Supporting Adaptive Delta Management
Systematic Exploration of Community Livelihood Adaptation as Uncertainty

Kulsum, Umme

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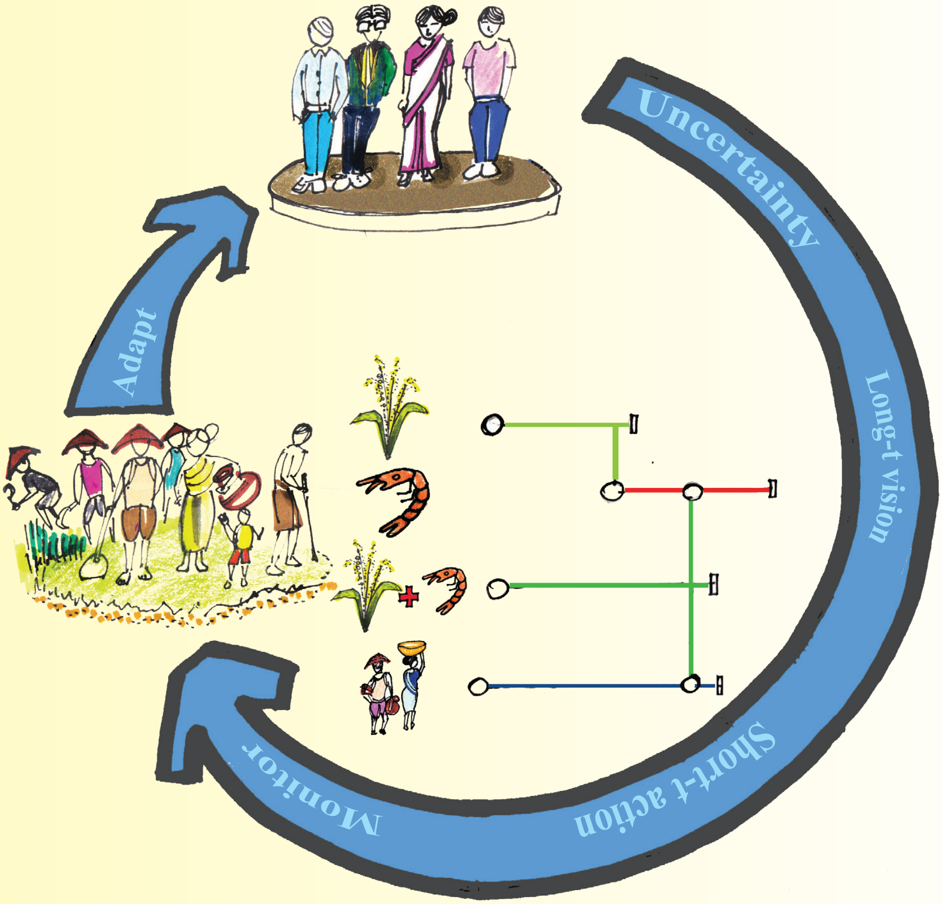

UMME KULSUM

Supporting Adaptive Delta Management

Systematic Exploration of Community Livelihood Adaptation as Uncertainty

Supporting Adaptive Delta Management

Systematic Exploration of Community Livelihood Adaptation as Uncertainty

Dissertation
For the purpose of obtaining the degree of doctor
at Delft University of Technology
by the authority of the Rector Magnificus, Prof.dr.ir. T.H.J.J. van der Hagen
Chair of the Board for Doctorates
to be defended publicly on 13 oktober 2021

By

Umme KULSUM

Master of Science in Environmental Science, Khulna University
Khulna, Bangladesh
Born in Khulna, Bangladesh

This dissertation has been approved by the Promotors

Composition of the doctoral committee

Rector Magnificus	Chairperson
Prof.dr.ir. W.A.H. Thissen	Delft University of Technology, Promotor
Prof. dr. M. Shah Alam Khan	Bangladesh University of Technology, Promotor
Dr.ir. J.S. Timmermans	Delft University of Technology, copromotor

Independent members

Prof.dr. T. Filatova	University of Twente
Prof.dr. A.R.P.J. Dewulf	Wageningen University
Dr.ir. L.M. Hermans	Delft University of Technology
Prof.dr.ir. N.C. van de Giesen	Delft University of Technology
Prof.dr.ir. A. Verbraeck	Delft University of Technology, reserve member

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Key words : Uncertainty, Community, Livelihood, Adaptation, Adaptive Delta Management (ADM), Polders, Bangladesh

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Umme Kulsum
Dhaka, Bangladesh

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List of Acronyms

ADM	Adaptive Delta Management
ATP	Adaptation Tipping Point
AEZ	Agro Ecological Zone
BBS	Bangladesh Bureau of Statistics
BDP 2100	Bangladesh Delta Plan 2100
BWDB	Bangladesh Water Development Board
BUET	Bangladesh University of Engineering and Technology
CEGIS	Center for Environmental and Geographic Information Services
CLA	Community Livelihood Adaptation
FBM	Foggs' Behavior Model
GED	General Economic Division
IWFM	Institute of Water and Flood Management
IWRM	Integrated Water Resource Management
KII	Key Informant Interview
MOA	Motivation Opportunity and Ability
MOTA	Motivation and Ability
NWO	Netherlands Organization for Scientific Research
PRA	Participatory Rural Appraisal
RWMA	Rapid Water Management Appraisal
UDW	Urbanizing Deltas of the World
WARPO	Water Resources Planning Organization

Summary

Supporting Adaptive Delta Management

Systematic Exploration of Community Livelihood Adaptation as Uncertainty

Sustainable delta management in recent years is challenged with uncertainties in socio-economic development and climate change. To deal with such deep uncertainties, adaptive delta management (ADM) has been developed. The core of this approach is to acknowledge uncertainties instead of ignoring them, thinking in terms of many possible future scenarios, and taking pre-cautionary short – term actions, while keeping adaptation options open, and continuous monitoring of actual developments. Bangladesh is one of the countries moving towards adaptive delta management in its Bangladesh Delta Plan 2100. The focus of the BDP 2100 is on robust and adaptive investment for socio-economic development under uncertain future conditions.

Following the IPCC scenarios, the scenarios used in the BDP 2100 have been developed around two uncertain external drivers: (i) future water conditions based on trans-boundary developments and climate change and (ii) economic development including land use changes. The scenario narratives define possible, plausible long-term development directions of the key attributes of the natural system and of socioeconomic conditions including livelihood and agriculture. The BDP 2100 strategic planning approach combines, in principle a wide stakeholder engagement with utilization of available data sources in the formulation of policy strategies. These are however based on fixed – not deeply uncertain - assumptions about how the local community will respond to the policy strategy. The effectiveness of such a strategic planning approach may be seriously harmed if the response of local communities during plan implementation at the regional or local context is different from what was envisaged or expected

Historical examples in southwest coastal Bangladesh illustrate that the community livelihood adaptation response can indeed be different from what policy makers expected and that this influences the effectiveness of a specific policy strategy implementation. Our historical analysis on the importance of community livelihood adaptation in (adaptive) delta management is based on literature review,

insights from interviews and field observation. Two historical cases of livelihood adaptation of farmer communities since 1960s are studied, i.e. commercial shrimp farming and tidal river management confronted with contemporary polder management for salinization and water logging in the polders of southwest Bangladesh. The findings confirm that adaptation is a process over time that can follow alternative pathways.

The research objective is thus to develop an approach to support adaptive delta planning and implementation by systematic exploration of Community Livelihood Adaptation (CLA) as uncertainty.

With Community Livelihood Adaptation (CLA) in this research we refer the process of livelihood adaptation of a group of actors, in particular farmers. The concept of CLA can be seen as the adjustment in livelihoods to moderate harm or to exploit benefits from changing conditions by groups of households (or individuals) that share material and non-material resources based on their differentiated abilities. Therefore, CLA is a complex and dynamic process that takes place in a local social-ecological system.

The overall research approach has been explorative and can be best characterized as a journey of discovery based on interdisciplinary concepts. Our research approach consists of three key phases: 1) conceptualization of CLA and examining its historical importance 2) designing different the approaches, testing them in case studies and illustrating this with policies 3) cross-case evaluation and discussion of the results. In the approach, the model development is based on actors' perceptions while the policy illustration with model result is from a policymaker perspective.

To achieve the research objective, the approach development is grounded in the application of available methods, theories, and frameworks. Two different approaches are developed; tested in empirical case studies of farmer communities (actors); and illustrated with a policy from BDP 2100.

For case study selection, the key criteria were (i) any of the hotspots of BDP 2100 and (ii) existence of a history of community livelihood adaptation with concurrent delta management under changing climate and socio-economic conditions (iii) accessibility and willingness of the community to participate. Based on these criteria, we selected the southwest coastal region under the 'Coastal Zone' hotspot in BDP 2100 as our case study area. The policy strategies for this coastal zone under BDP2100 are used to illustrate the possible livelihood adaptation pathways resulting from our analyses.

A first cognitive map-based unframed scenario approach combines mental modeling techniques (cognitive mapping) with unframed scenario development. The participatory elicitation of the mental models a community uses when considering adaptation decisions, results in a cognitive map of the community. This serves as a conceptual model for analyzing livelihood adaptation decision making in a future-oriented scenario analysis. To test the approach, a case study of cropping decision making of rice farmers communities under salinity at Polder 30 and 31 has been combined with a policy 'grow salt-resistant crop' of BDP 2100.

Results show that this approach is useful in structuring the cognitive and qualitative nature of the 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 possible adaptation direction of local communities for one or more policy strategies. The approach is practical for the purpose of in-depth analysis, illustrating and presenting factors and relationships for one specific decision domain, in the case study this is the cropping decision of a rice farmer community. In principle, the approach can be applied to any decision domain. However, use of this approach for multiple decision domains of livelihood adaptation (agricultural, non-farm, migration, etc.), might have practical constraints in terms of required time and effort.

In order to be able to describe the most important elements of CLA under uncertainty in a simpler general framework, other options have been investigated, and a second approach has been developed based on the Motivation and Ability Framework (MOTA) and related concepts in combination with a framed scenario approach. In the MOTA framework, decisions to adapt depend on (1) the motivation of actors for a specific decision, and (2) the ability or capacity of actors to implement the decision. Both factors are partly determined by physical and / or socio-economic conditions and developments or triggers.

The approach has two distinctive parts: (i) the conceptual model resulting from combining the motivation and ability conceptual framework with framed scenarios and (ii) the application of the resulting conceptual model to develop illustrative livelihood adaptation, and adaptive policy pathways. For this, the case of rice and integrated farmers in Polder 30 is illustrated with a policy 'Diminish drainage congestion and improve livelihood' of BDP 2100. The case application shows that it is very well possible to structure the key factors in adaptation decision making into triggering factors, motivating factors, ability factors and perceived opportunities/threats to derive livelihood adaptation action pathways under alternative scenarios. We conclude that also this approach can be used to explore community livelihood adaptation under uncertainty to support policy makers in adaptive planning and implementation.

A pilot computational version of the MOTA model has been developed to explore how quantitative assessments of the preference for adaptation options can be derived on the basis of estimated values of triggering factors and ability factors under specific scenarios. Data from the case of rice and shrimp farmers at polder 31 have been used to generate results for five livelihood adaptation actions of the rice (young/elderly) and the shrimp farmer community under specific scenarios. The model assesses possible livelihood adaptation actions as preferred, possible and non-preferred. The results are very similar to the preferences for livelihood adaptation actions under scenarios as expressed by the same farmer community, and also resemble their historical livelihood adaptation.

Overall, both approaches are, in principle, fit for their purpose. Some key aspects for example the data collection; the use of framed or unframed scenarios; the framing of the decision logic; and the way of organizing the adaptation responses are different and this has impact on the practical usability depending on the specific context. In practical terms of time and effort, the first approach seems to be more suitable to use for one specific (livelihood) decision domain of an actor community and the second approach is more suitable for all (livelihood) decision domains of an actor community.

Applications are so far limited to the case of three farmer communities in two polders, but general characteristics provide confidence that the approaches are applicable as well to large varieties of farmers in different social-ecological systems or other livelihood communities.

Concluding, both approaches developed in this research can support adaptive planning and implementation by systematically exploring community livelihood adaptation (CLA) as uncertainty. The quantification in a computational model could further help the policymaker in visualization and incorporating community livelihood adaptation in adaptive planning and policy implementation. Like other actor-modeling approaches, however, these approaches are based on a simplification of community livelihood adaptation and should therefore be applied with care.

The approaches can support the policymaker by getting a sense of how the livelihood adaptation action of a local community may look like under different conditions; how different factors influence their adaptation direction; and how policy strategy may be perceived by communities in this dynamic process. Like in a policy game lab, the policymaker and policy researchers can examine the possible adaptation response of a local community before actual implementation of the policy.

Reflecting on the overall research and its results, a number of limitations come to the front, each leading to an indication of further work; for example the number of case studies is limited and application to a wider set of communities with different characteristics is recommended to further assess the approaches. Also, variation of methods within the approaches should be explored, and more work is needed to improve the pilot computational model. In addition to addressing these various limitations of the modelling and analysis so far, several extensions are suggested for future work. These include extension of the current static model to a dynamic model, coupling of a computational model of CLA with physical system models, and including the interaction of livelihood adaptation with adaptive policies in a computational modelling framework.

