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A conceptual model-based approach to explore community livelihood adaptation under uncertainty for adaptive delta management

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ABSTRACT

Delta communities worldwide are facing a multitude of challenges in their life and livelihood. In many developing countries, improving the quality of life and livelihood is a key challenge. While development is a central goal of delta planning in such countries, the effectiveness of planning is challenged by uncertain changes in climate and socio-economy. Bangladesh (one of the countries) is moving towards the adaptive delta management approach to deal with such uncertainties. Historical examples illustrate that Community Livelihood Adaptation (CLA) can critically influence the effectiveness of a policy strategy. Therefore, there is a clear need to explore CLA under uncertainty. For that purpose, this paper develops and applies a conceptual model-based approach combining the mental model and scenarios techniques. Our approach starts by using a participatory process to elicit mental models a farmers' community uses when considering adaptation decisions; we capture these in the form of a cognitive map, and this map can serve as a conceptual model for analyzing livelihood adaptation decision-making in a future-oriented scenario analysis. To illustrate the approach, a case study of cropping decision-making of farmers community at a polder location under the saline condition in the southwest of Bangladesh has been elaborated. Results show that the approach is useful in structuring the cognitive and qualitative nature of complex decision-making process, and helps in understanding the dynamic interactions of farmers' adaptation decisions with other actors, their environmental attributes, and market traits. It can help policymakers anticipate the adaptation direction of policy strategies.

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1. Introduction

Delta communities worldwide are facing a multitude of challenges in their life and livelihood. In many developing countries, improving the quality of life and livelihood is a key challenge. While development is a central goal of delta planning in such countries, the effectiveness of planning is challenged by uncertain changes in climate and socio-economy (van der Voorn et al. 2017).

In response, an approach called Adaptive Delta Management (ADM) has been developed. Adaptive Delta Management (ADM) is rooted in Adaptive Policy Making (APM) (Walker et al. 2001) and robust decision-making (Lempert 2003). The core of ADM is to acknowledge uncertainties instead of ignoring them, thinking in terms of multiple possible future scenarios, taking precautionary short – term action while keeping adaptation options open, and continuous monitoring of actual developments (Walker et al. 2001, 2013; Lempert 2003).

Bangladesh is one of the countries moving towards that approach as part of the Bangladesh Delta Plan 2100 (BDP 2100). With wide stakeholder engagement, the approach taken has a top-down character, i.e. policies are developed at the national level, based on (fixed) assumptions about the way local communities will respond to the policy measures. During policy implementation, such an approach can be challenged with the response of local community in an uncertain direction which is illustrated by recent experiences in southwest Bangladesh. As documented (Nowreen et al. 2014; Dewan et al. 2015; Gain et al. 2017), in the period 1960s, the polder construction and management policy was implemented aiming at coastal land protection from daily tidal inundation of saline water for a single objective of increasing rice production; and assuming that the farmer communities would grow more rice at newly developed land with adoption of high yield varieties (HYV). However from the late 1970s, farmers (mainly large absentees) introduced commercial brackish-water shrimp farming; this was later adopted by all other farmers, and the rapid expansion of shrimp farming eventually reversed the functionality of polders from 'controlling the saline water inflow into the polder' to 'allowing the saline water inflow into the polder' (Nowreen et al. 2014; Kabir et al. 2016). The evolution of Tidal River Management (TRM) as a regional policy (Mutahara et al. 2017) can be seen as another unexpected response of local communities to the traditional polder management approach. In reverse of the polder management policy, and based on local knowledge, landowners, farmers and implementing agencies have in cooperation evolved towards controlled

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flooding to allow land accretion inside the polder and naturally dredge deposited sediment in the river (Zevenbergen et al. 2018).

This example illustrates that Community Livelihood Adaptation (CLA) can critically influence the success or failure of a particular delta management strategy or measure. Communities may adapt in other ways than expected, and ignoring this uncertainty may result in policy ineffectiveness. When CLA decision-making under uncertainty at their local social-ecological system is well understood, delta planners can anticipate what might happen, and include precautionary or adaptive elements in their policy. It is, therefore, necessary to understand and explore how the local people, particularly farmers in the primary production sector, make adaptation decisions under changing conditions in their social-ecological system. For that, we need an approach to capture the nature of the decision-making of relevant actors.

To address the problem stated above, this research develops and applies an approach to explore CLA under uncertainty. We focus on the case of rice farmers in polder 30 and 31. Our explorative approach has taken the lens of a national or regional policymaker to explore possible developments of CLA under uncertainty for a certain policy measure; this is combined with the farmers perspective of CLA decision-making in their local-social ecological system. Our approach starts by using a participatory process to elicit the mental models the farmers use when considering adaptation decisions; we capture these in the form of a cognitive map, and this map can serve as a conceptual model to explore possible livelihood adaptation decision-making under alternative policy scenarios. To illustrate and test the approach, a case study of cropping decision-making of a farmers community at a polder located in the southwest Bangladesh has been elaborated. Our approach is inspired by a participatory approach (Chambers 1994) and cognitive mapping (Elsawah et al. 2015) to develop scenarios (Maier et al. 2016) for exploring CLA under uncertainty.

The remainder of this paper will, first, briefly introduce six key concepts: community livelihood adaptation and adoption, uncertainty and scenarios, mental model and cognitive map (Section 2); next, the approach design, data collection, and analysis will be presented in Section 3; The test using a case study follows in Section 4; Section 5 reflects on the strengths and weaknesses of the approach, and Section 6 concludes with suggestions for further research and improvement.

2. Concepts and methods

2.1. Community livelihood adaptation or adoption

This research draws on the concepts of community, livelihood, and adaptation, and combines these three broad fields of study in social science and human systems (Scoones 1998, 2009; Parry et al. 2007; Dewan et al. 2015). Community Livelihood Adaptation (CLA) is seen as the process of adjustment in livelihood activities to moderate harm or exploit benefits from changing conditions by groups of individuals or households that share material and non-material resources, based on their differentiated capacity. The livelihood adaptation represents decision choices within a set of options open to a group of actors that include coping but also generate and sustain collective longer-term adaptation (Osbahr et al. 2010). The authors explain that the move from coping (adoption) to adaptation involves external factors like governance and legitimacy of action across different scales. Adaptation has a notion of durable behavioral change motivated by the task itself (intrinsic motivation) regardless of any external payoff (Andreasen 2002). Adoption is the short-term coping behavior to obtain incentives or external rewards or avoid some negative consequences (extrinsic motivation) (Binney et al. 2006).

