeman, 2006). The selected participants were invited to take part in these interactive sessions, which allowed us to collect community members' opinions (Wong, 2008; Freeman, 2006). Participants were asked about the village climate history, their knowledge about climatic stresses, the effects of these stresses on their livelihoods, and what initiatives and innovations had been undertaken by community members to adapt. Following the FGD best practices as suggested in Krueger and Casey (2009), each focus group was comprised of 8-10 members and lasted for 1-1.5 hour. A total of 15 FGDs were conducted during two different time periods (the post-monsoon period of 2015, and the pre-monsoon period of 2016).

One of the objectives in interviewing the key informants was to supplement FGDs, especially for the livelihood groups who were smaller in size and underrepresented (e.g., day labor, wage earners). Some of the interviews were conducted to triangulate FGD outcomes, while others obtained supporting perspectives from national and local government officials regarding the issues that were discussed in the FGDs. Thus, key informants were also selected purposively (DiCicco-Bloom and Crabtree, 2006). Since we had a diverse cross-section of informants, the interviews were limited to 7-8 open-ended questions after pre-testing, which were similar to the FGD questions (Johnson, 2002).

This research project was reviewed and approved by the McGill University Research Ethics Board. Informed consent of research participants was obtained prior to data collection, with the interviewers explaining the aims and implications of the research in the native language of the participants.

4.2 Data analysis

Because of mixed data types, we applied both qualitative and quantitative analysis followed by convergent-type integration of the outcomes (Feilzer, 2009; Johnson et al., 2007). This approach is commonly used to supplement quantitative analysis with qualitative observations and vice versa. Hence, this analytical approach ensures observational and analytical triangulation (Östlund et al., 2011).

4.2.1 Detecting different associations of asset variables

A common problem in statistical modeling is multicollinearity which arises because of the interconnected nature of independent variables (Alin, 2010). Hence, variable reduction based on data similarity is widely used to avoid this problem (Chong and Jun, 2005). Since one of our objectives is to better understand overlapping associations among different capital assets, we conducted exploratory factor analysis using the principal axis factor analysis technique with varimax rotation, and then used a regression technique for factor score calculation (Fabrigar and Wegener, 2011). Factor analysis is used to reduce a large number of observed variables to factors that represent underlying (unobserved) variables (Tinsley and Tinsley, 1987), considered particularly relevant to climate vulnerability and adaptation research (Jones et al., 2011; Below et al., 2012). Principle axis factor analysis was chosen because it provides better results when the observed variables are not normally distributed (DiStefano et al. 2009; Costello and Osborne, 2005; de Winter and Dodou, 2012). To determine how many factors should be retained for obtaining maximum variability, we estimated eigenvalues. Factors with an eigenvalue of more than 1 were considered for further analysis (Fabrigar et al., 1999), and it was observed that 5 factors were sufficient for explaining the maximum variability (cumulative variability 68% and 63% for Hakaluki and Tanguar *haors* respectively) of data for each study area. Hence, we calculated factor loading of each variable with each principle axis, and the highest value which indicated each variable's relation with each axis. We also preserved factor scores for each principle axis for further analysis (see Section 4.2.2). Cronbach Alpha values were also calculated for each factor; these values were more than or close to 0.7, which is the accepted level of data reliability (Bland and Altman, 1997). In addition, the Tucker Lewis Index of factoring reliability and the root mean square error of approximation index were also calculated.

4.2.2 Calculating livelihood sensitivity to climatic stresses and its relation to capital assets

Cinner et al. (2012) developed a sensitivity estimation equation for the coral-reef fishing communities in five western Indian Oceanic countries. Their equation was developed at a community level and was based on the community members' proportional dependence on fishing-and non-fishing-related activities. In this paper, we offer another equation for estimating sensitivity at the household level. Following Cinner et al. (2012), we calculated sensitivity based on natural resource and non-natural-resource-dependent livelihood activities. Here, we defined natural-resource-dependent livelihoods as activities that were directly related to wetland resources (e.g., agriculture, fisheries, and herding), with all other activities falling into the category of non-natural-resource-dependent activities (e.g., small business, day labor, wage labor etc.). We listed different livelihood activities that are performed by the household's members throughout a year. We also determined each household's livelihood identity based on which activity contributed the most income, which helped us to incorporate the household's socio-economic context into the equation.

$$S = \frac{NRA}{NRA + NNRA} \times \frac{NDsH}{NHC} - \frac{NNRA}{NRA + NNRA} \quad (1)$$

Here,
S = Sensitivity
NRA = Number of natural-resource-dependent activities
NNRA = Number of non-natural-resource-dependent activities
NDsH = Number of years with dissatisfactory harvest
NHC = Number of harvesting years under consideration