Finally, while various parts of the developed approaches can be improved and refined, practical application is highly recommended at this stage. Firstly, because it is better to pay attention to CLA as uncertainty in an approximate way than not to do it at all; Secondly, because participatory exploration of future developments and possible community adaptations in interaction with possible policies creates an environment for learning by both policy makers and local stakeholders and enhances mutual understanding in policy design.

The systematic and broader use of these approaches however requires an adaptive perspective of policymakers, policy researchers and all relevant decision makers. With a strategic plan like BDP 2100, the development oriented governance system in a developing country like Bangladesh doesn’t move to the adaptive process instantly. This will need time, perhaps ten years, twenty years, or more. Investment in capacity building of current and future policymakers/ decision makers on the advantages of the adaptive approach to deal with deep future uncertainties is therefore essential.

Samenvatting

Ondersteuning van adaptief delta management

Systematische verkenning van Community Livelihood Adaptation als onzekerheid

Lange-termijn Delta planning moet rekening houden met grote onzekerheden in sociaal-economische ontwikkeling en klimaatverandering. Adaptief Delta Management (ADM) is een benadering specifiek ontwikkeld om op verstandige wijze met zulke diepe onzekerheden om te gaan. De kern van deze aanpak omvat het erkennen van onzekerheden in plaats van ze te negeren, het denken in een breed spectrum van mogelijke toekomstscenario's, het nemen van voorzorgsmaatrege-len op korte termijn en het open houden van aanpassingsopties, en monitoring van actuele ontwikkelingen om tijdig aanpassingen door te kunnen voeren. Bangladesh is een van de landen die de gedachten achter ADM hebben opgepakt in het kader vanhet Bangladesh Delta Plan 2100 (BDP 2100). De focus van BDP 2100 ligt op robuuste en adaptieve investeringen ter bevordering van de sociaal-economische ontwikkeling onder onzekere toekomstige omstandigheden.

In navolging van de IPCC-scenario's zijn de in BDP 2100 gebruikte scenario's ontwikkeld rond twee onzekere externe factoren: (i) toekomstige watercondities onder invloed van grensoverschrijdende ontwikkelingen en klimaatverandering en (ii) economische ontwikkeling met inbegrip van veranderingen in landgebruik. De scenarioverhalen definiëren mogelijke, plausibele ontwikkelingsrichtingen op lange termijn van de belangrijkste kenmerken van het natuurlijke systeem en van de sociaal-economische omstandigheden, waaronder middelen van bestaan en landbouw. De strategische planningsbenadering van BDP 2100 combineert in principe een brede participatie van belanghebbenden met het gebruik van beschikbare gegevensbronnen bij het formuleren van beleidsstrategieën. Deze zijn echter gebaseerd op vaste - niet diep onzekere - veronderstellingen over hoe de lokale gemeenschappen op de beleidsstrategie zullen reageren. De effectiviteit van een dergelijke benadering kan ernstig worden aangetast als de reactie van lokale gemeenschappen tijdens de implementatie van het plan in de regionale of lokale context verschilt van wat werd voorzien of verwacht.

Historische voorbeelden in het zuidwesten van Bangladesh bevestigen dat de respons van lokale gemeenschappen inderdaad kan verschillen van wat beleids-makers verwachtten en dat dit de effectiviteit van een specifieke implementatie van een beleidsstrategie nadelig beïnvloedt. Onze historische analyse is gericht op aanpassingen in de keuze van de middelen van bestaan, in het Engels Community Livelihood Adaptation (CLA). De analyse is gebaseerd op literatuuronderzoek, interviews en veldobservatie. Twee historische gevallen van aanpassing van boerengemeenschappen sinds 1960 zijn bestudeerd, namelijk commerciële garnalenkwekerij en getijdenrivierbeheer in reactie op hedendaags polderbeheer en houtkap in de polders van zuidwest Bangladesh. De bevindingen bevestigen dat aanpassing een proces in de tijd is dat andere dan de verwachte paden kan volgen.

Tegen deze achtergrond is het doel van dit onderzoek om, ter ondersteuning van adaptieve deltaplanning, een aanpak te ontwikkelen voor systematische ex-ante verkenning van Community Livelihood Adaptation (CLA) als onzekerheid.

Zoals gezegd verwijzen wij in dit onderzoek met Community Livelihood Adaptation (CLA) naar het proces van aanpassing van de middelen van bestaan van een groep actoren, in het bijzonder boeren. CLA kan worden gezien als een aanpas-sing gericht op het beperken van schade of om te profiteren van de voordelen van veranderende omstandigheden, die plaats vindt door groepen huishoudens (of individuen) die materiële en niet-materiële middelen delen op basis van hun gedifferentieerde capaciteiten. Daarom is CLA een complex en dynamisch proces dat plaatsvindt in een lokaal sociaal-ecologisch systeem.

De algemene onderzoekbenadering is verkennend geweest en kan het best worden gekenmerkt als een ontdekkingsreis op basis van interdisciplinaire concepten. Onze onderzoekaanpak bestaat uit drie hoofdfasen: 1) conceptualisering van CLA en onderzoek naar het historische belang ervan 2) ontwerp van verschillende benaderingen, het testen daarvan in case-studies en illustreren hoe dit voor beleid zou kunnen worden toegepast 3) cross-case evaluatie en reflectie op de resultaten. In de aanpak is de modelontwikkeling gebaseerd op de perceptie van actoren, terwijl de illustratie van de toepassing voor beleid het perspectief kiest van een beleidsmaker.

Er zijn twee verschillende benaderingen ontwikkeld; getest in empirische case studies van boerengemeenschappen (actoren); en geïllustreerd met een beleidsvoornemen uit BDP 2100.

Voor de selectie van cases waren de belangrijkste criteria (i) een van de hotspots van BDP 2100 en (ii) het bestaan van een geschiedenis van adaptatie onder veranderingen in beleid, klimaat en sociaal-economische omstandigheden (iii) toeganke-lijk-heid en bereidheid van de lokale gemeenschap om deel te nemen. Op basis van deze criteria hebben we de zuidwestelijke kuststreek onder de hotspot 'Kustzone' van BDP 2100 gekozen als casestudiegebied. De beleidsstrategieën voor deze kustzone uit BDP2100 worden gebruikt om de mogelijke trajecten voor aanpassing van het levensonderhoud te illustreren die uit onze analyses voortvloeien.

De eerste benadering combineert technieken voor mentale modellering cognitive mapping met een open scenario-ontwikkeling. Op participatieve wijze worden de redeneringen die een gemeenschap gebruikt bij het overwegen van aanpassingsbeslissingen in kaart gebracht, dit resulteert in een zogenaamde cognitive map. Deze dient als conceptueel model voor het analyseren van besluitvorming over aanpassing in een toekomstgerichte scenarioanalyse. Om de aanpak te testen, is een case study uitgevoerd van teeltbeslissingen van rijstboeren als functie van het zoutgehalte van het oppervlaktewater in polder 30 en 31 bij een beleid gericht op ‘zoutbestendig gewas verbouwen’ van BDP 2100.

De resultaten tonen aan dat deze benadering bruikbaar is voor het in kwalitatieve zin structureren van het complexe besluitvormingsproces en helpt bij het begrij-pen van de dynamische interacties van aanpassingsbeslissingen van boeren met andere actoren, met de (fysieke) milieuomstandigheden en met marktkenmerken. Het kan beleidsmakers helpen anticiperen op de mogelijke aanpassingsrichting van lokale gemeenschappen bij een of meer beleidsstrategieën. De aanpak is goed toepasbaar voor een grondige analyse, en voor het illustreren en presenteren van factoren en relaties voor één specifiek beslissingsdomein. In de case studie is dit de besluitvorming over de gewas- en teeltkeuze van een gemeenschap van rijstboeren. In principe kan de aanpak op elk beslissingsdomein worden toegepast. Het gebruik van deze aanpak voor meerdere beslissingsdomeinen (landbouw, niet-landbouw, migratie, enz.) kent echter praktische beperkingen: het vereist relatief veel tijd en inspanning.

Om de belangrijkste elementen van CLA onder onzekerheid in een eenvoudiger algemeen kader te kunnen beschrijven zijn andere opties onderzocht, en op grond daarvan is een tweede benadering ontwikkeld op basis van het Motivation and Ability Framework (MOTA) en gerelateerde concepten in combinatie met een gestructureerde scenario-benadering. In het MOTA framework zijn beslissingen tot aanpassing afhankelijk van (1) de motivatie van actoren voor een specifieke beslissing, en (2) het vermogen of de capaciteit van actoren om de beslissing te implementeren. Beide factoren worden mede bepaald door fysieke en/of sociaal-economische omstandigheden en ontwikkelingen of triggers.

Deze tweede aanpak bestaat uit twee onderdelen: (i) het conceptuele model dat voortvloeit uit het combineren van het conceptuele MOTA kader met gestructureerde scenario's en (ii) de toepassing van het resulterende conceptuele model om aanpassing aan levensonderhoud te verkennen, en – vanuit het perspectief van een beleidsmaker - adaptieve beleidstrajecten te ontwikkelen die rekening houden met die mogelijke aanpassingen. Hiervoor wordt de casus van rijst en geïntegreerde boeren in polder 30 gecombineerd met een beleid gericht op 'Beperking van de drainage en verbetering van het levensonderhoud' van BDP 2100. De case studie laat zien dat het mogelijk is om de belangrijkste factoren die leiden tot mogelijke aanpassingen van de livelihood in MOTA termen te structureren, en daaruit adaptatiepaden voor CLA onder alternatieve scenario's af te leiden. We concluderen dat ook deze benadering kan worden gebruikt om CLA onder onzekerheid te onderzoeken en daarmee beleidsmakers te ondersteunen bij adaptieve planning en implementatie.

Er is tevens een pilot-computerversie van het MOTA-model ontwikkeld om te verkennen hoe op kwantitatieve wijze de voorkeuren voor aanpassingsopties kunnen worden afgeleid op basis van geschatte waarden van motivatie en capaciteit beïn-vloedende factoren in specifieke scenario's. Gegevens uit de case van rijst- en garnalenkwekers in polder 31 zijn gebruikt om in specifieke scenario's resultaten te genereren voor vijf aanpassingsacties van de rijst- en de garnalenkwekersgemeenschap. Het model evalueert de mogelijke aanpassingsopties als voorkeursoptie, mogelijke optie, en niet-gewenst. De resultaten komen op hoofdlijnen overeen met de voorkeuren voor aanpassingen onder scenario's zoals uitgedrukt door dezelfde boerengemeenschap, en lijken ook op hun historische aanpassingsbeslissingen.

Over het algemeen zijn beide benaderingen in principe geschikt voor verkenning van aanpassingsopties onder uiteenlopende omstandigheden. Er zijn echter belangrijke verschillen, bijvoorbeeld in de wijze van verzamelen van gegevens; het gebruik van open of gestructureerde scenario's; het opstellen van de beslis-singslogica; en de manier waarop de aanpassingsreacties worden geordend. Deze verschillen hebben invloed op de praktische bruikbaarheid, afhankelijk van de specifieke context. In praktische termen van tijd en moeite lijkt de eerste benade-ring geschikter om te gebruiken voor één specifiek beslissingsdomein van een actorgemeenschap en de tweede benadering is geschikter voor alle beslissingsdomeinen van een actorgemeenschap.

Toepassingen zijn tot nu toe beperkt tot de cases van drie boerengemeenschappen in twee polders, maar de algemene kenmerken geven het vertrouwen dat de benaderingen ook toepasbaar zijn op andere boerengemeenschappen, in verschillende sociaal-ecologische systemen of met andere middelen van bestaan.

Samenvattend kunnen beide in dit onderzoek ontwikkelde benaderingen adaptieve planning en implementatie ondersteunen door systematisch CLA als onzekerheid te onderzoeken. De kwantificering in een computermodel kan de beleidsmaker verder helpen bij het visualiseren en integreren van CLA verkenningen ter ondersteuning van adaptieve planning en beleidsimplementatie. Net als andere actor-modelleringsbenaderingen, zijn deze benaderingen gebaseerd op een sterke vereenvoudiging van complexe sociaal-economische processen en moeten daarom onder voorbehoud worden toegepast.

De benaderingen kunnen de beleidsmaker ondersteunen doordat zij een beeld verschaffen van hoe de aanpassing van het levensonderhoud van een lokale gemeenschap eruit kan zien onder verschillende omstandigheden; hoe verschillende factoren hun aanpassingsrichting beïnvloeden; en hoe beleidsstrategieën invloed kunnen hebben op gemeenschappen in dit dynamische proces. Daarmee kunnen beleidsbepalers en beleidsonderzoekers de mogelijke aanpassingsreacties van een lokale gemeenschap onderzoeken voordat het beleid daadwerkelijk wordt geïmplementeerd.

Als we reflecteren op het onderzoek en de resultaten, zien wij een aantal beperkingen die elk leiden tot een indicatie van verder werk. Zo is bijvoorbeeld het aantal casestudies beperkt en daarom wordt toepassing op een groter aantal gemeenschappen met verschillende kenmerken aanbevolen om de benaderingen verder te testen. Ook moeten variaties in de combinatie van methoden binnen de benaderingen verder worden onderzocht en is meer werk nodig om het rekenmodel te verbeteren. Naast het werken aan deze verschillende beperkingen van de modellering en analyse tot nu toe, worden ook uitbreidingen voorgesteld voor toekomstig werk. Deze omvatten uitbreiding van het huidige statische model tot een dynamisch model, en koppeling van een computermodel van CLA met fysieke systeemmodellen, inclusief de interactie van CLA met adaptief beleid in een kwantitatief modelleringskader.