While traditional delta management often focuses on 'adoption', the long-term success of the policy implementation requires, instead, a focus on long-term adaptive processes of relevant actors (Shiferaw et al. 2009; Thompson 2009). Therefore, it is worthwhile to assess and better understand how relevant actors actually make decisions, and how policymakers can work with such processes rather than attempting to mold the adaptive process of relevant actors to a pre-set policy design (Thompson 2009).

The literature on CLA suggests that the complex behavior of the local social-ecological system is driven by the collective outcomes of action made by the actors at multiple levels of the system (Elsawah et al. 2015). In a study of agricultural adoption and extension, Thompson (2009) puts emphasis on understanding how the producers are actually making decisions (Thompson 2009). Therefore to understand the CLA under uncertainty, the existing approaches of stakeholder (farmer) decision-making (Elsawah et al. 2015) and dealing with uncertainty in adaptive planning (Rotmans et al. 2000; Börjeson et al. 2006; Haasnoot 2013; Maier et al. 2016) can be combined.

2.2. Uncertainty and scenarios

Uncertainty is a situation of inadequate information due to inexactness, unreliability and bordered with ignorance (Funtowicz and Ravetz 1990). Uncertainty is also referred to as 'any deviation from the unachievable ideal of completely deterministic knowledge of the relevant system' (Walker et al. 2003). A core element of adaptive policymaking or adaptive delta management is to identify and analyze uncertainties systematically (Haasnoot 2013).

The use of scenarios is the most common method to encapsulate uncertainty (Maier et al. 2016) in adaptive delta management (Haasnoot 2013). Thinking in terms of scenarios to explore critical uncertainties is helpful to expand mental models beyond conventional thinking, and to identify possible surprising developments (Rotmans et al. 2000). Scenarios as coherent stories, created from mental maps and models, have value in their ability to provide insights (about the future) into the present. A wide variety of different types of scenarios is described in the literature (Rotmans et al. 2000; Börjeson et al. 2006; Maier et al. 2016).

One scenario classification makes a distinction between predictive, explorative and normative scenarios (Börjeson et al. 2006; Maier et al. 2016). Explorative scenarios are often used in the case of strategic issues. Explorative scenarios can be seen as a 'forward-looking' and 'problem-focused' to identify possible future conditions of interest (Parker et al. 2015; Maier et al. 2016). Explorative scenarios focus on the question 'what could happen?' Börjeson et al. (2006) have further categorized the explorative scenarios into two types: External and Strategic scenarios. Börjeson et al. (2006) explain that *'External scenarios respond to the user's question: What can happen to the development of external factors? And strategic scenarios respond to the question: What can happen if we act in a certain way?'*. The external scenarios are focusing on factors and developments out of control of the policymaker. But the strategic scenarios incorporate policy measures under control of the policymaker. Specifically, the strategic scenarios assume a certain policy and explore the possible responses to and impacts of that policy.

Another distinction is the one between *unframed* and *framed* scenarios. *Framed scenarios* are constrained by the priori consideration of particular driving forces as guidance for development (Maier et al. 2016). The development process of *unframed* scenarios is completely open, as a result, this approach has a greater ability to identify a wider range of multiple plausible futures which is seen as an advantage over *framed scenarios*. Unframed scenarios are however still constrained by human cognitive limitations of those who are involved in their development.

This paper takes the explorative approach from the view of a national or regional policymaker and explores possible developments of CLA for a certain policy measure. Hence, from the policymaker perspective, strategic scenarios are used, and the focus is on exploring how farmer communities might react to a policy measure under uncertainty. In conceptual model development, we use an unframed approach to ask about the perspective of farmers communities on the concerning factors for their adaptation decision.

2.3. Mental model and cognitive map

Cognitive mapping to represent mental models has been commonly used in structuring decision problems (Axelrod, 2015; Eden 2004; Elsawah et al. 2015). Mental models represent descriptive theories (how decisions are actually made) (Elsawah et al. 2015). Mental models explain how people make a decision based on how they perceive their surrounding world. Understanding the actor's behavior is important as a local actor's decisions and actions may substantially influence the outcomes of the management policies and the system behavior as a whole. Thus for robust (means coping with uncertainties) policy planning and implementation, it is prudent to be informed by an understanding of how local actors actually make decisions, how changing conditions affect their decisions, and how their decisions may affect and be affected by the policy measure implementation.

A cognitive map is a visual representation of a person's mental model about a particular issue or situation at a particular point in time (Elsawah et al. 2015). Cognitive mapping is a formal modeling technique (based on causal mapping) intended to represent the subjective world of the interviewee (Eden 2004). This research uses Eden's cognitive mapping approach (Eden and Ackerman 1998) grounded on Kelly's Personal Construct Theory (PCT) (Kelly 1955). The PCT proposes an understanding of how humans '"make sense of"' their world. It says that people continually develop and revise hypotheses depending on how they reason about a situation (Elsawah et al. 2015). The cognitive map shows a hierarchical network of nodes and arrows to represent goals at the top; then strategies or decisions at the middle; and the conditions and assumptions are located at the bottom of the map.

Cognitive mapping has commonly been used to understand decision-making (Axelrod 2015), to support groups working on strategy development (Eden and Ackermann 2004) and to elicit and represent individual mental models (Elsawah et al. 2015). In this research, we used cognitive mapping to elicit and represent the community (group) mental model and to serve as the conceptual model to explore CLA decision-making under uncertainty.

3. Designing of the approach

To reach the aim of this research, a modified knowledge elicitation and cognitive mapping technique of Elsawah et al. (2015) has been combined with the unframed strategic scenario development approach explained in Börjeson et al. (2006) and Maier et al. (2016). As illustrated in Figure 1, the resulting approach consists of four iterative steps of knowledge elicitation, cognitive mapping, restructuring cognitive map the form of a conceptual model and scenario development from the conceptual model. The sub-sections below present the steps, the purpose of each step and a brief introduction of the method specific to that step.

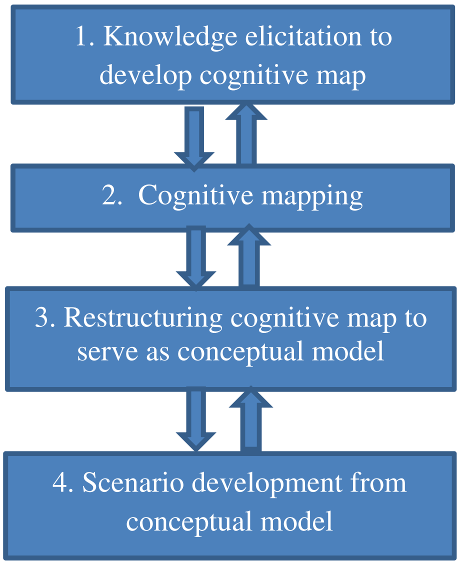

Figure 1. The designed approach to explore uncertainties in CLA for ADM.