This equation considers the number of natural- and non-natural-resource-dependent activities instead of the number of persons involved in these activities. Therefore, the equation helps to capture livelihood diversity rather than simply incorporating the employment status of household members. This is significant because, during the field survey, we observed that a person might have multiple livelihood activities or that more than one person from same household might sometimes be involved in same activity. Furthermore, to capture the historical nature of climatic stresses and their influence on natural-resource-dependent livelihood activities, we considered self-reported historical accounts of dissatisfaction with crop or resource harvests over the preceding ten years (see also Zheng et al., 2012). Recognizing these accounts were likely to be influenced by recall bias, we also asked respondents how many times their yearly harvests had been affected by different climatic stresses in order to help increase reliability. Although this historical account does not indicate the future trajectories of climatic stress, it helped us to understand the experience-based adaptation actions of the community members (Kelly and Adger, 2000). Notably, the first section of this equation describes the proportion of natural resource dependency, the second section captures the historical propensity of crop failure due to climatic stresses, and the final section represents the proportion of non-climate-sensitive livelihood activities. The value of each section of the equation varies between 0 to 1, while the value of sensitivity ranges from +1 to -1.

Dorward et al. (2009) identified three types of livelihood strategies based on asset combinations and performed activities. In the first strategy, 'hanging in', household assets remain the same and the assets are used to maintain livelihood strategies during the stress. This asset combination strategy keeps livelihood strategies stable and does not encourage experiments and innovations (Dorward et al., 2009). In the second strategy, 'stepping up', households invest in assets to increase productivity in their current activities. This strategy is particularly observed among highly natural-resource-dependent communities (Cramb et al., 2009). Although, resource use intensification may contribute to farm productivity, the livelihoods of households that employ this strategy always remain sensitive to climatic and non-climatic (e.g., environmental degradation) stresses (Paavola, 2008). In the third strategy, 'stepping out', households accumulate assets in order to move on to different livelihood activities. This strategy reduces natural resource dependence, which thus reduces sensitivity (Cinner et al., 2012). Consistent with these concepts, this equation suggests that those households that indicate a positive sensitivity value will tend towards the 'stepping up' strategy, those indicating a negative sensitivity value will follow a 'stepping out' strategy, and those indicating 0 will follow a 'hanging in' strategy. In addition, a household sensitivity value of 1 indicates that all of the livelihood activities of the household depend on natural resources, and its all harvests in last 10 years were dissatisfactory due to climatic stresses. To the contrary, a value of -1 suggests that the household's livelihood activities are completely non-natural-resource dependent with no climate sensitivity. Also, value 0 indicates that the negative effects of climatic stresses are neutralized by non-natural-resource-dependent activities.

We used the equation to calculate each household's sensitivity to climatic stresses and classified them into two groups using agglomerative hierarchal cluster analysis with Euclidian distances between individual observations to detect context-specific sensitivity thresholds. We considered two clusters to detect the sensitivity threshold for each study area based on its own range of sensitivity with an expectation that the sensitivity threshold would be 0 or the 'hanging in' strategy. The underlying concept for this expectation was that the community members do not show any response to the climatic stresses. Therefore, any threshold value other than 0 will indicate that the community members are showing adaptive responses either through 'stepping up' (values with '-' sign) strategies or by adopting 'stepping out' (values with '+' sign). Hence, we considered that values above or equal to the threshold level were identified as highly sensitive group, while the lower values were considered as lower sensitive group. We developed logistic regression models to observe the probabilistic relation between sensitivity level (higher sensitive group = 1 and lower sensitive group = 0) and the latent capital asset factors obtained from factor analysis. We used factors scores of each asset factor to develop the regression models. To test the significance of independent variables, we calculated Wald's χ^2 (Kyngäs and Rissanen, 2001).

4.2.3 Triangulation of quantitative results using qualitative data

We used content analysis in describing the qualitative data obtained from the FGDs and key informant interviews. Content analysis is a systematic and objective means of context-specific data analysis (Elo and Kyngäs, 2007). Following this analytical approach, we summarized the data using a coding protocol, which was developed after analyzing the quantitative data and identifying the key outcomes. The qualitative data were represented by depicting the indicative quotes from the interviews and FGDs, which was then merged with the quantitative observations on the basis of similarities and dissimilarities among the observations for triangulation. Thus, given their focus on similar issues, the qualitative and quantitative analysis ensured the desired validity of the study.

5. Results and discussion

This Section begins with an explanation of the interactive nature of capital assets, which is one of the major objectives of this study. After exploring the overlapping properties of the asset variables, the analysis goes on to identify how capital assets can serve as a buffer against climate sensitivity.

5.1 Associations among capital asset variables

Badjeck et al. (2010) posited that sustainable livelihoods require an analysis of how community members organize, transform, and combine their capital assets. The results of our factor analysis presented in Tables 2 and 3 help us to understand associations between different capital assets for Hakaluki *haor* and Tanguar *haor*, suggesting that the observed variables group into 5 factors in each case. Building on these results, we consider the nature of the different asset associations in each hoar and the implications for livelihood sustainability.