Hoewel verschillende delen van de ontwikkelde benaderingen kunnen en dienen te worden verbeterd en verfijnd, wordt ook praktische toepassing in dit stadium ten zeerste aanbevolen. Ten eerste omdat het beter is om bij benadering aandacht te schenken aan CLA als onzekerheid dan dat helemaal niet te doen. Ten tweede omdat participerend onderzoek naar toekomstige ontwikkelingen en mogelijke gemeenschapsaanpassingen in interactie met mogelijk beleid een leeromgeving creëert voor zowel beleidsmakers als lokale belanghebbenden en het wederzijdse begrip bij het ontwerp van het beleid verbetert.

Het systematische en bredere gebruik van deze benaderingen vereist echter een adaptief perspectief van beleidsmakers, beleidsonderzoekers en alle relevante actoren. De acceptatie van een strategisch plan zoals het BDP 2100 betekent nog niet dat adaptieve en systeembenaderingen in het governance systeem van een ontwikkelingsland als Bangladesh doorgedrongen en geïmplementeerd zijn. Dit heeft tijd nodig, misschien tien, twintig jaar of meer. Investering in capaciteitsopbouw van huidige en toekomstige besluitvormers is daarom essentieel.

Chapter 1

Introduction to Community Livelihood Adaptation as Uncertainty

1

Introduction to Community Livelihood Adaptation as Uncertainty

1.1 Community livelihood adaptation: an uncertainty not to be neglected in long-term delta planning

Delta communities worldwide are facing a multitude of challenges in their life and livelihood (Haasnoot, 2013; Van der Keur et al., 2008). 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 may be seriously affected by uncertain changes in climate and socio-economy (van der Voorn et al., 2017).

Adaptive Delta Management (ADM) is an approach specifically focused on dealing with deep uncertainties in delta planning and management. The core principle in this respect is to acknowledge uncertainties instead of ignoring them, to think in terms of many possible future scenarios, prepare options for future policy adaptation, and to continuously monitor actual developments to implement adaptations when necessary (Lempert, 2003; Walker et al., 2013; Walker et al., 2001). Bangladesh is one of the countries moving towards adaptive delta management in its Bangladesh Delta Plan 2100 (BDP 2100). The focus of the BDP 2100 is on robust and adaptive investment for socio-economic development under uncertain future conditions (GED, 2018a).

Following the traditional approach to developing context scenarios (Van der Heijden, 1996), also used in IPCC climate scenarios (Nakicenovic et al., 2000), BDP 2100 scenarios are developed around two uncertain external drivers: (i) future water conditions based on trans-boundary developments and climate change and (ii) economic development including land use changes. The scenario narratives define possible, plausible long-term development directions of the key attributes of the natural system and of socioeconomic conditions including livelihood and agriculture (GED, 2015). The BDP 2100 strategic planning approach combines a wide stakeholder engagement with utilization of available data sources in formulation of policy strategies. These policies are however based on fixed – not deeply uncertain - assumptions about the way the local communities will respond to the policy measures. The effectiveness of such a strategic planning approach may be seriously affected if the response of local communities during plan implementation at the regional or local context is different or unexpected.

The historical examples of commercial shrimp farming and tidal river management in southwest coastal Bangladesh since 1960s illustrate that community livelihood adaptation response to contemporary polder management strategy can indeed be different from what policy makers expected, and that this has influenced the effectiveness of polder management strategy (Dewan et al., 2015; Gain et al., 2017b; Nowreen et al., 2014). Ignoring this kind of uncertainty may even result in policy failure in the same manner as failure because of ignoring uncertain climate and socio-economic change. When community livelihood adaptation under uncertain changing conditions 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 actors, particularly farmers in the primary production sector, make adaptation decisions under uncertain changing conditions; and how the adaptation decision of actors may interact with the policy strategies. For that, there is a clear need for a systematic approach that can (i) capture the nature of the adaptation decision of relevant actors under future uncertain changing conditions and (ii) support adaptive planning and implementation in taking that uncertainty into account in delta management.

The research presented in this thesis has taken up the challenge to design and test such approaches.

The general context of the research is outlined above. The remainder of this introduction further discusses the uncertainties in planning and policy and the rise of adaptive delta management in Section 2.1. The research objective and questions are presented in Section 1.3. Then, in Section 1.4 the community livelihood adaptation as uncertainty for adaptive delta management is conceptualized. A first exploration of the state of the art of theories and methods is presented in Section 1.5; the research approach and case selection are outlined in Section 1.6 and finally the chapter concludes with the outline of the thesis in Section 1.7.

1.2 Uncertainty in planning and policy: the rise of ADM

1.2.1 The concept of uncertainty

The modern history of uncertainty begins around 1921, when Knight made a distinction between risk and uncertainty (Knight, 1921). According to Knight, risk denotes the calculable and thus controllable part of all that is unknowable. The remainder is the incalculable and uncontrollable uncertainty [1](Knight, 1921). Different authors adopted these labels to distinguish between decision making under risk and decision making under uncertainty (Luce and Raiffa, 1958). Decision making under uncertainty refers to both (i) the uncertain future state of the world and (ii) uncertainties resulting from strategic behaviour of actors involved in decision making (Quade and Carter, 1989).

The term *uncertainty* may also be defined simply as limited knowledge about future, past, or current events (Marchau et al., 2019; Walker et al., 2013). Uncertainty is a situation of inadequate information, which can be of three sorts: inexactness, unreliability, and border with ignorance (Walker et al., 2003). Uncertainty is also referred to as “any deviation from the unachievable ideal of completely deterministic knowledge of the relevant system” (Walker et al., 2003).

[1] Uncertainty is a broader concept than risk; risks are a low level of uncertainty that can be quantified by using losses and probabilities (Marchau et al., 2019).

Deep uncertainty is defined as "The condition in which analysts do not know or the parties to a decision cannot agree upon (1) the appropriate models to describe interactions among a system's variables, (2) the probability distribution to represent uncertainty about the key parameters in the models, and/or (3) how to value the desirability of alternative outcomes" (Lempert, 2003; Marchau et al., 2019). This uncertainty also arises from actions taken over time in response to unpredictably evolving situations (Haasnoot, 2013). Uncertainty literature recognizes that much uncertainty is rooted in human behaviour, socio-economic and cultural dynamics, social processes etc. and that these uncertainties are equally critical and can have significant impact on the outcomes of decision making (Brugnach et al., 2008; Haasnoot et al., 2013; Jensen and Wu, 2016). In decision making, uncertainty may also stem from subjectivity or ambiguity about intentions as well as knowledge coloured by underlying values, and the perspectives of various actors involved. Often implicit assumptions are made about these, but such assumptions can be a trap if left unexplored (Marchau et al., 2019).

In long-term decision making (as for example in flood risk management, in delta management), deep uncertainty is a reality even under the most favourable circumstances (due to unpredictable budget constraints, conflicting stakes, political turmoil etc.). While it may seem easy to ignore this deep uncertainty, such a choice may lead to failure. In this perspective, novel ways and methods to deal with deep uncertainty have been under development in recent years as illustrated by the overview given in (Marchau et al., 2019). One such approach is adaptive policy making, which has found application in, among other things, delta planning and management.

1.2.2 The rise of Adaptive Delta Management

To deal with deep uncertainty stemming from rapid socio-economic development and climate change, delta planners are in recent years embarking on Adaptive Delta Management (ADM). ADM is rooted in Adaptive Policy Making (APM) (Walker et al., 2001). This adaptive paradigm accepts that the future is 'intrinsically unknowable' and policy decisions have to be made in the context of this deep uncertainty (van der Pas et al., 2013; Werners et al., 2013).

There is an emerging consensus that planning decisions therefore should be flexible; they must be adaptable over time and avoid premature lock-in (Haasnoot, 2013; Lempert et al., 2013;Walker et al., 2013). In the Netherlands, the concept of Adaptive Delta Management (ADM) has been adopted as an approach to identify both the most promising short-term decisions and the decision space that should be kept open for the future (Haasnoot, 2013). The development of adaptive plans for regions such as New York City (Rosenzweig et al., 2011; Yohe&Leichenko, 2010), and the Thames Estuary (Reeder & Ranger, 2009) has adopted similar approaches. Practice in the Dutch Delta Programme so far showed that the ADM approach for incorporating uncertainty into policy strategy development can be pragmatic and accepted by decision makers and offers enough room for tailoring (Marchau et al., 2019; Zevenbergen et al., 2018).

Along similar lines, the Bangladesh Delta Plan 2100 (BDP 2100) is devised to achieve robust socio-economic development and provide safety in the face of disasters in (Zevenbergen et al., 2018). The focus of BDP 2100 is on robust investment for socio-economic development under uncertain future conditions (GED, 2018a). As of ADM principles, the vision, goals, scenarios, strategies and adaptive pathways are set accordingly. In the plan, the country is subdivided into six hotspots or representative planning units. The plan includes an investment plan and an implementation framework (GED, 2018a).

1.2.3 The ADM project and research context

This PhD research is part of the NWO funded ‘Urbanizing Delta of the World’ research project ‘Adaptive Delta Management (ADM): development, acculturation, and dissemination in Bangladesh and Indonesia’. In 2014, the project was undertaken by a consortium of multidisciplinary researchers from Delft University of Technology, University of Twente, Utrecht University, Bangladesh University of Engineering and Technology, Bandung Institute of Technology, CEGIS, PUSAIR, Deltares, PAO Delft and World Water Academy Nieuwegein. The overall project objective is *‘to translate and disseminate ADM concepts for supporting participatory planning for sustainable delta development under uncertain changing conditions to the context of developing countries, addressing current societal needs such as food security and pro-poor development’* (Thissen et al., 2013).

Of the several approaches that have been advanced for developing policies under uncertainties over last decades, the project's approach follows the fundamental concepts of well-known Adaptive Policy Making (Walker et al., 2001) and subsequent development of concepts in Dynamic Adaptive Policy (Kwakkel, 2010), Adaptation Tipping Points and Adaptation Pathways (Haasnoot, 2013; Kwadijk et al., 2010), and Dynamic Adaptive Policy Pathways (Haasnoot et al., 2013).

The project aims to develop a model-based integrated methodology for bio-physical system and socio-economic system analysis for Adaptive Delta Management where the modeling approach is embedded in a participatory process. For Bangladesh, two key components are distinguished in the project: bio-physical and socio-economic system modeling. This PhD research is focused on the socio-economic system modeling; with an outlook for integration with bio-physical system modeling and simulation platforms.

One key gap in meeting the project objective of supporting participatory planning for sustainable delta development is to deal with uncertainties arising from complex and dynamic interactions in the local social-ecological system. Here, sustained livelihood of the local community for secured income and food is an indispensable component of delta development. And the community livelihood adaptation represents the complex and dynamic interaction in their local system. Therefore, there is a need for an approach to explore community livelihood adaptation as uncertainty in adaptive delta management, which can possibly be integrated with the bio-physical system modeling approaches.

1.3 Research Objective and Questions

The research objective is to develop an approach to support adaptive delta planning and implementation by systematic exploration of community livelihood adaptation as uncertainty. To address the research objective the key research question is

What is a good approach to systematically explore community livelihood adaptation under a range of (uncertain) conditions, to support adaptive delta management?

To answer the main question, the following more specific research questions are formulated and discussed in detail:

1. *To what extent does CLA have historical importance as uncertainty for (Adaptive) Delta Management?*

   This first question concerns verification of the importance of community livelihood adaptation as uncertainty in the context of delta planning and management.

2. *What theories, methods, frameworks are applicable to explore CLA as uncertainty?*

   This question concerns the theoretical and conceptual aspects. Literature review is on the state of the art of theories, methods, frameworks and approaches for application in the design and testing of an approach to explore community livelihood adaptation as uncertainty.

3. *How can an approach to explore CLA under uncertainty be designed and tested?*

   Building on the result of the preceding question, this question addresses the practical and empirical aspects of designing and testing of an approach. Given the context of the research project on ADM, the approach, preferably, needs to be model-based.

4. *How can this approach be incorporated in Adaptive Delta Management (ADM)?*

   This question focuses on the contribution of this research in supporting adaptive delta planning and implementation in practice.

1.4 Analyzing CLA as uncertainty for ADM: requirements, concepts and methods

The long-term success of the policy implementation requires a focus on long-term adaptive processes of relevant actors (Shiferaw et al., 2009; Thompson, 2009). Therefore, it is necessary 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). With the word 'policymaker' we refer to the government actors in strategic policymaking and local implementation in general. Here, we provide a brief account of requirements, theories, models and methods that will be further extended in Chapters 3 and 4 for application to meet our specific purposes.

1.4.1 Requirements for the approach

In addition to the model-based 'requirement', the approach to be designed requires meeting certain functionalities and ensuring deliverables for the use of policymakers. In the context of the user at the data-scarce local condition, the mix of methods should enhance the quality of local policy decisions under future uncertainty. Therefore, for systematic exploration of community livelihood adaptation as uncertainty in ADM, the approach should include (i) a model of actors' livelihood adaptation decisions and (ii) application of the model to identify the possible livelihood adaptations in response to a policy strategy at various situations over time.

To be practically useful, the approach should be evaluated based on the following criteria:

(i) Functionality in terms of deliverables for which it is intended, i.e., does it indeed offer insight in the possible adaptation options of local communities, and does it help in developing an adaptive policy?

(ii) Credibility, i.e., is it based on the best available knowledge for representation of the CLA?