3.1. Step 1: knowledge elicitation

The purpose of this step is to elicit mental models or personal constructs of the decision-maker with a minimum instruction of the researcher. Participatory rural appraisal techniques such as semi-structured interview, Focus Group Discussion (FGD), use of crop calendars, etc., are useful for capturing rich data about people's perceptions, judgments, and decisions (Chambers 1994). The preparation for the interviews is discussed in detail at Elsawah et al. (2015) as: selection of the domain of action, identification of a set of open questions to stimulate the discussion, field or mock test for the flow of questions. For interviewee selection, a set of criteria depending on the research objective is defined. If it is important to explore diversity, data saturation may be more useful than the statistical significance of the sample. Data saturation means data collection can be ended when the researcher thinks no new concepts or links are captured.

3.2. Step 2: cognitive mapping of the community

The purpose of this step is to develop a single unifying view of the community that encompasses the individual views and includes the decision-making of individuals in a community. This is different from an approach in which individual cognitive maps are developed first, which are then merged into a collective map as explained by Elsawah et al. (2015). Instead, this research proposes a more simple step of group data collection in a focus group discussion (step 1) followed by developing a single cognitive map of a community that encompasses the views of participating individuals. Such a group cognitive map is sometimes referred to as a 'cause map' with the same formalisms as those for cognitive maps (Eden 2004). The cognitive map can be developed in two ways: 'on the go' during the interview session or offline afterward based on interview transcripts (Elsawah et al. 2015).

The cognitive maps are made up of nodes (represents concepts/constructs) and arrows (causality/beliefs) linked to form chains of action-oriented argumentation (Eden and Ackermann 2010). Typically, a node without an out-arrow is referred as head and a node without in-arrows is tail. This hierarchical structure is most often in the form of a means/ends graph with goal type statements at the top (Eden 2004). The goals are identified by head nodes that have no outgoing link. The direction of the arrow indicates the direction of causality or influence: means to ends, options/actions to outcomes (Eden and Ackermann 2010). For example, certain conditions may lead to specific decisions, which in turn might lead to specific outcomes (Elsawah et al. 2015). Whenever possible, the ideas are formulated in bi-polar statements 'A rather than B' to simply capture the individual's preferences and diversity of perceptions. The concepts are formulated as 'action-oriented' statements that make the map explicit about 'what action is taken' and 'by whom'.

The drawing of a cognitive map in *vensim* (Pruyt 2013) has extended the use of 'causes tree' tools to show the causal relations (links) of concepts (conditions) with the decisions of relevant actors. The causes tree represents how many concepts (conditions) are influencing a decision; thus, outcomes may result from any change of these conditions.

3.3. Step 3: restructuring cognitive map to serve as the conceptual model

In this step, the cognitive map of the community (group) that encompasses the views of all participating individuals is restructured to identify the triggering concepts or exogenous factors influencing decision-making. These triggering concepts are of great importance in decision-making as they represent both the contextual (e.g. changes in climate conditions) and internal (e.g. experience, aim and interests) factors that affect the relevant actor's decision (Elsawah et al. 2015). The possible development of such contextual and internal factors can influence the conditions and the decision of relevant actors, and, in that way, lead to alternative stories or narratives of scenarios. The researchers' insights gained through data collection and analysis can spot similarities as well as differences between mental models of different individuals. They may notice that a particular socio-economic characteristic is influential and discussed in several ways but not included by the participants. For this, researchers may add concepts representing influential socio-economic characteristics to the cognitive map that will be validated with the participants.

3.4. Step 4: scenario development from conceptual model

The purpose of this step is to ascertain the suitability of the resulting cognitive map (restructured) as a conceptual model for exploration of relevant actor's decision-making under uncertainty. We use an unframed approach to explore possible conditions and reactions to them with the relevant actors. The rich variety of exogenous contexts, internal factors, conditions, interests, aims, goals from step 3 can be applied to form coherent stories or narratives in scenarios. Here the underlying Kelly's theory provides the rules to explain how people act based on their reasoning (perception) about a situation or conditions (Kelly 1955). The scenarios can be illustrated as a coherent storyline of possible adaptation responses of relevant actors to a specific set of conditions, including specific (national) policy implementations.

In concluding of this iterative approach, the researcher can revisit data analysis, examine inconsistence and omissions. Elsawah et al. (2015) have indicated the multiple uses of outputs in each step through sharing for data validation, stakeholder engagement in the modeling process, learning and communication of outcomes.

4. Testing the approach in a case study: farmer's cropping decision in polders of southwest Bangladesh

The southwest coastal region of Bangladesh is an ecologically and economically important zone because of its agriculture, energy and marine resources (Kabir et al. 2016). The region covers around 16% of the total land area (~16135 sq km) and 10.4 million people (BBS 2011). The area represents an agro-ecological landscape of Ganges tidal floodplains and a 'Coastal Zone' hotspot in BDP 2100. As agriculture is the dominant sector (~40%) for livelihood (Hossain et al. 2016), this case is particularly focused on the decision-making of the farmer communities. Most of this hydro-dynamically active delta has been transformed into a polder system in the 1960s (Nowreen et al. 2014). Participant farmer communities are from two such polders, namely: Polder 30 and 31 in *Batiaghata* and *Dacope* Upazila of *Khulna* district. Figure 2 shows the study area.

The farmers in the wet season usually all decide to cultivate the *Aman* rice. So for capturing the diversity in decision-making, this research focused on the cropping decision in the dry season. The farmers have trusted us and felt comfortable for sharing in-depth details necessary for this research.

4.1. Step 1: knowledge elicitation and validation with farmers' community

Two focus group discussions (FGD) and four semi-structured interviews were designed and conducted in April 2016 based on Chambers (1994). Two groups of 10 farmers each in polder 30 and 31 have participated in the FGD. The farmers were selected based on (a) have rice farming land (owned/leased) at the same location, and (b) sufficient variety in terms of type of farmers (large, small and landless), age group (young/elder), and male/female (at least two women farmers who are actively involved). Two local key-informant NGOs have supported the participants' selection and the arrangement of the FGD sessions. A team of three researchers, with the specified roles of facilitation, note taking and recording, have facilitated the FGD sessions. The sessions took about three hours each, and around two hours for each semi-structured interview.

Earlier during preparation, a set of semi-structured questions were prepared to capture how farmers perceive and interpret information as a basis for their agricultural decision and action. The questions asked to the participants to stimulate the discussion are: who takes an action, what action is taken and when this action is started regarding both strategic and operational adaptation in cropping. The information intended to elicit was: what crops and varieties to grow over the last years, what is the motivation and argumentation to grow these crops and variety, what factors are of most concern to farmers and finally the physical and social context conditions that stimulate to move to another crop/livelihood. See Appendix I for the guiding questions for FGD and Interviews.