5.1.1 Hakaluki *haor*

i. Resource ownership facilitates access to other assets: In the case of Hakaluki *haor* (Table 2), we observe that natural-resource-dependent household productivity related variables (e.g., cost of natural-resource-dependent production, household savings with community or non-government organizations, high and low land ownership rates, amount of shared cropping land, total price of domestic animals, ownership of ponds, price of agricultural equipment, and price of household resources) were nested under the first principle axis, and were therefore named as 'primary production variables'. Usually, households that are more dependent on natural resources (e.g., land, pond, domestic animals) for household productivity require higher production input (e.g., fertilizer, pesticide, payment for fishing, fodder for domestic animals during rainy season), which we presume to be the underlying reason for the association among the natural, financial, and manufactured capital variables.

(Table 2)

ii. Social capital complements the lack of financial capital: The second principle axis, which we label as 'credit access', is comprised of variables from both the financial (e.g., loan sources, loan amounts, monthly loan payments) and social capital groups (e.g., linking social capital and activeness score). Microcredit, which is provided by locally-operated non-governmental organizations, is necessary if smallholders wish to financially invest in productive activities in order to supplement losses due to climatic and non-climatic stresses. This association of variables indicates that the credit recipients must also possess sufficient linking social capital in order to establish communication with these organizations. However, several studies have suggested that poor households often have a deficit of linking social capital because of bureaucratic processes and authoritative governance (Woolcock, 1998; Dale and Newman, 2010). Notably, the microcredit organizations in Bangladesh work in a deliberative way; in addition to providing support to the villages, the organizations also practice relationship-marketing by interacting with loan recipients on a personal level, which is a common, modern day business strategy (Peppers et al., 1999).

iii. Local-innovation and experience reduce dependence on external support for human capital: The third axis hosts knowledge-related variables (e.g., age of household head, professional experience, and adequacy of professional knowledge), which we label as 'production knowledge'. Although expected by the community members, non-governmental organizations do not usually provide any support (e.g., dissemination of agricultural knowledge, agricultural inputs or aid) other than microcredit. Conversely, different government agencies (e.g., Agricultural Extension Department and Bangladesh Agriculture Development Corporation) provide several programs that offer training in advanced agricultural techniques and technologies. However, many household heads have much experience dealing with and persevering through climatic stresses, and this leads them to believe that their knowledge is adequate to maintain their livelihoods and continue to deal with climatic stresses- a belief that only grows stronger with age and continued involvement in these activities. For example, one elderly farmer noted that,

> *"Many people ask me about the cultivation process since I experiment with new varieties and keep notes on when to intervene in different operational activities in the field. ……… I also consult with seed, fertilizer, and pesticide sellers to learn about new seed varieties."*

iv. Collective actions fail because of poor connectivity and networks: The fourth axis is the location of bonding social-capital-based collective action variables (e.g., number of members in community organizations, number of participants in different collective actions and decisions, bonding social-capital-based community cooperatives, and types of livelihood knowledge), which has been labeled, 'community organizations'. Despite the fact that collective interventions are often considered to be effective actions for obtaining property rights and other adaptation measures (Adger, 2003), they appear to be less effective or in their infancy in Hakaluki *haor*. It was observed in the field that large farm holders are unwilling to participate in these actions since the activities involve resource sharing (e.g., agricultural equipment, labor, and knowledge) and small saving. However, these farm owners could assume the vital role of 'mediator' between government and community due to their social and political position (Ballet et al., 2007). In support of this observation, we note a comment of a local leader who owned a relatively large farm and had a high income.

> *"You will find that most of the rich farmers are engaged in different political parties. You will also find them participating in different village- and union-level development activities like school, mosque, or temple building. However, they usually do not take part in farmer's cooperatives because these are usually established by the poor farmers who have low income and savings. Thus, active engagement pays little."*

Moreover, these large farm holders usually have access to the alternative services (e.g., formal banking services, hired labor, or communication with government offices for agricultural knowledge). Sometimes, their active communication with the government leads to opportunities to obtain collectively available incentives like mechanical irrigation and harvesting systems. One conversation with such a farmer, who was not a member of any farmer cooperative but held a position in a government-driven community-based flood control organization, exemplifies the situation.

Interviewer: "Do you possess agricultural equipment like irrigation machines, harvesters or tractors?"
Respondent: "I have a tractor and an irrigation pump."
Interviewer: "How much money did you spend to buy them?"
Respondent: "Actually, I got them from Bangladesh Agriculture Development Corporation."
Interviewer: "Do you have a membership in farmer cooperatives, because as far as I am informed this equipment is usually distributed among the farmer cooperatives"
Respondent: "Not really. Actually, the government officers know me very well, and they have given them to me since the people in my village respect me, and I sometimes share them with my neighbors. Otherwise, the farmers would end up with conflict."

This conversation indicates the way in which richer local leaders enjoy strong control of incentivized supports, which increases frustration among the poorer community members. For example, in a focus group discussion with members of a farmer's cooperative in another village, one person stated that:

"After a year-long conversation with government officials, this year we finally received an irrigation pump for our forty member cooperative. However, we see some people, who do not even need these things, and obtain them with relatively less effort. We cannot complain a lot because these people are more powerful, and sometimes some of our members need to depend on them for many non-livelihood-related issues."