(iii) Transparency and communicability of the approach development process for relevant actors and policy makers

(iv) Time and effort required

(v) Generalizability, i.e., applicability to a variety of situations and actor types

(vi) Potential for linking up to a computational modeling framework for systematic future uncertainty exploration.

1.4.2 The concept of community livelihood adaptation

Community Livelihood Adaptation (CLA) in this research refers to the process of livelihood adaptation of a group of actors i.e. farmers. The concept of CLA can be seen as the adjustment in livelihoods to mitigate harm or to exploit benefits from changing conditions by groups of households (or individuals) that share material and non-material resources based on their differentiated abilities (Dewan et al., 2015; DfID, 1999; Field, 2012; Parry et al., 2007; Scoones, 2009). Therefore, CLA is a complex and dynamic process that takes place in a local social-ecological system[2] (Elsawah et al., 2015). With the word 'community' in this research, we acknowledge diversity or heterogeneity in a group of actors (Dewan et al., 2014).

The livelihood in its simplest sense is the means of gaining a living; the livelihood refers the (adequate) stock and flows of resources i.e. cash, food etc. to meet the basic needs (Chambers and Conway, 1992). A livelihood comprises the assets, activities and access to those natural, physical, human, social and financial resources that together determine the living gained by the individual or household (Allison and Ellis, 2001). Livelihoods differ in their environmental, social and institutional settings and vary in terms of resource base, production relations and marketing (PDO-ICZM 2002). The decision domain is often used to specify the livelihood domain, for example agricultural, non-farm, labor, migration etc. (Hebinck and Lent, 2007). 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).

1.4.3 The complexity of community livelihood adaptation

The community livelihood adaptation can be uncertain as we will see in the historical examples of commercial shrimp farming and tidal river management above. Assuming a specific response of local communities to a policy may lead to failure of the policy; hence there is a need for policymakers to have insight in the determinants of community response. We assume that the local community

[2]A social-ecological system can be referred as a coherent system of biophysical and social factors that regularly interact in a resilient and sustained manner (Holling and Gunderson, 2002)

responses to a policy strategy are a multi-actor, multi-scale and dynamic process and a model of this process can play a role informing policy making and actors' communication (Elsawah et al., 2015) as discussed below.

Multi-actor: The farmers, policymakers, market actors and other social actors have their own goals, interests, preferences and perceptions that differ across and also within the actor groups; therefore they employ different strategies and take different decisions (Elsawah et al., 2015). A broad set of processes and factors such as learning, experience, social environment, characteristics of policy strategy or new technology determine the perception of an actor community on their situation and options for change (Thompson, 2009). The heterogeneity makes an agreement on policy strategies more difficult to reach for a policymaker and uncertainties may arise in such a situation (An, 2012; Barreteau et al., 2001).

Multi-scale: The collective outcome of decisions made by actors at multiple levels of the system (individual, group, organizational) can strongly drive the complex and dynamic nature of the local social-ecological system (Elsawah et al., 2015). On the other hand, the (livelihood adaptation) decision of actors is shaped by a multitude of forces and factors in their system that are themselves constantly shifting (DfID, 1999; Scoones, 2009). This multi-scale process may make a promising strategy (perceived by policymaker) unacceptable (perceived by the actors) at certain situation.

Dynamic and constantly adaptive: The CLA occurs in a complex social-ecological system with a shift in the goals and decision of actors over situation and time. Actors adapt to changes by learning from experience (Sterman, 2010). Such a dynamic system is able to adapt to and evolve with a changing environment (Chan, 2001; Holland, 1992). Moreover, the actors decision making balance immediate intuition (gut feeling) with a logical rationale (Sadler-Smith and Shefy, 2004). Therefore the actors may perceive the same policy strategy as acceptable or unacceptable depending on changes in the situation over time.

Role of models: There is wide recognition of the role a model or decision support tool can play in informing policy making and actors' communication. However, models are often criticized for their limited capacity to address the sheer complexity and variety of dimensions of actors' decision making in a complex system

(Döll et al., 2013). Sometimes the complexity of human response is reduced to a simple input scenario or a single parameter or simplistic rational assumption on human cognition and behavior (Pahl-Wostl, 2007). A good model however needs to capture and represent the decision rules and guiding protocols that generate a flow of actors' decisions under various situations (Forrester, 1992).

A model-based approach that can capture and represent this complex and dynamic process can therefore be of critical importancefor informing policymaking.

1.4.4 What modeling methods for CLA might be useful?

In recent years, the application of social science and behavioral science theory and concepts to understand the actor's behavior in complex social-ecological system has gained momentum (Enserink et al., 2010; Fogg, 2009; Hermans and Cunningham, 2013; Hermans and Thissen, 2009; Nguyen et al., 2019a; Phi et al., 2015; Rothschild, 1999). The decision modeling methods are broadly based on descriptive decision making theories and/or rational decision making theories. The sustainable livelihood framework (DfID, 1999) is the most commonly used one in recent developments.

Sustainable Livelihood Framework

In the Sustainable Livelihood Framework (SLF) of the Department for International Development (DfID, 1999) livelihoods are analyzed in terms of five capitals (natural, physical, social, human, financial), and of institutional processes and strategies that comprise of activities for living (DfID, 1999; Scoones, 1998). The vulnerability context (trend, shocks, seasonality) frames the external environment in which people are living. A livelihood is considered 'sustainable' when it can cope with and recover from stresses and shocks, maintain or enhance its capabilities and assets, while not undermining the natural resource base (Chambers and Conway, 1992). In recent years, awareness has grown of the need for more fundamental transformations in livelihood pathways into the future (Scoones, 2009) and insights in how to guide such livelihood transformations, as wider-scale, system- level changes for sustainability (Nguyen et al., 2019a; Scoones, 2016). Researchers however stressed the importance to recognize the subjective personal drivers in livelihood change also (Bebbington, 1999). In their study, Nguyen et al. (2019a) urge to consider farmers' motivation explicitly in livelihood adoption and how that interacts with given or perceived conditions, available resources and capabilities for sustainability. In line with the foregoing, we conclude that our focus, indeed, should not be on the aggregated level of the DfID framework, but on the individual farmers who, as part of their community, are the decision making units in our case.

Descriptive decision modeling methods

Descriptive decision modeling methods based on descriptive decision theories are one way of modeling decision making of actors. Descriptive theories explain how decisions are actually made (Elsawah et al., 2015). Some commonly used modeling methods include: cognitive mapping to represent mental models (Axelrod, 2015; Eden, 2004; Elsawah et al., 2015); descriptive models of cropping/livelihood decision making (Gonzales-Intal and Valera, 1990; Lampayan et al., 1994; Siddika, 2019); descriptive models for sustainable livelihood security (Mutahara et al., 2016).

Mental models represent descriptive theories; and describe how people make a decision based on how they perceive their surrounding world. Cognitive mapping to represent mental models has been commonly used in structuring decision problems (Axelrod, 2015; Eden, 2004;Elsawah et al., 2015). Eden's cognitive mapping approach (Eden and Ackerman, 1998) grounded on Kelly's Personal Construct Theory (PCT) (Kelly, 1955) is the one which is used for describing viticulture farmers decision making by Elsawah et al. (2015). The method is used for eliciting, representing and analyzing the stakeholder knowledge specifically in the case of decision making of Viticulture farmers in their specific complex social-ecological systems.

Actor based modeling methods

Several actor based models and frameworks based on assumptions of subjective rationality have been developed and tested empirically (Hermans and Cunningham, 2013; Hermans and Thissen, 2009). The actor based methods range from a focus on

- Reconstructing individual argumentations (as in cognitive mapping);
- Analysis of actor positions with respect to specific issues; these generally

identify actor perceptions regarding a situation, actor interests, actor resources or power, and actor dependencies,

- Methods for actor-network analysis;
- Methods focusing on actor interactions such as those based on social theory (Coleman), game theories, or, more recently, agent-based modeling.

Rational action theories of individual actors and the concept of interdependence of actions, which exists when actions of individuals impose changes in the macro-level structure confronting other individuals, are often used to explain system behavior (Coleman, 1994). A family of Rational Action Theories exists and is commonly used to explain the action of individuals (Becker, 2013; Boudon, 1994; Coleman, 1994; Goldthorpe, 1998; Hausman, 1992; Lindenberg and Frey, 1993; Popper, 2013; Simon, 1982). Authors argue that these theories constitute the appropriate theory of action in all circumstances that entail economizing (Timmermans, 2004). Many authors use the subjective rationality based on the actor's own definition of the situation (Boudon, 1994; Lindenberg and Frey, 1993).

Some relatively simple descriptive models and frameworks rooted in rational action theories are the Opportunity and Ability (MOA) conceptual framework (Rothschild, 1999), Fogg's Behavioral Model (Fogg, 2009) and the Motivation and Ability (MOTA) conceptual framework (Phi et al., 2015). The MOTA framework explains the choice of an action as the causal consequence of trigger, motivation and ability; where the outcome is the result of the chosen action (Phi et al., 2015). The practical utility of the MOTA framework in identifying the differentiated motivation and ability of various actors (including farmers) for a set of alternative planning options has been demonstrated in recent applications (Arora, 2018; Korbee et al., 2019; Nguyen et al., 2019a; Nguyen et al., 2019b; Phi et al., 2015). The framework has originally been developed and applied to assess actor-oriented implementation maturity (Nguyen et al., 2019b; Phi et al., 2015) and farmers adoptability (Nguyen et al., 2019a), but has not yet been applied in the wider field.

In concluding, the descriptive decision modeling methods specifically cognitive mapping and simpler frameworks such as the MOTA framework are interesting and could contribute to our purpose. However from the literature, it is not possible to identify a priori favorite.

1.4.5 What methods to capture uncertainties and their implications for policy?

The use of scenarios is the most common method to encapsulate uncertainty (Maier et al., 2016) in adaptive delta management (Haasnoot, 2013). 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(Börjeson et al., 2006; Maier et al., 2016;Rotmans et al., 2000). One scenario classification makes a distinction between predictive, explorative and normative scenarios (Börjeson et al., 2006; Maier et al., 2016). For our purpose, the explorative scenario seems promising. Explorative scenarios can be seen as 'forward-looking' and 'problem-focused' to identify possible future conditions of interest (Maier et al., 2016; Parker et al., 2015). Explorative scenarios can be either external or strategic . The external scenarios are focusing on factors and developments that are out of control of the policy or decision maker. 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 while the development process of *unframed* scenarios is completely open (Maier et al., 2016).

For linking uncertainty identification and analysis to policy development, the concepts from two adaptive planning approaches: the adaptive policymaking approach (Kwakkel et al., 2010; Walker et al., 2001) and the adaptation pathway approach (Haasnoot, 2013) can be considered useful for application. In adaptive policymaking, a basic plan is developed which is to be adapted to new information over time with a contingency planning (Kwakkel et al., 2010) and the adaptation pathway provides a concretization and visualization of the conditions and sequence of adaptation actions over time (Haasnoot, 2013). The adaptation pathway concept and method have many useful applications that include the BDP 2100 (Ahmed et al., 2017; GED, 2018a;Haasnoot, 2013).

We choose to adopt the forward-looking explorative scenarios approach to capture the main uncertainties. Both the unframed and framed scenario development processes are interesting and could contribute. Following the starting points of the UDW project of which this research is part, we also adopt the adaptive policymaking approach and the adaptation pathway concept.

1.4.6 Choice of methods for the new approach

The choices of methods for designing a new approach to serve our purpose are guided by the requirements and logics that are presented in the previous sub-sections. Given the possible variety, and lack of convincing a priori evidence for a single best fit to our purpose, we chose to explore more than one combination of approaches. Practical limitations led us to explore two approaches, each combining a different combination of conceptual model, scenario development approach, and use of adaptation pathways.

First approach

The application of cognitive mapping in the case of viticulture farming has shown it's suitability as conceptual model. Because of the open nature of cognitive mapping, it seems more logical to combine it with the completely open unframed scenario development approach. For visual presentation of possible livelihood adaptations the use of adaptation pathway is promising. These methods will be further elaborated, modified (if required) and used in our first step towards developing an approach, and will be further described in Chapter 3.

Second approach

The recent application of MOTA framework specifically to explore farmers adoptability have established it's potential to serve as conceptual model for our purpose, and it seems logical to integrate it with the framed scenario development approach. These methods will be reviewed, modified (if required) and used in the development and test of our second approach, and will be further described in chapter 4.

1.5 Research approach

The overall research approach has been explorative and can be best characterized as a journey of discovery based on interdisciplinary concepts. Our research approach consists of three key phases as illustrated in Figure 1.2:1) conceptualization of CLA and examining its historical importance 2) testing different versions of an approach in case studies and illustrating this with policies 3) cross-case and cross approach evaluation and discussion of the results. As a consequence, the research questions 2, 3 and 4 have not been addressed consecutively, but iteratively, each case study adding new material on each of these questions.

The case studies are in a series at the learning by doing style. The *first approach* development is grounded on the application of an unframed scenario approach, cognitive mapping, and adaptation pathways; the approach is tested in an empirical case study of rice farmer communities (actors); and is illustrated with a policy from BDP 2100. After our experience with the first approach, we developed the *second approach* based on the Motivation and Ability (MOTA) framework, a framed scenario approach and adaptation pathways; the second approach is tested with the cases of a rice farmer and an integrated farmer community and illustrated with a policy implementation from BDP 2100. The second approach is further developed to demonstrate the potential of computational modeling and tested in cases of rice and shrimp farmer communities. Each of these two approaches has its own conceptual, empirical and modeling methods. The results from cases are used to analyze and reflect on the value of the approaches.