During the introduction of the session, the objective was explained and participants' consents were obtained for audio recording. The information and data were cross-checked with participants. Based on the data saturation approach (Elsawah et al. 2015), the session ended with thanks for the contribution, when no new concepts or links were being captured. For cross-checking and in search of new concepts and links from individual perceptions, we conducted an in-depth interview of four individual farmers who had participated in the group discussion. The transcript of the focus group discussion and interviews has been used for further analysis. After step 3, the structure and content of the cognitive map were validated in a follow-up FGD with the same farmer's community in October 2016.

4.2. Step 2: cognitive map to represent a mental model of the farmer's community

To get a quick sense of the data and to identify the relevant parts of the cognitive map, the audio records and transcripts were analyzed. The data were analyzed through a number of themes: goals, actions/decisions, concerned conditions/situations, external drivers, management options, perceived learning, and communication gap. The concepts

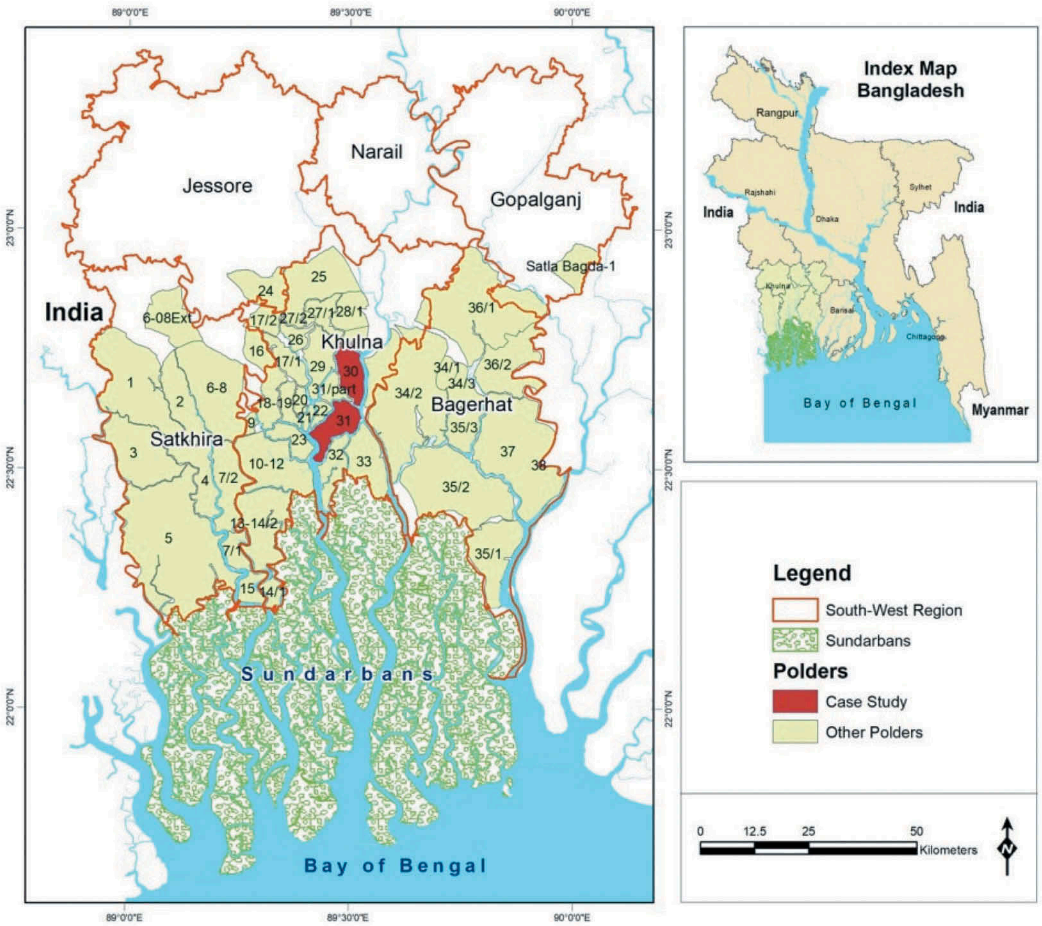

Figure 2. The study area: polder 30 and 31 in southwest region of Bangladesh.

and links between them were identified based on the participants' perceptions. Only the concepts that have a direct link with a strategic decision of farmers in the dry season were included in this cognitive map. For simplification purpose, the day-to-day operational decisions like irrigation schedule, application of fertilizers, pesticides, etc., of farmers were considered implicit in the strategic decisions. Following the methodology as explained in (Elsawah et al. 2015), three key concepts that influence the farmers cropping decision were identified by the researchers, namely 'farmers land owned … leased', 'farmer's family cycle at young … old stage', 'perceived opportunity for off-farm income … no (opportunity for) off-farm income'. During validation with the participants, most of them have agreed with the concepts, only one concept 'outsider influence … no influence' was corrected by them as 'influencial people's influence … no influence'. After validation, the cognitive map was updated accordingly.

The cognitive map in Figure 3 includes the summary concepts of participating farmers for their strategic cropping decision in the dry season. There are a total of 48 concepts (nodes) and 62 relationships (arrows) identified. The map density (arrows to node ratio) is 1.29 that represents a highly complex map, as Eden (1992) defines a complex cognitive map that has a ratio between 1.15 and 1.20.

The structural analysis of the cognitive map shows two goals: 'farmer production profitable' and 'farmer's production meeting family food demand'. The analysis identified three interlinked key decisions: decisions about crop variety, about investment in irrigation water, and about land planning. The causal relationships and conditions up to two connection distances that influence the farmer's decision to change crop variety were explored with the 'Cause Tree Tool' of *Vensim*. The decision to change in crop variety is influenced by a total of 29 conditions (without repetition) as shown in Figure 4.