Moreover, the government agencies that distribute the incentives do not have any institutional mechanism for identifying the most climate-affected poor farmers. Thus, they rely on local government channels and receive suggestions from Union Councils. One government official noted that:

"Many community organizations do not have formal registration, a prerequisite for obtaining relatively larger incentives like irrigation pumps and harvesters. We support individual farmers with seeds and fertilizers. However, we do not maintain any farmer database, and we do not have any centrally developed beneficiary selection guidelines, although we are suggested to distribute the incentives among the poor farmers. Thus, we need to depend on local government representatives."

However, the community members reported less trust in the local government apparatus, since local-level politics are often subjected to elite capture. Hence, the absence of mediators from the community, and the failure of local governments to assume that role, has created an 'institutional gap' that leads to poor networks and connections (Rahman et al., 2014a; Goulden et al. 2013). This situation is particularly observable in the case of fisheries resources, which is a common phenomenon in wetland resource management in Bangladesh (for more detail see Rahman et al., 2012; Rahman, et al., 2015).

v. Clustering of financial investment and social capital increases income, but may reduce natural capital: The remaining variables (types of fishing rights, household gardens, price of household products, bridging social capital, household size, household income and expenditure) that mostly relate to 'production support variables', belong to the fifth axis. Notably, fishing rights show negative loading with this axis because most households in the study area primarily engage in farming, which makes them ineligible to participate in common fishing property ownership according to the government's fisheries resource management policy (Rahman et al., 2015). Again, most of the households largely depend on bridging social capital and financial capacity to generate alternative livelihood practices in both peripheral urban areas and abroad, which has also been reported in the case of northern Bangladesh (Etzold et al., 2014). There is a considerable difference in income between laborers in local areas and laborers who work abroad. Laborers who work abroad earn significantly higher wages than local laborers, which has made migratory work popular among people in poorer rural areas. To bear the cost of sending a family member to work abroad, poor households often sell some or all of their land, and become landless and non-natural-resource-dependent. This indicates that community members are willing to make a 'trade-off' among the capital assets to enhance income generation (Chambers, 1989; Scoones, 1998). For example, one focus group discussion involving local farmers revealed that,

> *"It is not like the landless farmers were always landless. People sell their land for many reasons. However, the most common reason nowadays is for sending one or two household members to work abroad. For example, a person who has two bighas of low land (local land measurement unit; 1 bigha = 0.33 acre), can harvest at most thirty-five to forty monds (local weight measurement unit; 1 mond = 40 kilogram) of rice. In the present market, this production is equivalent to 24,000 thousand takas at best (1 taka = 0.0125 USD). After calculating the production cost, the profit is minimal, and sometimes we experience a loss. It's true that farming ensures us rice (staple food of the Bangladeshi people) for consumption. However, if a household sells the land, and sends one member abroad, he can send at least 10,000-15,000 taka back home each month. So, if anyone gets such opportunity, he does not care about land ownership."*

5.1.2 Tanguar *haor*

In the case of Tanguar *haor,* we observed some common and contrasting features with Hakaluki, which is probably attributable to the social-ecological and socio-economic differences.

i) Access to natural capital facilitates access to manufactured capital: Within variable block analysis using factor analysis on Tanguar *haor* data (Table 3) suggested that 'household resource' related variables (e.g., production cost of the natural resource based activities, amount of shared cropping land, price of domestic animals, agricultural equipment and price of household resources) nested under the first principle axis. Field observation revealed that most of the shared croppers in Tanguar *haor* were landless and that they gained access to land through shared cropping, which particularly motivates them to obtain manufactured capital. Despite having a low amount of high lands, these households usually keep natural capital like domestic animals so they can sell them during periods of stress.

(Table 3)

ii) Institutional development facilitates access to natural and financial capital: 'Organizational participation'-related variables (e.g., organization membership number, activeness in the organization, number of days participating in organizations, and loan sources) are grouped on the second axis. Unlike Hakaluki, Tanguar *haor* is managed under a co-management scheme, where the community members directly participate in wetland resource management activities under the guidance of the local government and the non-governmental organization responsible for implementing the co-management project. Along with maintaining the system, the organization supports the community with micro-credit. However, similar to Hakaluki, Tanguar *haor* communities also develop collective-action-based community organizations for saving money.

iii) Experience is considered before taking financial supports: The third axis hosts 'production knowledge' related variables such as the age of household heads, professional experience, and knowledge adequacy. Interestingly, monthly loan installments negatively loaded in this axis because older household heads were more unwilling to take loans from external agencies. Perceptions of risk and prior experiences may influence these decisions. For example, one elderly farmer noted that,