1.6 Case study area

For case study selection, the key criteria are (i) any of the hotspots of BDP 2100 and (ii) existence of a history of community livelihood adaptation with concurrent delta management under changing climate and socio-economic conditions (iii) accessibility and willingness of the community to participate. Based on these criteria, we selected the southwest coastal region under the 'Coastal Zone' hotspot in BDP 2100 as our case study area. The policy strategies for this coastal zone under BDP 2100 are used to illustrate the possible livelihood adaptation pathways resulting from our analyses.

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). Figure 1.1 shows the study area: Polder 30 and 31 in southwest region of Bangladesh.

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., 2016a), this research 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 1960s (Nowreen et al., 2014).

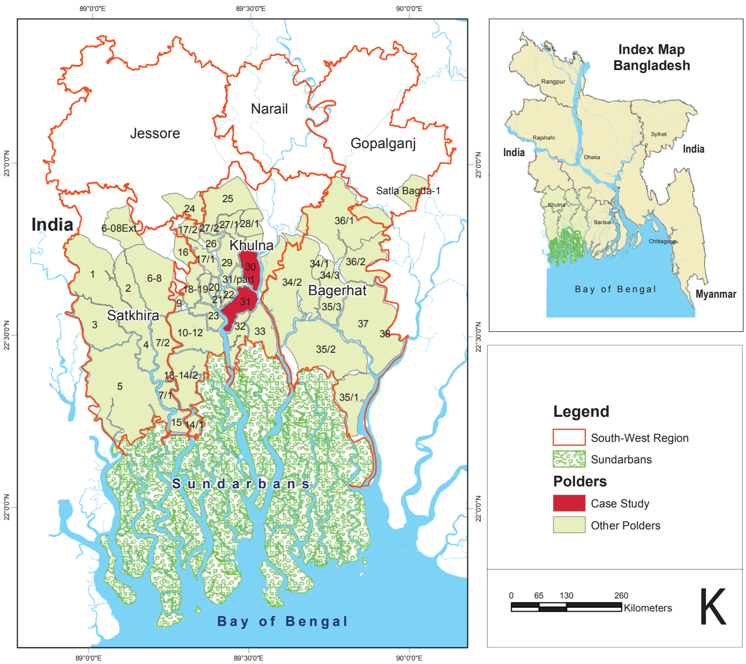

Figure 1.1 The study area: polder 30 and 31 in southwest region of Bangladesh

Participant farmer communities are from two such polders namely: Polder 30 and 31 in *Batiaghata* and *Dacope* Upazila of *Khulna* district. We visited these two polders and organized participatory data collection/validation sessions in April/October of 2016 and February/May of 2018. The detail description of Polder 30 is in Chapter 4 and Polder 31 is in Chapter 5.

1.7 Thesis Outline

This thesis is structured into seven chapters as shown in figure 1.2. Two chapters (2 and 3) consist of copies of two papers one of which has been published, while another one is accepted with major revision for the scientific peer reviewed journal. As a result, there is some overlap in the content between these chapters (papers) and the rest of the thesis.

Chapter 2 reviews and confirms the historical importance of community livelihood adaptation as uncertainty for (adaptive) delta management. The first cognitive map-based unframed scenario approach is presented and tested in the case of rice farmers at Polder 30 and 31, then illustrated for a policy strategy of BDP 2100 in Chapter 3. A second approach, based on combination of a MOTA conceptual model and a framed scenario approach is presented and tested for the case of rice and integrated farmers community in Polder 30, then illustrated for a policy strategy of BDP 2100 in Chapter 4. Based on the experience of the second conceptual model, Chapter 5 demonstrates a computational extension of the second approach for the case of a rice and shrimp farmers' community in Polder 31. The cross approach analysis and overall evaluation are presented in Chapter 6. Final conclusions, reflections, and an outlook for further research are presented in Chapter 7.

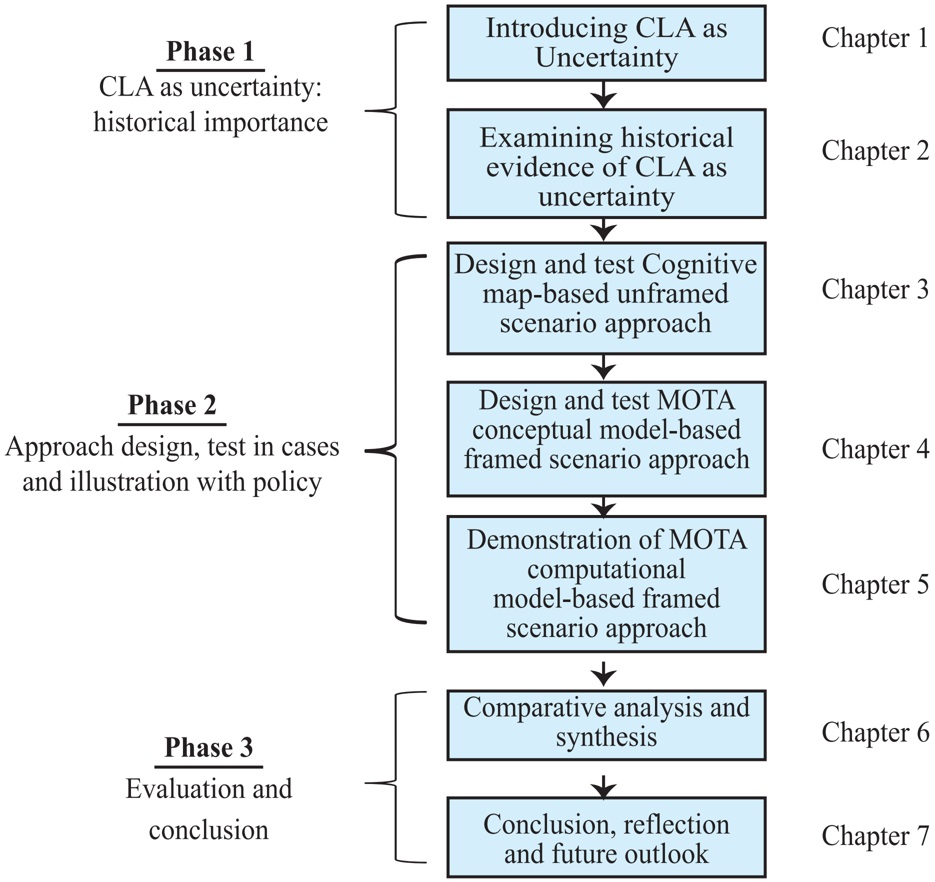

Figure 1.2 Research approach and thesis outline

Chapter 2

The Importance of Community Livelihood Adaptation as uncertainty for (Adaptive) Delta Management:

A Case Study in Polders of Southwest Bangladesh

This chapter has been accepted with revision in the Journal of Environmental Science and Policy as

Kulsum U.,Timmermans J., Haasnoot M., Khan M.S.A., Thissen W. (accepted with revision). The importance of community livelihood adaptation as uncertainty for (adaptive) delta management: A case study in polders of southwest Bangladesh. Journal of Environmental Science and Policy (dynamic deltas issue)

Photo courtesy: Author (2016)

Abstract

To deal with large uncertainties about future climate and socio-economic developments, planners in deltas are adopting an integrative and adaptive planning approach referred to as Adaptive Delta Management (ADM). Bangladesh has used the ADM approach for the development of its adaptive plan; Bangladesh Delta Plan 2100 (BDP 2100). The success of policy strategies in an adaptive delta plan critically depends on a specific adaptation of livelihoods of local communities (Community Livelihood Adaptation; CLA), especially in an agriculture-oriented society like Bangladesh. For example, while triple rice cropping might be evaluated as a robust strategy in all futures considered, its success eventually depends on whether farmers' will actually make that choice, which is deeply uncertain. In this paper, we use literature review, insights from interviews and field observations to examine how the uncertainty in CLA impacts (adaptive) delta management. We study two historical cases of livelihood adaptation of farmer communities confronted with salinization and waterlogging in the polders of southwest Bangladesh since the 1960s. We conclude that historically the uncertainty about CLA in polders has been ignored in the development of policy plans, leading to the failure of anticipated policy outcomes. We recommend planners in Bangladesh and other deltas worldwide to take account of CLA as uncertainty when developing long-term adaptive plans.

Key words: Uncertainty; Community Livelihood Adaptation (CLA); Polders; Adaptive Delta Management (ADM); Bangladesh.

Highlights:

- Community Livelihood Adaptation (CLA) can have significant impacts on (adaptive) delta management;
- The land use change from rice to shrimp farming, as an unanticipated livelihood pathway in response to salinization, has changed the polder functionality;
- Tidal River Management (TRM) has emerged as an adaptation to waterlogging for enabling livelihood and triggered by the social (un)acceptance of traditional water control-based approaches;
- Delta planners should pay more attention to CLA, and take uncertainties resulting from CLA into account for robust and adaptive investments.

2

The importance of community livelihood adaptation as uncertainty for (adaptive) delta management:

A case study in polders of southwest Bangladesh

2.1 Introduction

Large uncertainties about the future arising from rapid socio-economic developments and climate change have triggered planners in deltas to use an integrative and adaptive planning approach to prepare and adapt depending on how the future unfolds. In the Netherlands this approach is referred as Adaptive Delta Management (ADM) (Seijger et al., 2016; Zevenbergen et al., 2018) and has since then being exported to other deltas. Scientifically, the ADM approach is built upon both adaptive planning approaches including adaptive policy making (Walker et al., 2001), robust decision making (Lempert, 2003), and adaptation pathways (Haasnoot et al., 2012), as well as integrated water resources planning management (GWP, 2000; Loucks and van Beek, 2017). Core principles of ADM include a) exploring relevant uncertainties; b) connecting short-term targets to long-term goals over time; c) committing to short-term actions while keeping options open; d) monitoring continuously and take action if necessary; and e) linking delta management with ambitions in other policy fields such as the economy, natural environment and spatial development (Bloemen et al., 2019; Delta Programme, 2012).

In ADM, uncertainty refers to "any deviation from the unachievable ideal of completely deterministic knowledge of the relevant system" (Walker et al., 2003). It can be defined simply as limited knowledge about future, past or current events; a situation of inadequate information due to inexactness, unreliability, and the border with ignorance (Walker et al., 2013). Elements of ADM have been used in various deltas including the Thames Estuary (Reeder and Ranger, 2011), the Dutch Rhine Delta (Bloemen et al., 2019; Van Alphen, 2016), Mekong Delta (Marchand and Ludwig, 2014; Tran et al., 2019) lower Ganges Delta (GED, 2018a) etc.

Bangladesh is a country at the lower Ganges-Brahmaputra delta and has adopted ADM as a principle for long-term planning in the Bangladesh Delta Plan 2100 (BDP 2100). The main focus of the BDP 2100 is on robust and adaptive investment for socio-economic development under uncertain future conditions (GED, 2018a). The vision of BDP 2100 is to “Achieving a safe, climate-resilient and prosperous delta” through the implementation of preferred strategies. To assess to what extent these preferred strategies contribute to meeting the vision and goals for the Bangladesh delta in different plausible futures, scenarios are developed. Following the ‘scenario-axes’ technique (Van der Heijden, 1996), an approach that has been used for IPCC climate scenarios (Nakicenovic et al., 2000) and the Dutch delta scenarios (Bruggeman et al., 2011), the BDP 2100 has developed four explorative external scenarios[3] (GED, 2015). The two key uncertain external drivers considered as the two axes are: (i) future water conditions based on trans-boundary developments and climate change and (ii) economic development including land-use changes. Each scenario narrative defines a possible, plausible long-term development direction of key attributes of the natural system and of socioeconomic conditions including land use changes (GED, 2015; Seijger et al., 2017).

BDP 2100 scenarios are an instrument to stimulate thinking through possible futures and to develop ‘robust’ policy strategies (i.e. that perform reasonably well across a wide range of scenarios (Lempert, 2003). They should therefore include the major uncertainties affecting policy outcomes. Despite that the livelihood adaptation of a local community may be a key to the success and thus the robustness of the policy strategy for an agriculture-oriented society like Bangladesh, it is not considered as an uncertainty in the current scenarios.

Community Livelihood Adaptation (CLA) is defined as the adjustment in livelihood activities to mitigate 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 (Dewan et al., 2015; DfID, 1999; Field, 2012; Parry et al., 2007; Scoones, 2009). Livelihood adaptation represents decisions within a set of options open to a group of actors that include coping but

[3] Then two policy options were identified: ‘Business as Usual (BAU) Policy option’ describing the concerned efforts and long term socio-economic outcomes in the event of the projected natural hazards and climate change risks without the adoption of BDP 2100; ‘Delta Plan Policy option’ describing the same with the adoption of BDP 2100 (GED, 2018a)

also generate and sustain collective longer-term adaptation (Osbahr et al., 2010). This complex and dynamic process takes place in the local social-ecological system (Elsawah et al., 2015).

CLA in agriculture is commonly studied as 'response' to changing natural and socio-economic conditions. Various deterministic approaches have been used in attempts to predict or anticipate CLA, for instance: enterprise budgeting (Kabir et al., 2016), bivariate probit analysis (Rahman, 2008), and logit models (Uddin et al., 2014). Other authors highlight the importance of an uncertainty perspective in analyzing CLA for sustainable long-term development (McNamara and Buggy, 2017; Scoones, 2009). Uncertainty literature recognizes that much uncertainty is rooted in human behavior and decision making in interaction with social processes such as CLA (Brugnach et al., 2008; Haasnoot et al., 2013;Jensen and Wu, 2016).