4.3. Step 3: restructuring of cognitive map to serve as the conceptual model

The cognitive map of the farmer's community from the earlier step is restructured to more clearly distinguish the contextual and internal factors; their relationships and the iteration of the process over the years. Figure 5: the cognitive map (restructured) to serve as a conceptual

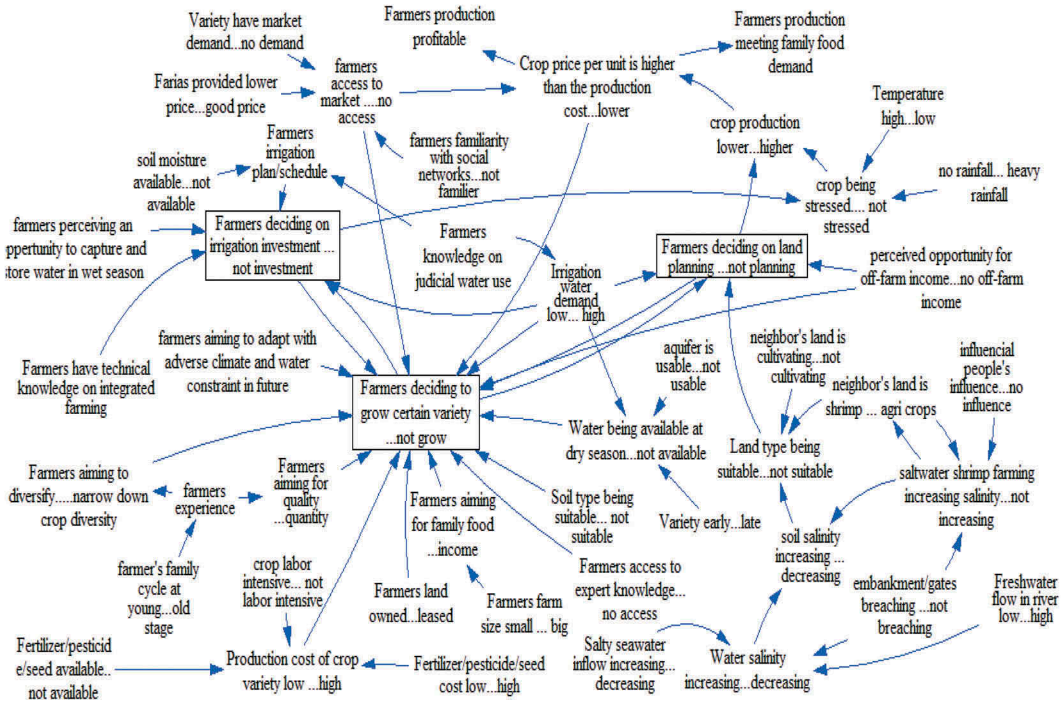

Figure 3. Cognitive map of farmer's community for strategic cropping decision in the dry season. ('. . . ' should be read as 'rather than' to express the contrasting pole). The rectangles represent farmer's decisions, the arrows represent causal links and the rest are conditions.

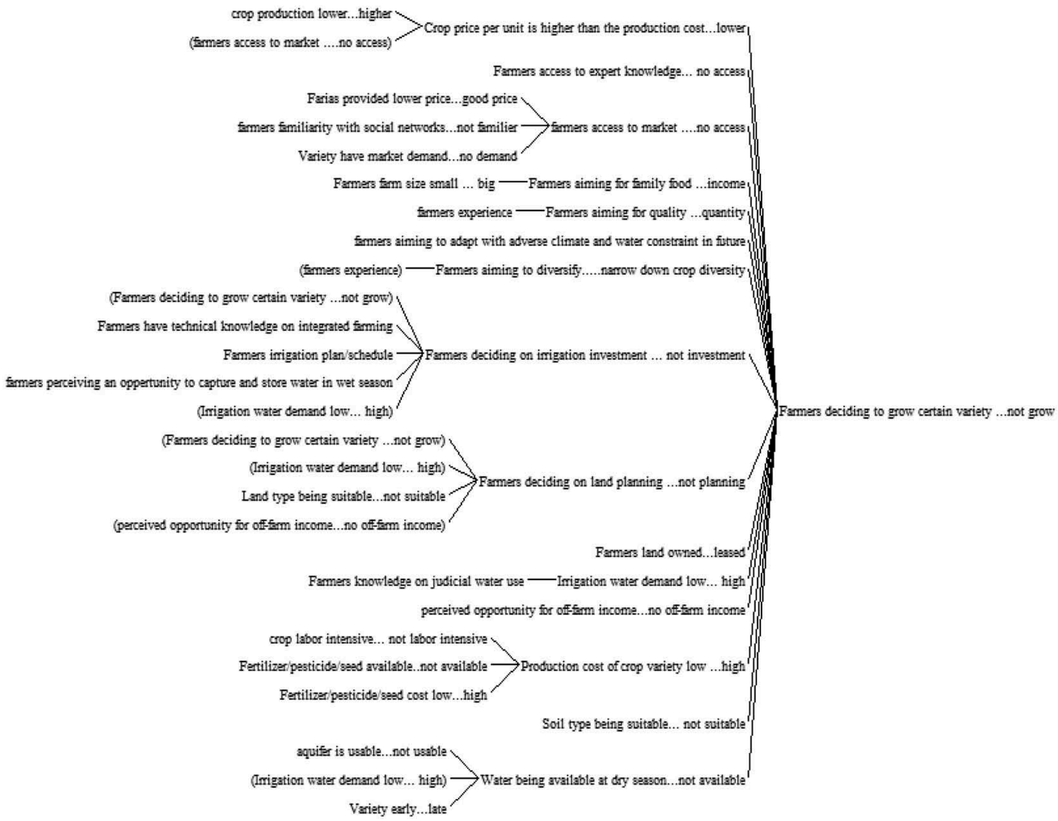

Figure 4. The conditions and relationship in the strategic decision on crop variety.

model shows how the triggering factors and conditions may lead to the strategic decisions and goals. The yearly decisions may lead to meeting or not meeting the goals, and this result will feedback into the iteration of the same process at the next cropping season and into the next year.

4.4. Step 4: scenario development of farmer's CLA decision-making for long-term strategic policy development at national scale

To explore the possible impacts of a relevant delta management strategy or measure, this research investigated the recently prepared 'Bangladesh Delta Plan 2100' for thematic strategies for the hotspot 'Coastal Zone' that encompasses the case study area (GED 2018). One strategy of BDP for salinization is to grow salt-resistant crops (varieties that can grow in saline environment of 5 PPT). The strategy selected for scenario development is: Expand the cropped area with salt-resistant varieties for the coastal area.

The cognitive map (restructured) of Figure 5 serves as the conceptual model that provides the rules to explain how different farmers in a unified small community act based on their reasoning (perception) about a situation or conditions. The subsections below discuss a possible policy implementation scenario and various possible adaptation scenarios, i.e. the possible responses of farmers on the selected policy measures.

4.4.1. Policy implementation scenario

In this policy strategy, the government wants to increase rice-growing areas by introducing the salt-resistant variety in order to replace the traditional rice variety and to bring fallow land under cultivation in the dry season. For that, we assume that the government (i) provides seeds and technological support for farmers; (ii) renovates gates and re-excavates canals for freshwater flow and storage to irrigate; (iii) provides incentives (subsidy money) for qualified farmers to cover the risk and production cost of this new variety.