> *"Taking a loan from microcredit organizations is risky to us because of production uncertainty. If we face loss, monthly installments become an extra burden on us. A young man can go to work anywhere, but it is difficult for us."*

iv) Different clusters of natural capitals are used for achieving financial capital: 'Primary production variables' (e.g., high and low land ownership, production knowledge, financial saving, and loans) are clustered under the fourth principle axis. Larger land owners have more access to and familiarity with different services like training facilities, government subsidized agricultural equipment, and formal banking systems that are usually only available in urban areas. However, due to insufficient communication networks and remoteness, poor households have insufficient access to these facilities. Moreover, government interventions to serve these segments of society are also inadequate. For example, one local leader noted that, *"Our communication system, particularly in dry season, is terrible. If a farmer plans to take bank loans or wants to participate in any government-related activities, he has to travel all the way to Tahirpur (Sub-district), which is almost 20-30 kilometers away. He also needs to spend at least 800 takas just for travel. One cannot finish their daily work. Thus, he has to travel frequently. The daily income of most villagers less than 300 takas. So, how can you expect that they will participate in these activities? Moreover, it is also difficult for government officials to come to these villages, often for the same reasons."*

v) Access to locally available resources reduces bridging social capital: 'Production support variables like fishing rights, income, expenditures, household gardens, pond ownership, and number of household members are grouped under fifth principle axis. These variables are negatively associated with bridging social capital. This cluster best describes fishing communities. The co-management scheme in Tanguar *haor* increases income contribution from fishing. However, locally available natural-resource-dependent livelihood activities and income generating opportunities reduce community members' enthusiasm to build bridging social capital, likely because finding local opportunities requires lower transaction costs. Additionally, geographic isolation may also be an important issue.

5.2 Calculating climate sensitivity and its relation to estimated capital asset variables

Our results in Section 5.1 describe that the assets are mostly positively related to each other, although some relations are negative. This suggests that the assets are not in a 'rigidity trap' as described in resilience literature (Holling, 2001). This Section also identifies that the asset variables are organized in a diverse way, and the variables are not highly independent from each other, suggesting that the assets are not in a 'poverty trap'. While the asset properties indicate favourable conditions for innovation and adaptation, socio-economic disparity, inadequate amount of assets and poor institutional and organizational functioning may limit the potential of asset combinations in sustaining livelihood activities (Maru et al., 2012).

In this Section, we calculate sensitivity levels by applying Equation 1. We classified the observations into two clusters, and we identified -0.15 and 0.12 as the thresholds for Hakaluki and Tanguar *haors*, respectively (Table 4). Thus, the observations with values equal to or above the threshold values were considered highly sensitive, and the remaining observations were classified as the less-sensitive group. We can also observe that threshold values were close to 0, which indicates that the households are responding to stresses by avoiding the 'hanging in' approach to asset use. For example, the Hakaluki *haor* communities exemplify the 'stepping out' approach by using assets to move to non-natural-resource-dependent activities. Conversely, the Tanguar *haor* communities appeared to employ 'stepping up' strategies in using assets to intensify natural resource use.

(Table 4)

Logistic regression models, which were developed for understanding the relation between sensitivity level and the principle axis variables obtained from factor analysis (Table 2 and Table 3), further elaborated these findings (Table 5). These newly calculated variables also represent different asset combinations, and thus, allow us to observe which variable combinations are influential in reducing climate sensitivity. For example, in Hakaluki, climate sensitivity increases when the primary production (primary production variables in Table 5) of households depends on natural resources whereas private ownership of natural resources (primary production variables in Table 5) reduces sensitivity in Tanguar. As stated earlier (see Section 5.1.1), Hakaluki households require the private ownership of natural resources in order to generate non-natural-resource-related activities, which is a scenario that has also been reported in the case of China (Fang et al., 2014). However, landlessness or poor land holdings reduce the capacity to 'step out' from climate-sensitive activities. One useful strategy that might aid landless or those with small land holdings could be the use of microcredits. However, the models suggest that microcredit is positively related to climate sensitivity. Field observations suggest that the microcredit was invested in agriculture in both study areas, and more climate sensitive households require more credit access if they encounter frequent stresses. Pitt (2000) posited that investment in agriculture facilitates shared and rental cropping practices, which are the two different modes of agricultural self-employment. However, considering how susceptible these activities are to climatic stresses, Cinner et al. (2012) have appropriately identified them as highly sensitive livelihood strategies. Moreover, Mallick (2012) found that tight payment schedules and unavailability of seasonal working capital increase the potential for farmers to become dependent on informal money lenders who charge high interest. On the other hand, Anderson et al. (2002) have noted that microcredit organizations can contribute to human capital generation, which can in turn improve natural capital. However, the tendency of households to rely on their own knowledge and the absence of human capital generation programs in both study areas may be responsible for poor innovation in non-natural-resource-dependent activities through the use of microcredit. Therefore, it can be argued that, despite the equal levels of stress, private resource owners can reduce sensitivity more efficiently than can poorer households. Hence, climatic stresses contribute to socio-economic inequality and persistent poverty, which Dow et al. (2006, pp. 79-96) identify as one of the root causes of injustice in adaptation. Again, we found that community organizations were positively related to climate sensitivity in Hakaluki, possibly because of less effective organizations to support communities' demands, and also the potential for elite dominance in decision-making as previously discussed.