Although CLA is a relevant uncertainty for long-term delta management, to our knowledge this has not been considered in the design of adaptive plan. Current adaptive plans have used scenarios describing the external context and explored adaptation strategies and pathways from a social-planner's perspective; i.e. a governmental actor that would assess a strategy for maximum social welfare. For a country like Bangladesh, this social-planners perspective would be challenging, as many actions are not controlled top-down, but also occur bottom-up at community level. For example while triple rice cropping might be evaluated as a robust strategy in all futures considered, its success eventually depends on whether farmers will actually make that choice, which is deeply uncertain.

In this paper, we examine how and to what extent the uncertainty in CLA can have an impact on the success of long-term delta planning and management. After an initial literature review, we focus our analysis on two cases of historical CLA in polders[4] in southwest Ganges delta in Bangladesh that were constructed in the 1960s and managed in response to salinization and waterlogging. In case study 1, we analyze how CLA developed as a response to salt intrusion. In case study 2, we explore how CLA driven by waterlogging evolved into Tidal River Management (TRM). We conclude by drawing lessons about the relevance of uncertainties in CLA and by formulating recommendations for delta planners based on our findings in these two cases.

[4] A polder is a low-lying tract of land that forms an artificial hydrological entity reclaimed from sea or river and enclosed by embankments known as dikes

2.2 Research material and methods for data collection

To examine 'CLA as uncertainty' for (adaptive) delta management we focus on whether and to what extent the CLA preferences manifested in livelihood choices and social responses are different from what is assumed or expected in the concurrent governing national policy plan.

In an initial literature review, we identified several cases of CLA, such as the adoption of High Yielding Variety (HYV) crops (rice, wheat etc.), agricultural technologies, and integrated rice-shrimp farming approaches. For a better understanding of how CLA could influence the success of an adaptive plan, our detail literature review focused on the identification of cases of CLA that were different from what was assumed or expected in the original plan. We identified four polders in the southwest of Bangladesh (Figure 1) that were confronted with different water-related problems as a result of changing environmental conditions. Case study 1 explores developments in polder 30 and polder 31 that experienced salinization, and case study 2 studies polder 24 and 25 that were confronted with waterlogging. Both cases were identified based on their dynamic and unique history that fits the aim of this research.

We use a multi-method research approach adapted from Participatory Rural Appraisal (PRA) (Chambers, 1994). As a basis, available empirical research on agricultural livelihood and polder management in Bangladesh around southwest region in general and specifically the selected polders were identified and studied (Table 2.1). In addition, the relevant policy documents such as BDP 2100 and Guideline for Participatory Water Management (GED, 2018a; MoWR, 2001) were studied. To capture the perception of relevant stakeholders the participatory research and literature are important in this study.

In Case 1, the literature study was combined with Focus Group Discussion (FGD), individual interviews and field observation to appendage the perception of local stakeholders on the recent story of CLA. In Case 2, we relied on the literature study because the perception of local stakeholders on the evolution of TRM since the late 1980s is well documented using a variety of participatory approaches in the recent scientific literature (as shown in table 2.1).

Table 2. 1: List of key empirical and participatory literature reviewed.

No.	Relevant aspect for our research	Methodology used	Reference
Delta management in Bangladesh and southwest Bangladesh			
1	Water governance trends	Policy review, FGD with water user group, experts consultation	Gain et al., 2017b
2	Shifts in water governance	interviews with policymakers, researchers, consumers, and NGOs	Chan et al., 2016
3	Shift towards IWRM	Policy review, experts interview	Rouillard et al., 2014
4	Shift in polder management and livelihood adaptation	Literature review	Nowreen et al., 2014
5	Shift in community engagement with polder management	Literature review, KII	Dewan et al., 2015
6	ATP in delta management and community engagement	Literature review	Kulsum et al., 2017a
Case 1: Livelihood adaptation in agriculture: Polder 30 and 31			
7	Shrimp culture VS crop diversification in polder 31	Literature review, Village census, KII	Kabir et al., 2016
8	Community water management and cropping system synchronization in polder 30	Farmer interview (37)	Mondal et al., 2015
9	Factors affecting farmers adaptation in Sathkhira	Survey (100 farmers)	Uddin et al., 2014
10	Situation analysis polder 31	FGD/ KII	Bakuluzzaman, 2012
11	Rice versus shrimp in polder 31	Farmer interview (120)	Fatema et al., 2011
12	Rice to shrimp in southwest	60 sample plots data	Ali, 2006
Case 2: Tidal River Management :Polder 24 and 25			
13	Social learning in TRM	RWMA[5] methods: FGD, Stakeholder meeting Institutional survey, interviews	Mutahara, 2018
14	TRM: shift in polder management	Literature review	van Staveren et al., 2017
15	TRM as Transdisciplinary approach	qualitative case study, workshops, site visit, and literature review	Gain et al., 2017a
16	Local stakeholder perception on TRM	Literature review and Individual interview	Karim and Mondal, 2017
17	TRM in the frame of stakeholders	participatory maps, interviews, document review	de Die, 2013

Two FGDs and four interviews with farmers at *Pankhali* village in polder 30 and at *Gongarampur* village in polder 31 were conducted during 2016. To get key information and selection of farmers in the study area, two NGOs who have been working for a long time in these polders were contacted as local key informants. The criteria for respondent selection were farmers (rice/fish) with a minimum age of 30 who are residing in the locality for a long time; a variety in land ownership (large/small/medium); and gender (male/female). In FGDs, a set of open questions was used to allow participants to articulate their story about livelihood

[5] Rapid Water Management Appraisal

decisions, relevant factors, and polder management retrospectively. Selected farmers were organized into two sessions (10 farmers per session) in two polders. Three researchers, each with a specified role of facilitation, note-taking and recording, have facilitated the FGD sessions. During the session, the objectives of the session were explained. After the FGD sessions, two farmers (one man and one woman) were selected for an in-depth interview based on their long history of living. During field visits the current land use, livelihood patterns, embankments, canals, rivers etc. were observed to capture the current situation of CLA.

To identify the reflection of experts from key planning and implementing agencies on ‘the importance of CLA as uncertainty’ we observed stakeholder consultation and research sharing sessions from the BDP 2100 study with the involvement of the General Economic Division (GED), Bangladesh Water Development Board (BWDB), the Water Resources Planning Organization (WARPO) and Bangladesh University of Engineering and Technology (BUET) during 2016-2017.

To keep the focus on ‘CLA as uncertainty’ the narratives of cases explain the empirical findings with an implicit consideration of the elements of power, scale of politics, institutions, social discriminations (rich/poor) or social movement.

2.3 Results

2.3.1 General characteristics and developments in the study areas

The region in which the two case study areas are located is downstream in the dynamic delta of the western Ganges in southwest Bangladesh as shown in figure 2.1. The region covers around 16135 km^2, is home to around 10.4 million people (BBS, 2011b) and includes the Sundarbans, the world’s largest continuous mangrove (Kabir et al., 2016). The relatively flat, fertile plains are part of a tidal river system of streams and water-filled depressions locally called beels (Nowreen et al., 2014). In this ecologically and economically important zone, agriculture remains the main livelihood. Other livelihoods include fisheries, shrimp farming, forestry, and day labor (Hossain et al., 2016a).

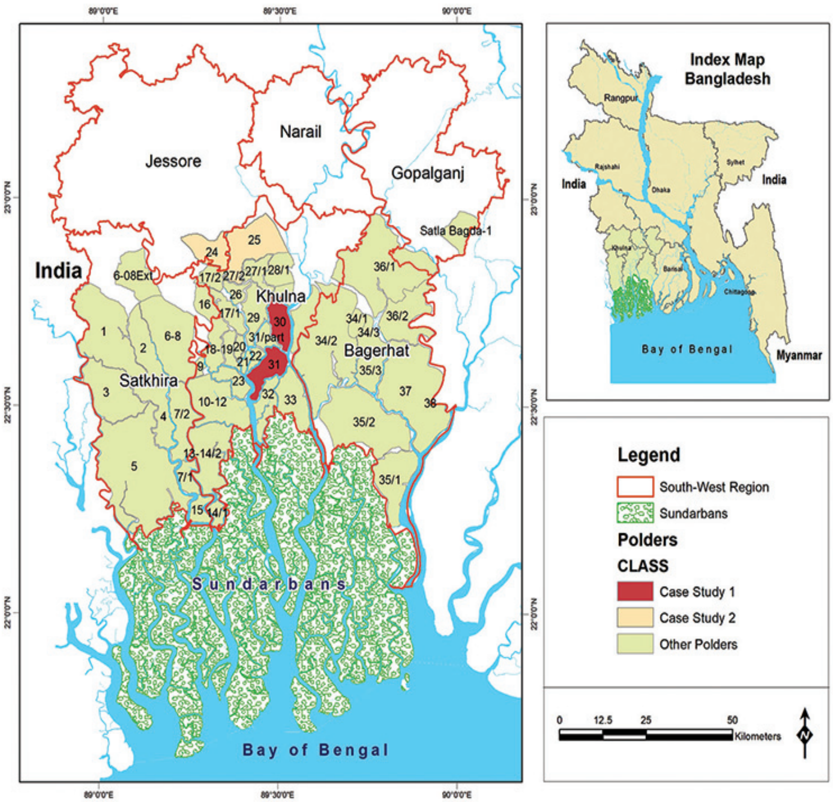

Figure 2.1: The study area showing Case 1 (Polder 30 and 31) and Case 2 (Polder 24 and 25)

Since 1960, this region has seen five distinguished transitions in the water/land management regime (Figure 2.2). Before the year 1990, the region was dominated by water and flood control (Gain et al., 2017b), with a parallel evolution from no community participation at all (the 1960s) to pro-poor community participation (1980s). Afterward, in line with the countrywide, and even global developmentsin flood risk management, an integrated and formal participative approach was adopted since 1990 (Dewan et al., 2015). Since 2000, the integrated water resource management approach has developed towards long-term Delta planning with since the 2010s the formation of the Bangladesh Delta Plan 2100. Figure 2.2 (based on literature in table 2.1) illustrates the historical timeline of transitions and shifts in delta management including the key objectives, system concerns, and driving factors.

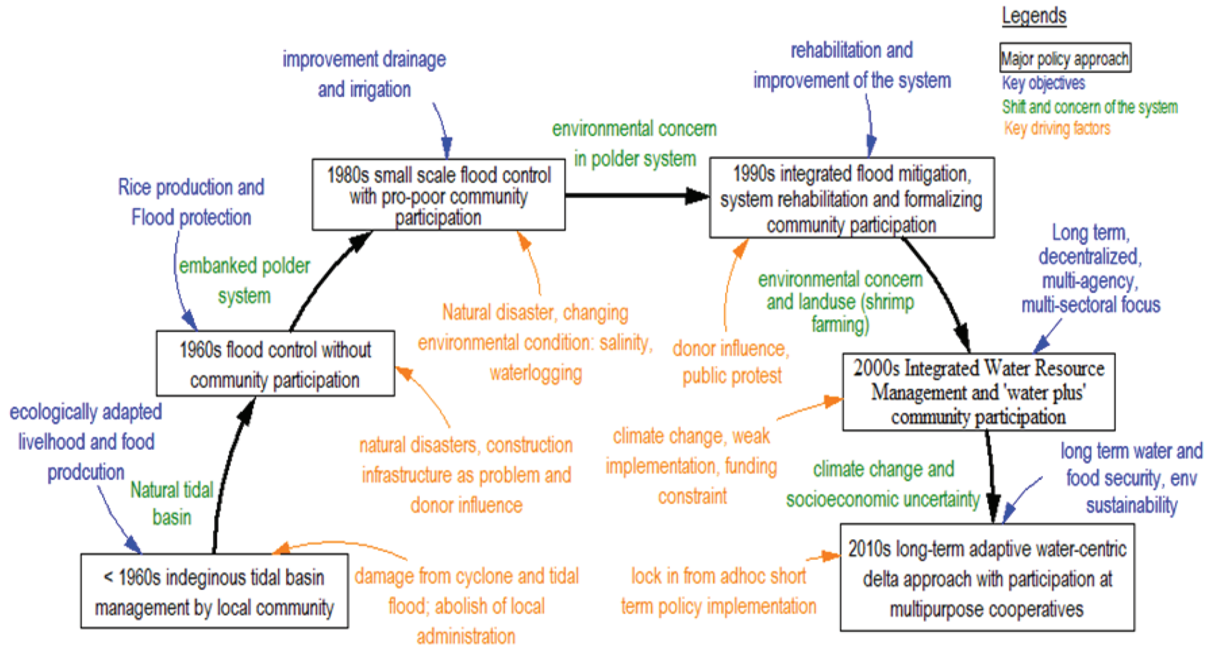

Figure 2.2: *Historical timeline of transitions and shifts in delta management (based on literature in table 2.1). The six major policy approaches are shown in the boxes. The key objectives are in blue color; Major shift and concern of the system are in green color and key driving factors are in orange color.*

Between 1960 and 1975 the natural tidal system of this region was transformed into a ‘Polder’ enclosure system with 139 polders (GED, 2018b; Kibria et al., 2015). Along with this development, the socio-cultural context of the local community in agricultural livelihood has transformed from an ecologically adapted temporary closure system to a permanent closure system (Nowreen et al., 2014). In the period from the 1960s to the 2010s, Environmental challenges, land-use change, climate change, and socioeconomic developments increasingly became the key system concerns in policy-making (Gain et al., 2017b). Damages from natural disasters such as floods, cyclones, tidal surges, and other changing environmental conditions were important driving factors (Ahmed et al., 2015). Socio-political drivers included donor influence, the abolishment of local administration, weak or late implementation of planned projects, funding constraints, social un-acceptance and public protest (Ahmed et al., 2015; Dewan et al., 2015). Global discourses such as the green revolution, participatory water management, climate change etc. have also played a key role in these transitions (Dewan et al., 2015). Single focused, short-term policy objectives have shifted toward multi-sector, multi-agency and long-term sustainability in recent years (Gain et al., 2017b; Nowreen et al., 2014).