As a result, we assume that the canals of this locality have been re-excavated partially and gates have been renovated, the canal has contained more water in the last wet season. The Agriculture Extension Department (AED) has set up communication and promotional activities about the provisions of seeds, technology, and incentives to cover production costs. The new early salt-resistant rice variety is said to have a much higher production rate than the variety the farmers have now. The question now is: what could happen in the livelihood adaptation of the farmer's community when this delta management strategy has encouraged expanding the cropped area with salt-resistant varieties for the polders in the coastal area?

4.4.2. Adaptation scenarios: how farmers' community may reason and act

The farmers in a small community have their agricultural lands in the same locality near the canal in the polders. Some have high, some have low land. So irrigation demands are different in the dry season. Some of these farmers are qualified and receive technical support, seeds, incentives, etc., from the AED. We illustrate two divergent main scenarios about how the farmers may react to the government's policy implementation of 'expanding the cropped area with salt-resistant varieties'. We call them the 'hero' adaptation scenario and the 'zero'

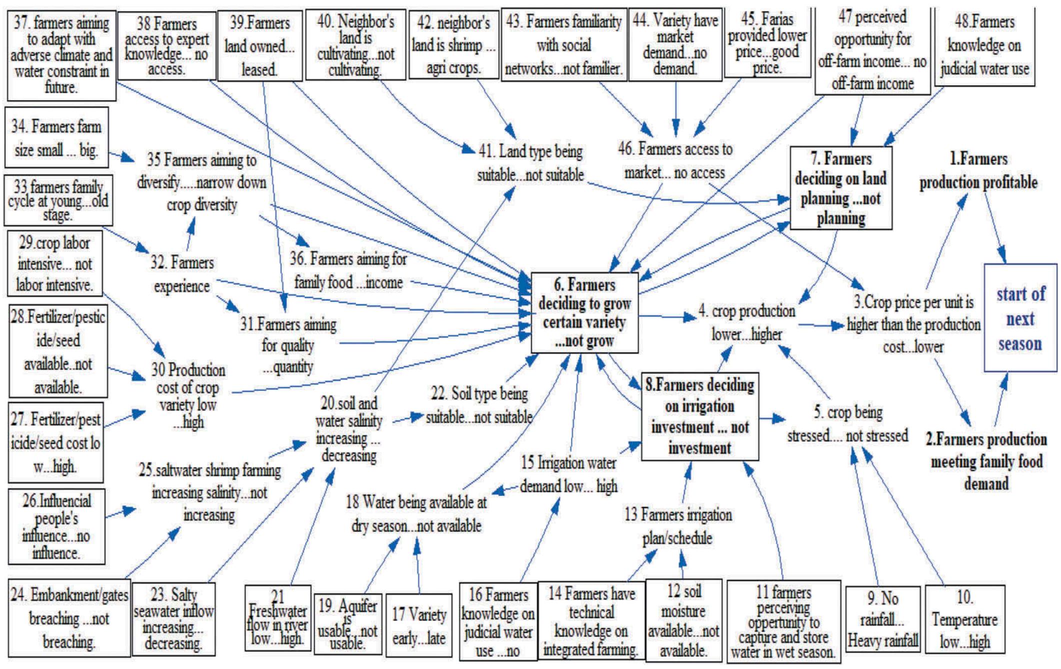

Figure 5. The cognitive map (restructured) to serve as a conceptual model.

adaptation scenario. Both are derived from the combination of relevant external factors and conditions illustrated in the conceptual model (Figure 5). In each of these main scenarios, we distinguish between a number of different farmer types/situations. The numbers in the text refer to the corresponding numbers in Figure 5.

4.4.2.1. Hero adaptation scenarios. i. ***Together to grow salt-resistant rice***: The high productivity (4) of the salt-resistant rice variety in the demonstration plots at saline conditions has sensitized the local farmers. Farmers are suffering from low productivity (4) of their own variety and search for a viable solution for ever-increasing saline conditions, dry and hot weather. Some farmers aim to adapt to adverse climate and water constraints in future (37). The farmers of that locality (both small and large landowners) (34) get access to the provisions of seeds, fertilizers, pesticides and technical knowledge (28) of this early variety at a reasonable price (27) as promotional advantages. They also perceive a good market (44) of this rice as it tastes good (31) and thus has a good market price from *Faria* (local businessman) or regional market (43, 45and 46). The soil and crop management is keeping salinity low (22) at the critical growth stage. The harvesting techniques are quite simple and familiar with farmers. Many farmers of that locality perceive this is a good opportunity. They decide to go for production of this early variety together so that they can share labor and costs for production activities, irrigation and manage pests efficiently (27 and 29).

ii. ***Rice in the fallow land***: The young farmers (33) in the locality are enthusiastic to diversify their crops (35) and enhance rice productivity (4). Some farmers have their own land (39) that they need to keep fallow due to salinity, and they now have hope to grow rice with this salt-resistant variety, improved gates (24) and availability of irrigation water (18). Some elder and young farmers (33) have knowledge of judicial water use (16) including land planning (7). So they are willing to invest in irrigation (8 and 11) and organic fertilizers to make the soil suitable (22) for cultivating the salt-resistant variety in the fallow land, even the farmers who lease land (39).

iii. ***Integrated rice-shrimp cultivation***: some farmers have knowledge of integrated farming (14) but get lower production (4) from their shrimp cultivation in the dry season due to virus attacks and other problems. They prefer to adopt the salt-resistant rice variety to cultivate along with shrimp in an integrated farming system.

iv. ***Compete with local salt-resistant variety***: Some elder (33) and experienced farmers (32) who feel like a farmer to grow rice both for their family food and income (36) are eager to diversify their crops (35). They observe that one of their local varieties (tested for some two to three years in a saline part of their land) has a good production (4) in spite of the saline condition. The rice is good in quality (31), has a good taste thus a good price in the market (45), also has demand (44) in family food consumption. Some other nearby farmers show interest to grow this variety at least partially to their saline prone land. As they get seeds at their own farmer's community (28), they have the interest to grow this local salt-resistant variety along with the new salt-resistant variety.