(Table 5)

Although it was observed that the communities in both study areas were close to a 'hanging in' situation, we found that both internal and external interventions were contributing to reducing sensitivity. Chambers (1989) has suggested that poorer households reduce vulnerability not by increasing income, but by diversifying livelihood strategies and reorganizing asset combinations. Consistent with these observations, we found that households in both the study areas relied on different asset combinations based on their availability. Although it is not clear which combination is most supportive, we can argue that it depends on which type of livelihood strategy is adopted by the community members. However, regardless of which livelihood strategies are chosen, external supports like market integration and the active involvement of government and non-governmental organizations are necessary. Thus, it is important to note the effectiveness of externally designed institutional structures (Rahman et al., 2014b). For example, the qualitative degradation of natural resources due to intensive use has been well-documented in many areas of the world. Thus, the ecological carrying capacity of resource systems should be assessed in order to identify the limits of adaptation support, and further attention should be given to identifying how this concern has been considered in internally and externally supported initiatives. More specifically, future research should focus on whether the current sensitivity reduction practices have the potential to cause future resource and opportunity decline. For example, migration to urban areas for non-natural-resource-dependent activities in Bangladesh has the potential to expose migrants to unfamiliar urban climate stress (Braun and Aßheuer, 2011; Rotberg, 2010).

6. Conclusion

According to the SRL Framework, capital assets are the cornerstones of livelihood sustainability in the face of risks and uncertainties like climatic stresses. It is widely recognized that these assets are key in enabling alternative livelihood activities (e.g., non-natural-resource-dependent livelihood activities like day labor, wage earning, small business ownership) that have less or no sensitivity to stresses. However, the organization of assets follows a complex process that is often influenced by socio-economic and socio-political factors - a process that is relatively underexplored in both development and adaptation literature. Both resilience thinking and development economics posit that lower levels of assets and poor connectivity ensnare rural communities in a 'poverty trap', while the SRL framework contends that poor organization, transformation, and combinations of assets impede innovation and adaptability. This paper borrows from both concepts, and offers a novel methodological approach in an attempt to understand how different asset combinations contribute to innovations in livelihood opportunities that can reduce sensitivity to climatic stresses.

We applied a mixed methods research design to collect data from the two study areas of the wetland-dominated northeastern floodplain of Bangladesh, and we analyzed the interactive associations among the capital assets. Once the data had been collected, we calculated sensitivity levels using an equation that was specifically designed for this purpose. After identifying the sensitivity thresholds for each study area, we determined the probabilistic relations of livelihood sensitivity with different asset portfolios. This systematic approach helped us to identify the asset use strategies that directly and efficiently contribute to reducing livelihood sensitivity, providing valuable insights that are relevant to both adaptation policy and practice. For example, we observed that community members in our study areas were combining, substituting and organizing assets for adapting and innovating new livelihood activities. Although the community members have not advanced to a large extent in securing non-natural-resource-dependent livelihood activities, active interventions into the communities are supporting them in escaping a climate-induced 'poverty trap'. As a whole, we observed that two major strategies were commonly being used in our study areas: i) communities in Hakaluki *haor* were mobilizing their networks with large-scale socio-economic systems (e.g., sub-national, national and, international) to generate alternative livelihood activities; and ii) Tanguar *haor* communities were intensifying natural resource use, which was being facilitated by active government interventions. Building on the methodological approach presented in this paper, future research could incorporate the outcome dimensions of the different asset combinations (e.g., monetary and non-monetary outcomes from different asset portfolios) in order to further justify and enhance the insights for adaptation policy.

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Table 1. Description of the variables.