Currently, being at high risk of climate change and sea-level rise, the region faces increasing challenges and substantial threats of cyclonic storm surges, salinity intrusion and waterlogging to the lives and livelihoods of the local community (GED, 2018b; Hossain et al., 2016a). A total of 19 severe cyclones (wind speed 118 km/h) including recent cyclone *Sidr* in November 2007 and *Ailain* May 2009 have hit the coast of Bangladesh during 1960-2009 (Kibria et al., 2015). An increase of salinity in the *Rupsa* River at Khulna is observed from 0.7 ppt to 16.8 ppt from 1962 to 2011 while saline groundwater can be found up to 100 km inland (GED, 2018b). The salt-affected area between 1973 and 2009 has been increased by about 26.7% with different degrees of salinity. Many polders are suffering from riverbed sedimentation, subsidence (inside the polder), and drainage congestion and waterlogging for quite a long period. The world’s highest annual sediment load (at least one billion tons per year) shaped and reshaped the delta through river sedimentation and erosion (Gain et al., 2017a). The land subsidence rate in the coast is high may be up to 6 mm/year (GED, 2018a). Relative sea-level change[6] along the coast shows an increase of annual mean water level in the southwest coast (*Hiron point*), *Meghna* estuary (*Khepupara*) and Chittagong coast (*Rangadia*) by 6.8mm, 3.7mm and 4mm per year, respectively (GED, 2018a). All these challenges have influenced the transitions in the south-west region polders we studied.

2.3.2 Case study 1: Adaptation of Agricultural Livelihoods in Polder 30 and 31

The polders included in case study 1 were constructed during 1967-72 and illustrate the national transitions in policy approach during 1960s to 2015. They are located in two adjacent Upazilas of the Khulna district. Figure 2.3 presents the major features of the Polder 30 and 31.

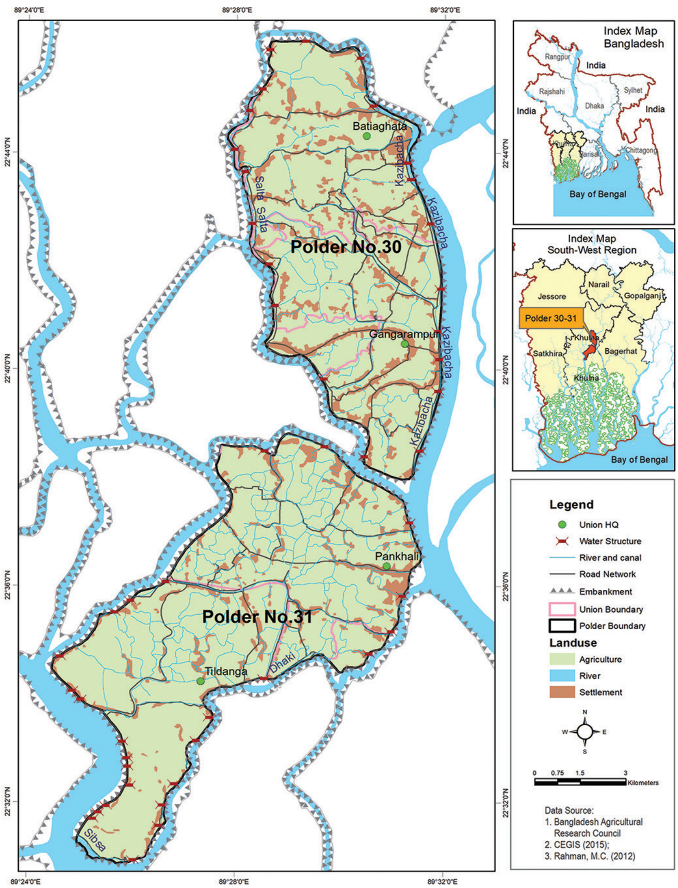

Figure 2.3: Major features of the Polder 30 and 31

[6] The local change in sea level relative to the elevation of the land at a specific point on the coast

The Polder 30 is located in *Batiaghata*, *Gangarampur*, and *Surkhali* Unions of *Batiaghata* Upazila. An embankment of ~40 km length protects an area of 6,455ha, with 66% Net Cultivable Area (NCA), 29% settlements, 4% water bodies (*Khal*) and 1% roads (CEGIS, 2015). About 9,490 households have a total population of 38,240 of which 18,940 are male and 19,300 are female (BBS, 2011a). About 38% of the total population is in the main working force of the age group 30 to 49 years (BBS, 2011). About 83% of the population is engaged in the agricultural sector (BBS, 2011a). It is surrounded by the peripheral rivers (*Sholmari, Salta, Jhopjhopia and KaziBacha*) (CEGIS, 2015).

The Polder 31 is located downward in *Tildanga* and *Pankhali* union of *Dacope* Upazila. A 47-km long embankment protects an area of 7529 ha (WARPO, 2018). About 7830 households have a total population of 32,576. About 27.5 % of the total population is in the main working force of the age group 30 to 49 years. About 57% of the population is engaged in the agricultural sector (BBS, 2011a). It is surrounded by four rivers; *Monga, Badurgacha, Dhaki,* and *Shibsha* (Bakuluzzaman, 2012).

2.3.2.1 Environmental conditions: compound context including salinization

The dynamics of the environmental conditions and polder management approaches summarized in figure 2.4 have shaped livelihood adaptation in the case study polders from the 1960s onward. During this period, in the fully embanked polder system, the environmental conditions have shifted towards more salinization into water and land; reduction of freshwater flow; an increase of upward saline water intrusion; drainage congestion and sedimentation in the tidal river system (Kabir et al., 2016).

The anthropogenic causes for reduced freshwater flow, increasing river-bed sediment deposition and drainage congestion include the absence of routine maintenance dredging, lack of maintenance of coastal polders, intensification of shrimp culture, upstream water withdrawal at the Farakka barrage and larger irrigation projects (i.e G-K Project) (Gain et al., 2017a). The natural delta processes' contributions include the amplification of tidal influence combined with major cyclones (Nowreen et al., 2014), the eastward migration of the

Ganges (Hore et al., 2013), climate change-induced sea-level rise higher than global average (Hinkel et al., 2014), increased temperature and changes in rainfall patterns.

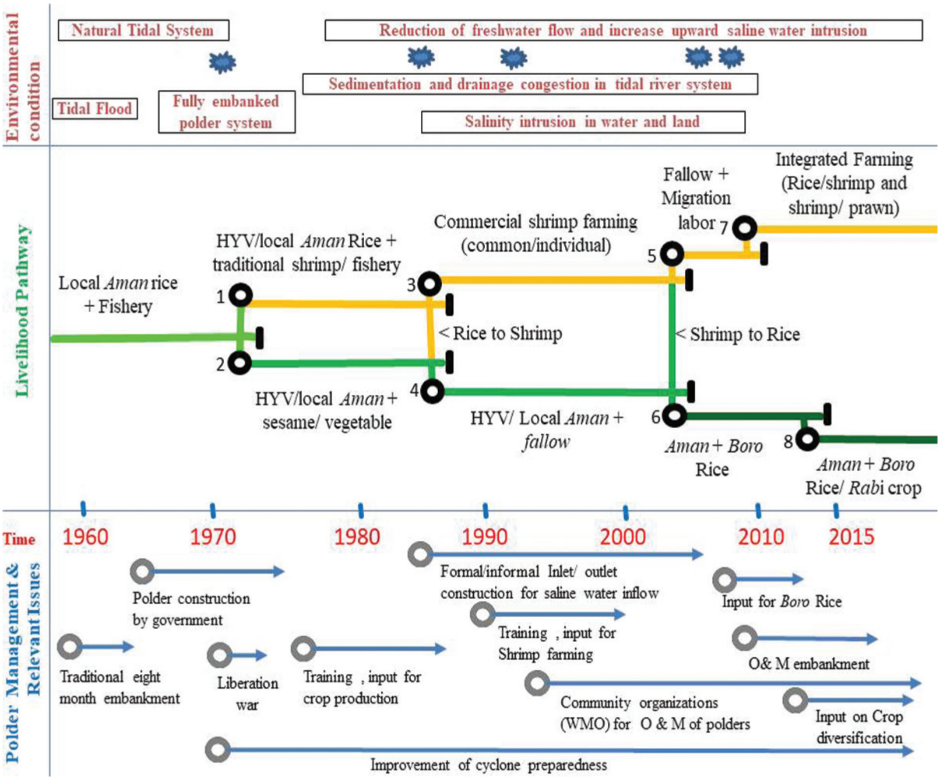

Figure 2.4: Livelihood pathways of local farmers' community (middle low), with an indication of relevant environmental conditions (top row), and polder management and other relevant issues (bottom row), The green line shows the rice cultivation pathway and the yellow line shows the shrimp farming pathway. and number represents the transfer of livelihood, represents the terminal of livelihood, represents the timing of issues. represents major cyclones. HYV denotes High Yielding Varieties.

2.3.2.2 General developments in polder management

A number of general developments in polder management strategies that are not specific for our case study area took place (Dewan et al., 2015; Gain et al., 2017b; Zevenbergen et al., 2018). In most cases, shifts in polder management approaches were connected to international developments in water management like integrated or adaptive management brought to Bangladesh in collaboration with the international donor organizations and consultants (Dewan et al., 2015; Zevenbergen et al., 2018). Polder management focused on operation and maintenance of embankments; construction and repairing of water control infrastructures (sluice gates, inlets/outlets); and drainage rehabilitation. The formation and promotion of water management organizations (WMO) for operation and maintenance were salient. In the same period of 1960 to 2015, agricultural livelihood development towards HYV rice cultivation, shrimp farming, and crop diversification were supported by training, inputs (i.e seeds, pesticides, fertilizers etc.) and irrigation (equipment, technology etc.). The cyclone preparedness of the coastal community has improved with the building of more than 2000 cyclone shelters and an extensive network of radio communication (GED, 2018b).

2.3.2.3 Community Livelihood Adaptation in polders 30 and 31

As illustrated in Figure 2.4, two distinct pathways can be observed in the historical adaptation of the agricultural livelihood in polder 30 and 31: the rice cultivation pathway and the shrimp farming pathway. As these two pathways have developed in parallel, we present them in parallel at two transfers around a similar time period. Major agricultural livelihood adaptations are simplified into eight transfers and represented with black-colored transfer stations. These will now be discussed in greater detail.

Transfer 1 and 2: Choice between HYV Aman and local Aman and new opportunities for dry season cropping and traditional shrimp farming

The period from pre-1960 to 1970s started with the local *Aman* rice cropping and fishing with the traditional eight-month embankment system. In this system, local people constructed seasonal embankments to grow one crop (usually rice) during the dry season and allowed the floodplains to be under tidal influence the remainder of the year (de Die, 2013; Nowreen et al., 2014). After consecutive flood damages, the then government initiated the permanent polder enclosure system in the Coastal Embankment Project (CEP). The objective of CEP that coincided with the green revolution was to increase rice production. The key strategies focused on increasing the production area with coastal land protection and increasing the production per area with an extension of HYV. Indeed, the farmers were able to grow more crops in the newly protected or developed land along with the adoption of High Yielding Variety (HYV) of *Aman* rice (van Staveren et al., 2017).

Elder farmers shared their memories in retrospect, for example: “We used to produce local *Aman* rice in monsoon with an eight-month temporary embankment and were engaged in the fishery for rest of the year” *Nikunjo Bihari Sarkar*, a 70 years old farmer explained. The respondents described that the key challenges in the pre-polder period were dealing with the daily tidal inundation, and tidal flooding. Previous studies describe similar findings (Nowreen et al., 2014; van Staveren et al., 2017). The respondents defined the period of 1967 to 1972 as the period of transformation into a polder enclosure system in a new-born country. After this transformation, they started to perceive their life and livelihood as safe and protected from saline tidal inundation and storm surge.

In the polder system, the farmers adopted as second crop mainly sesame and vegetables in the dry season along with *Aman* rice in the newly developed land inside the polders. The availability of training, seeds and input support from the agricultural government departments influenced the adoption of HYV *Aman* variety. In the focus group session, farmers mentioned that many of them, however, continued growing the local *Aman* rice variety because of preferred taste and lower input requirements in terms of cost and effort. Traditional shrimp cultivation with fishery was insignificant till the 1970s.

Generally, community adaptation was in line with the objectives of government plans in terms of *Aman* rice cultivation in newly developed land. However, the adoption of HYV by local farmers was low compared to the expectation of the agricultural department. Socio-cultural and behavioral factors influenced this lower adoption of HYV.