4.4.2.2. Zero adaptation scenarios. *i.* ***Comfortable with known variety***: Small farmers who usually aim for family food (36) may not be interested in shifting to another variety because their farms are small (34), and mostly leased not owned (39). Some land owners are too small; such farmers may not be willing to take the risk of a new variety, and neither qualify for the criteria of AED. Some farmers have low access to expert knowledge (38) also. Their rice production in the last dry season was very low (3, 4) and hardly met the family food demand (2). Some of them are eager to diversify their crops (35) and their experience (32) drives their aim for quality (specifically taste) or for quantity (more production) (36) of crops. The farmers observe from the demonstration plot of AED that the salt-resistant variety has a good production (4) but is very cost and labor intensive (27, 29 and 30), some failed to get profit due to the lower market demand for the variety (44). They perceive an opportunity for capturing more irrigation water in the re-excavated canal (11) and low saline water inflow (20, 23 and 22) from improved gates/embankment (24). They are perceiving a lot of rainfall (9) in this year also. As they have seeds of their own variety (28), they decide to continue their own rice variety instead of the salt-resistant rice variety.

ii. ***Shrimp for income***: Some influential farmers (26) near the periphery of the embankment have started shrimp cultivation for income in the dry season along with the *Aman* rice in the wet season. That causes increased soil and water salinity (25) in the polders. The low freshwater flow in the nearby river increases the salinity of river-water, made the soil (22) near the embankment too saline for rice cultivation, so the fallow land is under shrimp cultivation in the dry season now. The small farmers are cultivating shrimp as their neighbor's land is shrimp (41 and 42) and their rice production has dropped drastically (4). So these farmers do not have an interest in a salt-resistant rice variety.

iii. ***Fallow is more***: As the rice production is non-profitable due to the type of land (41) in the dry season, the large landowners (34) are reluctant to invest in rice production, and when their land is neither suitable for shrimp (41), they keep it fallow. Again some elder farmer's family members (mainly young labor force) (33) perceive a better opportunity to go for income (36) to a nearby city or other regions (47) instead of investing on such land. The low productivity (4) discourages to lease such lands. The small landowners alone are unable to cultivate rice or other crops due to a higher risk of pest, rat and cattle attack as the neighbors land is not cultivating (40). This is the same for cultivating a different early or late variety (17) than the variety other farmers cultivates at that location. In this context, the early variety (17) of salt-resistant rice is perceived as non-suitable by the farmers.

iv. ***Income with lower irrigation***: Some farmers have a good relationship with the market (46) on *rabi* crops. As *rabi* crops require lower irrigation (15) than rice, and as they are profitable due to good market demand (44), some farmers are willing to cultivate *rabi* crops for income (36). Some farmers who have leased land (39) cultivate rice in the wet season. In the dry season, they rather earn income as a day laborer (47) during the sowing and harvesting period on other farmer's land. So they decide to a crop that requires lower labor, irrigation and production cost (15 and 27) but will have some income (36) at the end of the season, so they decide to cultivate sesame instead of a salt-resistant rice variety.

From the above, we may conclude that some farmers as, for example, who have access to the provision of new varieties/technologies, who had to keep their land fallow but want to diversify crops, who want to integrate saline-resistant rice with shrimp might exploit the opportunities provided by the policy. But other farmers who are comfortable with known variety in spite of the production loss or have income from shrimp or have opportunity in income with lower irrigation or perceive fallow are more than investing in non-profitable land might be reluctant in exploiting the opportunities provided by the policy. The extent to which this will happen depends on many factors (around 48 factors) as, for example, farmers' type, aim, experience, land type, soil type, crop type, irrigation water availability, climatic condition, neighbors coordination, market value, and price, etc., many of which are uncertain. So the adaptation process of farmers is uncertain, and so is the extent of policy impact. Figure 6 Livelihood adaptation pathway map: farmers possible response to salinization, shows the variety of livelihood adaptation pathways in the hero or zero adaptation scenarios under the condition of increased water and soil salinity (low-high) at the qualitative scale of 1 to 10. Due to the low yield of rice and/or shrimp, the integrated rice-shrimp cultivation may shift as 'fallow is more' or 'shrimp for income' by 2038. The non-expected reaction like 'comfortable with known variety', 'shrimp for income', 'fallow is more' or 'income with lower irrigation' by the farmers' community may, in the end, have a higher potential to cope with the new saline condition and hence be adopted by a majority of farmers. This illustrative adoption scenario of some years may lead to the zero adaptation pathway by the farmers within 2050, as the adaptation decision of farmers are embraced with a number of uncertain factors.

However, farmers may switch from one livelihood to another over time that may lead to hero adaptation

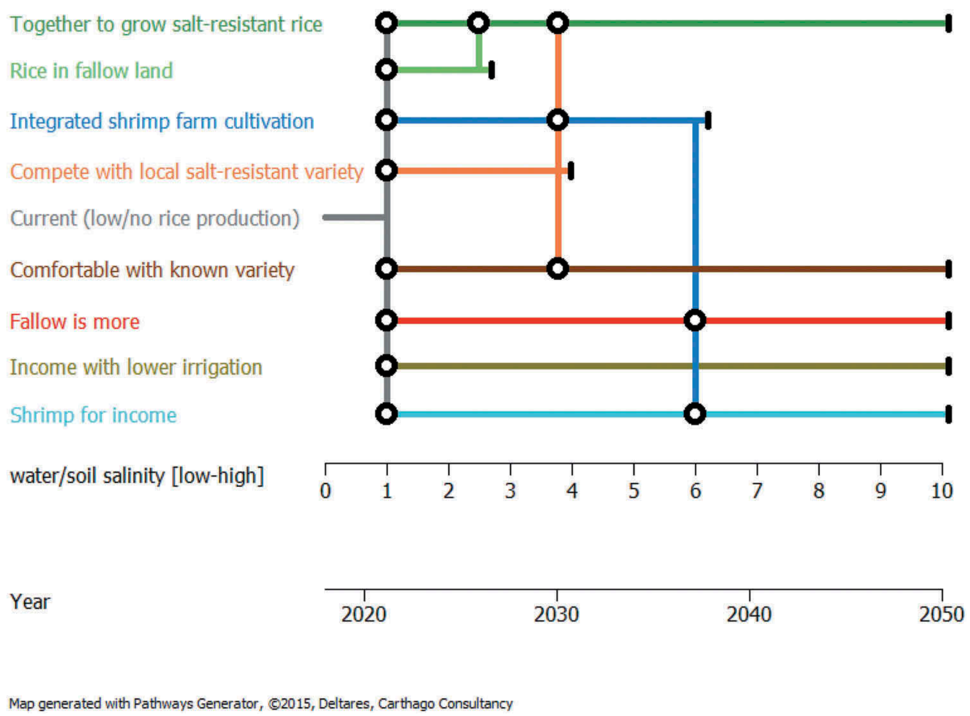

Figure 6. Livelihood adaptation pathway map: farmers possible response to salinization. All are for illustrative purposes only. The black (round) transfer stations illustrate the livelihood adaptation decision from one to other by local farmer communities. The black terminal has illustrated the condition in which a livelihood is not suitable anymore.

also. The local salt-resistant rice variety may seem to be more familiar and 'known variety' to farmers by 2030; or switch to the salt-resistant variety (policy promoted) may be acceptable to farmers as 'together to grow salt-resistant rice' or integrated rice/shrimp farm cultivation in the context of increased salinity by 2030.