Capitals	Variables	Description of the variables	Hakaluki	Tanguar
Financial	mon_inc	Monthly income: Calculated from self-reported approximate yearly income (in thousand taka)	16.15 (±10.55)	10.28 (±4.95)
	mon_expen	Monthly expenditure: Self-reported monthly expenditure for household maintenance and consumption purpose (in thousand taka)	15.28 (±9.65)	10.62 (±4.74)
	amt_loan	Amount of loan: Amount of present loan taken from formal, informal or both sources (in thousand taka)	27.63 (±54.30)	42.53 (±64.40)
	mon_inst	Monthly installment: Monthly installment of money against loan (in thousand taka)	1.99 (±3.57)	4.15 (±9.69)
	prod_cost	Production cost: Total yearly cost for production activities (e.g. agriculture, fisheries, domestic animal) (in thousand taka)	37.75 (±46.28)	33.17 (±29.33)
	loan_sour	Loan source: Loan taken from formal sources (e.g. micro-credit organization, formal banking system)	154 (65%)	63 (53%)
	sav_org	Saving in organization: Amount of money saved in the organizations	4.38 (±16.19)	1.07 (±2.75)
Natural	high_land	High land: Amount of land privately or permanently owned by a household that is not affected by regular seasonal floodwater, and usually used for housing, gardening and sometimes for agriculture	0.97 (±2.53)	0.37 (±0.57)
	low_land	Low land: Amount of land privately or permanently owned by a household that is fooled by regular seasonal floodwater, and usually used for agriculture and fishing	4.21 (±8.93)	5.03 (±8.80)
	am_sh_lan	Amount of shared cropping land: Amount of land that is taken with shared agreement that a cropper will provide with a portion of production to the private owner of the land	7.75 (±9.49)	2.59 (±4.22)
	pr_dom_an	Price of domestic animals: Present market price of domestic animal (in thousand taka)	37.84 (±51.55)	35.78 (±53.95)
	tyo_fis_rgt	Type of fishing right: Households enjoy common fishing property right	19 (8%)	54 (46%)
	hh_gr	Homestead garden: Households have homestead gardens	63 (27%)	3 (2%)
	own_pon	Ownership of pond: Households have ponds	60 (25%)	2 (1.6%)
	pr_hh_res	Price of household resources: Household level saleable natural resources like trees	23.27 (±22.08)	0.00 (±0)
Manufactured	pr_hh_prod	Price of household products: Approximate price of domestic assets (e.g. television, bi-cycle, motor cycle, mobile phone etc.)	8.41 (±30.80)	16.31 (±11.68)
	pr_prod_equip	Price of production equipment: Present market price of privately owned agricultural and fishing equipment or the amount of money spent for production equipment services (e.g. lending tractors, harvesters) each year (in thousand taka)	24.86 (±42.48)	22.03 (±24.69)
Social	num_org_mem	Number of organization membership: Total number of membership of household members in community level,	0.72 (±0.73)	1.30 (±0.94)

		NGO and government driven organizations		
	num_part	Number of participation: Number of days the organization members spend for participating in the different activities in a month	5.12 (±5.54)	6.5 (±4.68)
	act_scor	Activeness score: Activeness of participation in organizational decision-making	1.35 (±1.28)	1.87 (±1.11)
	org_bsc	Bonding social capital based organizations: Member of organizations developed by the community members through collective actions	76 (32%)	65 (55%)
	org_lsc	Linking social capital based organizations: Member of organizations developed by non-government and government organizations	69 (29%)	72 (61%)
	brsc	Bridging social capital: Opportunities to work outside the community using personal network	157 (67%)	45 (38%)
Human	hh_siz	Household size: Total number of household members	7.23 (±3.06)	6.46 (±2.26)
	age_hh	Age of household head	49.67 (±13.11)	48.30 (±14.38)
	prof_ex	Professional experience: Years a household head employed in his/her primary livelihood activities	27.83 (±14.64)	27.43 (±13.87)
	adq_prof_ex	Adequacy of professional knowledge: the household heads think that he has sufficient knowledge for primary production activities	167 (71%)	89 (75%)
	typ_liv_kno	Type of livelihood knowledge: Type of knowledge for primary production activities (e.g. training, self-learning through experiment, traditional, knowledge sharing)	1.14 (±0.39)	1.04 (±0.2)

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Table 2. Connectivity among the capital asset variables in Hakaluki *haor*.

Asset variables	**PA1 (primary production variables)**	**PA2(credit access)**	**PA3 (production knowledge)**	**PA4 (community organizations)**	**PA5 (production support variables)**
prod_cost	**0.80**	0.23	0.05	0.27	0.13
sav_org	**0.56**	0.2	-0.03	0.2	0.1
high_lan	**0.57**	-0.01	0.01	-0.03	0.17
low_lan	**0.76**	0.04	0.08	-0.02	0.05
am_sh_lan	**0.58**	0.22	0.05	0.11	0.17
pr_dom_an	**0.55**	0.14	0.02	-0.02	0.19
own_pon	**0.51**	0.02	-0.02	0.03	0.30
pr_prod_equip	**0.74**	-0.02	0.03	0.08	0.12
pr_hh_res	**0.57**	0.01	0.13	0.08	0.27
loan_sour	-0.01	**0.75**	0.02	0.11	-0.08
amt_loan	0.33	**0.57**	0.09	0.11	0
mon_inst	0.31	**0.59**	0.16	0.11	-0.01
act_scor	0.03	**0.57**	-0.01	0.53	-0.11
org_lsc	-0.17	**0.87**	0.06	0.13	0.05
age_hh	-0.01	0.04	**0.64**	-0.01	0.15
prof_ex	0.06	0.06	**0.97**	0.01	-0.02
adq_prof_ex	0.15	0.05	**0.57**	0.04	0.08
num_mem_org	0.08	0.32	0	**0.86**	0.05
num_par	0.04	0.43	0.02	**0.71**	0.09
org_bsc	0.32	-0.29	-0.06	**0.82**	-0.09
typ_liv_kno	0.02	0.11	0.06	**0.58**	0.14
tyo_fis_rgt	0.06	-0.07	-0.12	0.02	**-0.51**
hh_gr	0.27	-0.02	0.03	-0.05	**0.59**
pp_hh_prod	0.19	-0.12	0	0.08	**0.58**
brsc	-0.06	-0.09	0.03	0.08	**0.51**
hh_siz	0.07	0.01	0.11	0.03	**0.64**
inc	0.36	-0.09	-0.04	0.07	**0.72**
expen	0.24	0.02	0.06	0.05	**0.57**

Note: Tucker Lewis Index of factoring reliability = 0.703; RMSEA index = 0.093 and the 90 % confidence intervals are 0.09 and 0.096; BIC = -416.7.

Table 3. Connectivity among the capital asset variables in Tanguar *haor*.

Asset variables	**PA1 (household resources)**	**PA2 (credit access)**	**PA3 (production knowledge)**	**PA4 (primary production variables)**	**PA5 (production support variables)**
prod_cost	**0.95**	-0.03	0.08	0.06	0.11
am_sh_lan	**0.51**	0.16	0.12	-0.25	0.14
pr_dom_an	**0.51**	0.13	-0.01	0.17	0.09
pr_prod_equip	**0.77**	-0.05	0.04	0.2	0.07
pr_hh_res	**0.55**	0.13	0.17	0.45	0.06
loan_sour	0.01	**0.67**	-0.1	0.2	-0.04
hh_gr	0.01	**0.57**	-0.1	0.01	-0.02
num_org_mem	0.12	**0.84**	-0.08	-0.04	0.23
num_part	0.1	**0.83**	-0.13	-0.02	-0.03
act_scor	-0.02	**0.68**	-0.08	0	-0.21
org_bsc	0.08	**0.52**	-0.03	-0.12	0.29
org_lsc	0.02	**0.81**	-0.19	0.14	-0.18
age_hh	0.08	-0.16	**0.86**	-0.09	0.05
prof_ex	0.13	-0.08	**0.95**	-0.04	-0.04
adq_prof_ex	0.09	-0.1	**0.62**	0.2	-0.07
mon_inst	-0.03	0.2	**-0.54**	0.12	0.3
sav_org	0.21	0.21	0.04	**0.52**	-0.01
high_land	0.05	0.01	-0.05	**0.56**	-0.07
low_land	0.24	-0.1	0.06	**0.82**	0.02
amt_loan	0.23	0.27	-0.03	**0.53**	0.26
typ_liv_kno	-0.09	0.06	-0.02	**0.52**	0.2
tyo_fis_rgt	0.06	0.22	-0.03	-0.27	**0.52**
own_pon	0.05	-0.05	0.03	-0.03	**0.56**
Inc	0.36	-0.02	0.12	0.49	**0.61**
expen	0.31	0.04	0.16	0.41	**0.72**
brsc	-0.01	0.11	0.05	0.03	**-0.59**
hh_siz	0.26	0	0.23	0.11	**0.58**

Note: Tucker Lewis Index of factoring reliability = 0.775; RMSEA index = 0.091 and the 90 % confidence intervals are 0.066 and 0.092; BIC = -684.4.

Table 4. Properties of equations for the cases.

Variables	**Hakaluki *haor***	**Tanguar *haor***
Natural resource dependent activities	1.547 (±0.972)	2.152 (± 1.767)
Non-natural resource dependent activities	0.795 (±0.874)	0.780 (±0.859)
Total livelihood activities	2.342 (±1.271)	2.932 (±1.920)
Number of dissatisfactory harvest years in last 10 years	4.427 (±1.449)	4.765 (±1.696)
Sensitivity	0.025 (±0.449)	0.0775 (±0.434)
Estimated threshold	-0.15	0.12
Highly sensitive	125	59
Low sensitive	109	59

Table 5. Climate sensitivity and the capital asset factors.

Hakaluki *haor*			Tanguar *haor*		
Variables	**Coefficients**	**Odds ratio**	**Variables**	**Coefficients**	**Odds ratio**
intercept	0.19976 (0.1381)	1.2116	intercept	-0.0215 (0.1949)	2.5866
primary production variables	0.20206 (0.1754)	1.2127	household resources	0.0178 (0.2497)	0.8316
credit access	0.39881*** (0.14131)	1.5025	credit access	0.12829 (0.18212)	1.3494
production knowledge	0.08425 (0.13386)	1.0519	production knowledge	-0.15555 (0.19239)	0.9114
community organizations	0.3773** (0.16558)	1.2744	primary production variables	-0.66472** (0.27629)	0.6553
production support variables	-0.1526 (0.13761)	0.8568	production support variables	0.04908 (0.22255)	0.8932
Wald's χ^2	6.8**		Wald's χ^2	17.6***	

Note: **p < 0.1, **p < 0.05, ***p < 0.001;* standard error is in parentheses