The delta planners may improve the design and implementation of a policy strategy if they are aware of the variety of possible adaptation responses, may prevent certain unexpected response or can be prepared if, in case, the unexpected response occurs. The planners may prepare with a contingency plan if monitoring shows that farmers do not do what they intend. As, for example, if monitoring shows a local salt-resistant variety is more popular and effective, the policy strategy should encourage the seed production, storage, promotion and marketing of local salt-resistant variety among the farmers. This may ensure the success in terms of increased cropped area with an adaptation of local crop variety and livelihood sustainability. Moreover, can promote the farmers' ownership over seeds, enhance local biodiversity. Other examples of adaptive policy planning and implementation can come from the monitoring of the adaptation process of farmer community, i.e., income with lower irrigation, shrimp for income, etc.

5. Discussion: reflecting on the application of the approach

To be robust against any uncertain development of CLA, the design of delta management strategy needs to understand and account how local people, particularly the farmers, make agricultural adaptation decisions in their social-ecological system. This paper aims to contribute to developing better ways to explore community livelihood adaptation under uncertainty. The mental model techniques from the fields of environmental psychology and scenarios from the fields of future exploration and adaptive planning are combined. The approach can improve the understanding and representation of dynamic complexity in the human and social dimensions of delta planning. In this section, the SWOT analysis as of Elsawah et al. (2015) is used to reflect on the experience of applying the approach.

5.1. Strengths

The approach has combined the strength of two well-established methods: Cognitive mapping and scenario development. Cognitive mapping taps into the richness and diversity of subjective mental models and decision-making processes. The scenarios make use of the cognitive map as the conceptual model to develop coherent stories or narratives about 'what might happen in community decision-making if a specific policy measure is implemented?' Framing options as a bi-polar statement in the cognitive map make actors' perception and decision-making clear. The use of group or community cognitive mapping captures the participating individual's perception and visualizes the network of complex interactions of system processes and relations to specific decisions. It thereby helps understanding conditions that are relevant for decisions. The modeling process structures the understanding of complexity in a simplified way for easy understanding. Moreover, the graphical format and day to day languages of relevant actors make it easy-to-explain tools to communicate and learning. The approach identifies critical conditions that are relevant to the perception of actors and researchers as triggering factors. Clarity and transparency exist in the modeling process as the modeler can share the output of any step with decision-makers (in our case with farmers) and can revisit the earlier steps.

5.2. Weaknesses

The method of data collection that encourages the participants to 'tell stories' may end up with a very rich qualitative dataset, but sometimes lead the researcher to get lost in the analysis. The same dataset may lead to a different cognitive map depending on the purpose of modeling; therefore, it is good to be clear about the purpose of the modeling to develop the cognitive map accordingly. The unframed approach may lead to a rich variety of conditions that arise from structural analysis of the cognitive map and this can make it difficult to develop a limited set of scenarios. Moreover, different combinations of conditions may have different effects, for example: farms owned or leased are both important. Some conditions are independent, some combinations of conditions are more expressed. That what farmers say they would do may be different from what they actually do. That might cause other uncertainties that influence the decision-making of farmers. The rich diversity of concepts related to the farmers' adaptation decision-making captured in this approach may seem too much to deal with by the policymaker for adaptive delta management.

5.3. Opportunities

The participatory part of the approach may be beneficial in building rapport. As a basis for changing local participants' perception on future thinking, the modeling process itself might contribute to changing how they will react in future. Moreover, policy may be informed sufficiently to plan for this level of uncertainty. Cognitive mapping offers a useful approach to collect and apply basic data obtained in a qualitative way.

5.4. Threats

The success of a multi-method approach highly depends on the researcher's skill to cross the boundaries of different paradigms and communicate ideas to find new ways for understanding decision-making in complex social-ecological systems. The elicitation and conceptualization of maps is sensitive to subjective factors such as: the researchers own preferences, biases, mapping, and analytical skills. This can be compensated with data validation, language standardization, etc.

6. Conclusion

This research has presented a four-step iterative approach to explore community livelihood adaptation under uncertainty. The approach applies mental models of relevant actors' decision-making to develop possible scenarios to inform adaptive delta management. The approach combines the use of different data collection, mapping and conceptualization techniques from multiple fields including community livelihood adaptation, uncertainty, scenarios, cognitive mapping, and mental models.

This research has shown how the approach can be applied to- (i) elicit and represent the mental model of a farmer's community for their strategic cropping decision and (ii) develop forward-looking scenarios using the conceptual model. Experience shows the approach is useful in structuring the cognitive and qualitative nature of complex decision-making process; helps in understanding the dynamic interactions of farmers' decisions with other actors, their environmental attributes, and market traits. The transparent progression of this approach makes it worth applying it to enhance social learning and engagement of relevant actors in policy design and implementation processes. Future research and extension into other cases may help improve the approach for application in practical planning and implementation.

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Disclosure statement

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Appendix I: The guiding questions for FGD and Interviews

Introduction

A short introduction of this PhD research and objective of the FGD and Interview should be shared at first. It is to be ensured that their views are critical and will be heard. They can raise any question or issues safely. The information will be used for research purposes.

Part I: to explore the triggering factors and core conditions for livelihood adaptation

(1) What is the main source of livelihood of your family?
(2) What crop or varieties do you grow annually?
(3) Why do you grow these crops? (physical and social)
(4) Do you change this from one year to another or this is pretty stable?
(5) If you decide to grow different crop/variety what factors will you consider making such a decision?
(6) What you do differently to adapt with the changed physical and social condition?

Part II: to explore the rules in making adaptation choice in livelihood

(1) Why have you chosen or started or come at this livelihood?
(2) In what condition you have changed or did different from earlier livelihood?
(3) How often do you revisit your decision?

Part III: to explore the rules in making adapted livelihood ‘secured’

(1) What is the context or requirement to ensure your current livelihood secured?
(2) In what condition you want to change or do anything different of your current livelihood?
(3) How do you think the factors may change in future?
(4) What will you do in response to the change?
(5) Thinking of your livelihood future what issues do concern you?
(6) What questions about the future you would like to have answer for?

Wrap-up

At last, wrap up the information and clarify the understanding of data with the participants. Ask for their feedback on this session, if any. Ask for their willingness for validation session at another day. The session closes with providing thanks for their time and contribution.