Transfer 3 and 4: Livelihood Dilemma between commercial shrimp and rice cultivation

From the late 1970s, the respondents observed that the irrigation water became more saline in the dry season, causing lower yield. In the same period, some larger farmers (mostly influential landlords) have introduced commercial brackish-water shrimp farming in the case study polders. Between 1975 and 2000, the country's shrimp production area increased from less than 20,000 ha to 141,000 ha (Ali, 2006), mostly in the southwest region. The key driving factors for shrimp farming identified by the respondents were the high international market demand, favorable land, availability of saline water and wild post-larvae; these findings are similar to previous studies (Fatema et al., 2011; Kabir et al., 2016). Small pieces of land surrounded by shrimp *ghers*[7] were perceived unsuitable for rice by the landowners, or rice productivity was lowered unacceptably due to increased salinity and attack of rats, pests etc. Many farmers were therefore compelled to do brackish water shrimp cultivation either by themselves or by leasing with a lump sum rental. Under the influence of the shrimp farmers, the management of the polder embankmentshifted from protecting saline water to allowing saline water (Fatema et al., 2011; Nowreen et al., 2014). As a result, social tensions developed between the shrimp farmers and the rice farmers.

The shrimp farming appeared to be nine times more profitable than rice (Ali, 2006). Mostly larger absentee farmers who owned shrimp farms have seen remarkable profits during the first five years till the early 1990s. Through continuous campaigns, the poor smallholder farmers gained operating rights for shrimp and rice-fish farming in common *gher* systems (Kabir et al., 2016). Then, individual *gher* systems became popular during the late 1990s. During this period, the shrimp farmers received training from Government and development agencies. To react on the tension between the practical situation of shrimp farming and the formal design of infrastructure (to prevent saline water inflow), the government

[7] Gher- is the trench or trough inside the earthen enclosure of land to increase water depth for shrimp farming.

projects supported the infrastructural facilities such as construction and repairing of inlet/outlet/sluice gates (for inflow of saline river water into the polder) under the third and fourth fisheries project (Bakuluzzaman, 2012). Water Management Organizations (WMOs) were established by the Bangladesh Water Development Board (BWDB) for the maintenance and operation of water structures. The respondents informed that the shrimp farmers captured the operation of polder structures for inflow and drainage of saline water in that period. Within a short period, however, the long-term environmental impacts of shrimp farming became visible, such as salinity intrusion, low crop production, loss of biodiversity etc.

However, around the 1980s, many farmers in a community or village collectively decided against adopting shrimp farming. Respondents informed that the unavailability of well-suited arable lands for shrimp culture, awareness of the adverse environmental consequences and availability of good quality rice cropping land interior of the polders were the main drivers for rice cultivation, also observed by Kabir et al. (2016).

In many cases, the farmers decided for shrimp farming in the land near the embankment for income, and rice farming in the interior land with irrigation facilities for family food consumption see, e.g. Ali (2006). The wet season rice production increased steadily mainly due to the adoption of HYV *Aman* variety. Depending on land type very few lands were used for vegetables cropping in the dry season.

The overall conclusion is that the local CLA (initiated by larger farmers) to commercial shrimp farming was unanticipated when the decision was made for the closed polder system. The social power dynamics within the local community influenced the polder management in favor of shrimp farming, which changed the polder functionality. Then, government projects, e.g., the creation of inlets, have provisioned for shrimp farming. Overall, many different factors have determined the choice of local farmers between shrimp and rice.

Transfer 5 and 6: Constrained choice between migration labor with fallow land and reviving rice cultivation.

Due to a decline in both crop and shrimp productivity, many landholders turned into rice–deficit and food-insecure households with high debts by 2005. Respondents informed that many of them were forced to switch to seasonal agricultural work in another area or to be a day laborer, rickshaw puller etc. in nearby cities.

After 2005, a large scale adoption of modern saline tolerant cultivars by local farmers occurred, specifically *Boro* rice cultivation during the dry season. Local farmers were motivated by the availability of seeds, training and technical knowledge of production management by the government agricultural extension department and NGOs. By 2008, the anti-shrimp social movement gained momentum. The virus infestation, NGO advocacy and prolonged impact of embankment breakage during cyclone *Aila* in May 2009 contributed to this momentum. After a verdict of the court, shrimp farming decreased immediately by the end of 2009 (Bakuluzzaman, 2012; Kabir et al., 2016). Most of the farmers left their land fallow for one or two seasons and were looking for a more planned farm management approach. A certain number of farmers returned to the rice cultivation pathway during this period. This was facilitated by increased freshwater reserves and the prevention of saline water intrusion for shrimp farming. The shrimp farming area in DacopeUpazila decreased from 13,395 ha in 2008 to 2464 ha in 2012 (Kabir et al., 2016).

Transfer 7 and 8: Shift towards integrated farming and less water intensive Rabi crops

Since 2010, the farmers have learned to integrate shrimp farming with rice/fish and vegetable cultivation supported with training by government and development agencies. These include changes in cultivation practice, operation practice, soil management and physical structure of the gher. Investing higher production costs and labor in HYV rice cultivation does not always ensure higher yield and profitable market prices. The production cost per hectare has increased around 6 fold from ~20,000 BDT in 2001 to ~123,000 BDT in 2010, while mean crop yield (kg/ha) has increased 3 fold from ~3600 (kg/ha) in 2000 to 10,600 (kg/ha) in

2010 (Hossain et al., 2016b). On the other hand, rice-fish cultivation in the wet season and shrimp farming in the dry season have become profitable. Mixed farming of all-season fish, brackish-water shrimp, and fresh-water prawn cultivation have also become popular in recent years.

In recent years, the farmers have faced an irrigation water shortage during *Boro* rice cultivation and saline water intrusion from broken sluices/inlets/outlets of the embankment. The unavailability of required irrigation water for HYV rice cultivation has decreased rice yields as well as increased the production cost. To address this irrigation shortage and gaining more income, the farmers started to cultivate less-irrigation intensive *Rabi* crops like sunflower, sesame, vegetables etc. Respondents explained that the farmers negotiate with each other when they make cropping decisions, taking irrigation water supply and the land elevation into account. For example, the farmers who irrigate from the same canal during the dry season are used to synchronize by choosing lowland (low irrigation demand) near the canal for rice and higher land far from the canal for Rabi crops (with low irrigation water). However, this negotiation depends on socio-political power relations also which develops a consensus of similar crops for effective pest control, input and harvest management. This way of synchronizing cropping decisions, watershed management, and pest control in the farmers' community was also observed in previous studies (Kulsum et al., 2017b; Mondal et al., 2015).

Case conclusion

Our overall conclusion from this case is that the farmers' adaptation in agricultural livelihood is not only motivated by their own objectives, but also by a number of factors exogenous to them. The polder construction along with the promotion of an HYV rice variety was the first government intervention that influenced farmers towards more production in newly developed land. Commercial shrimp farming introduced by larger farmers forced smallholder farmers to shrimp farming. Social power dynamics and the international market were dominant factors. As a result, the objective of polder construction in line with the green revolution has shifted towards a changed functionality with shrimp farming. Subsequently, a number of socio-economic and environmental factors contributed to integrated farming and the multi-cropping practices of farmers in recent years. The government interventions in this polder system had to shift as 'reactive adaptation' to support unexpected[8] CLAs, for example, shrimp farming, integrated farming, and multi-cropping system. In this way, the impacts of CLA, among others, are evident in the subsequent polder development interventions, for example, the construction of inlets for shrimp farming. Aligned with this case conclusion, the experts from key planning and implementing agencies reflect that the consideration of the heterogeneous need and perception of the local community in the planning and implementation is a challenge but obligatory for long-term sustainability (stakeholder consultation, 2016-17).

2.3.3 Case study 2: CLA strategy for waterlogging in Polder 24 and 25

Case study 2 concerns a vast tract of waterlogged areas around different polders mainly polder 24 and 25 as shown in figure 2.5. As the drainage capacity of the rivers decreased gradually, waterlogging[9] started to occur in many areas in the southwest delta particularly in Jessore, Khulna and Satkhira districts (de Die, 2013). This case will focus on how delta management and CLA have co-evolved to deal with waterlogging.

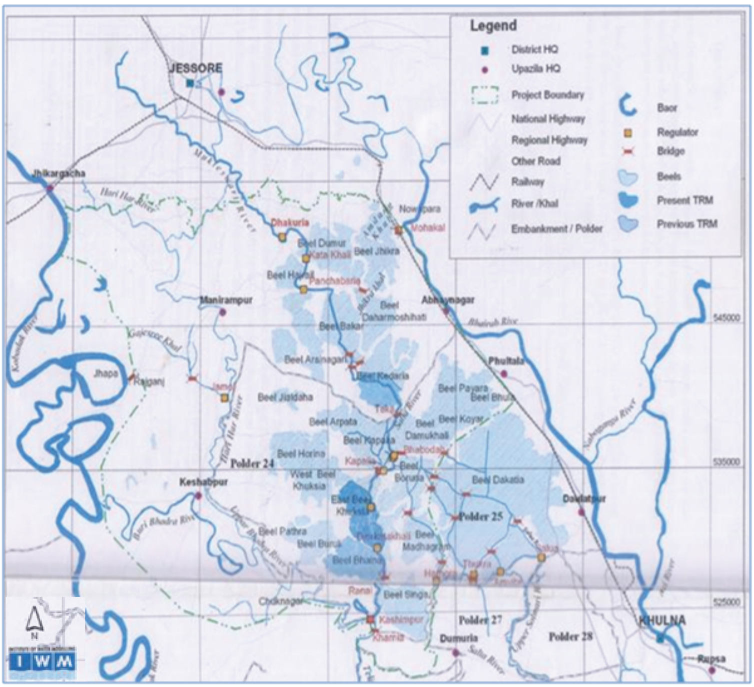

Figure 2.5: TRM areas around polder 24 and 25 under KJDRP project (de Die, 2013)

[8] Not assumed or expected in the single focused objective of grow more rice at the time of plan.
[9] The saturation of soil with water, impeding plant growth.

2.3.3.1 Environmental condition: waterlogging and drainage congestion

In 1984, part of polder 25, *Beel Dakatia* became waterlogged due to siltation for the first time about fifteen years after the construction of coastal embankment (Gain et al., 2017a). Then, the waterlogging spread to more polders and lands in *beels due* to drainage congestion in three major rivers, the *Hari-Mukteshwari*, *Bhadra* and *Kabodak* (van Staveren et al., 2017).By the 1990s, an area of more than 100,000 ha in Khulna, Jessore and Shatkhira districts became structurally waterlogged (Awal, 2014). No sedimentation in polders anymore. Moreover floodplains into the polders are subsiding. On the other hand, the sediments deposited in the riverbeds and sluices have halted the natural flow (with gravity) of water (rainwater in monsoon) from the floodplain inside the polder to the river permanently (de Die, 2013). Sedimentation in riverbed increased dramatically with a decreased tidal prism[10] due to polders, embankments led to the decrease of volume of tidal water stored in the floodplains thereby a decrease in river discharge and flow velocity also (de Die, 2013). Besides Coastal Embankment Project (CEP), the sedimentation process is accelerated with the reduced upstream freshwater flow due to the eastward movement of Ganges, climate change, construction of Farakka barrage, large irrigation project (G-K project) and so on (Gain et al., 2017a; Mutahara, 2018). It was classified as 'man-made disaster' and many people were forced to live on the embankment and migrate due to loss of livelihood, income and minimum living conditions (Nowreen et al., 2014). However, waterlogging was not a problem for all alike as impact varies among livelihood communities (for example rice and shrimp farmers), socio-political power groups and so on.

2.3.3.2 Polder Management and Community Livelihood Adaptation

To address waterlogging and improve drainage, the Asian Development Bank funded the Khulna- Jessore Drainage Rehabilitation (KJDRP) Project (1994 -2002). It was implemented by the Bangladesh Water Development Board (BWDB) (Gain et al., 2017a). The project aimed to improve drainage in 100,000 hectares that were worst affected by the drainage congestion in the southwest

[10] The volume of water exchanged through a coastal or transitional system typically measured between high tide and low tide.

delta, by improving infrastructure and community participation in water management. During the project period, 106 formal Water Management Groups (WMG), 9 Associations (WMA) and one overarching Water Management Federation (WMF) were established. The project covered approximately 25% of the CEP area with a population of 800,000 people (de Die, 2013).

The project emphasized structural engineering solutions, i.e. construction of large regulatory gates and dredging of rivers. However, from an early stage of the KJDRP project formulation in 1984, the local people around the periphery of Polder 24 and 25 protested against the traditional engineering solution and proposed indigenous tidal basin management instead (Dewan et al., 2015). Despite the presence of community participation mechanisms, however, the KJDRP has implemented the structural engineering solutions in contrast to the community proposed indigenous tidal basin management (Mutahara, 2018). In the following sections, we present the historical evolution of Tidal River Management (TRM) as community response and policy response in five *beels* from *beel Dakatia* to *beel Pakhimara*.

Community responses and adaptation in *Beel Dakatia*

The structural engineering solution of the KJDRP project faced strong public protest. The *'Beel Dakatia Andolon'* (a social movement to get rid of waterlogging problem) within polder 25 in 1989 protested the structural solution and made a 'public cut' in the embankment to remove water from *Beel Dakatia*. With this local initiative, the *beel* was again connected with the river Hamkura. Within two years, from 1990 to 1992, 1050 ha of land were made free from permanent waterlogging (Tutu, 2005). The success in draining water encouraged people from adjacent waterlogged areas to undertake similar actions. Later, the army deployed by the authorities has closed the cut point and stopped the practice in 1994.

Community responses and adaptation in *Beel Vaina*

The violent social protest continued, and a new public cut was made at *Bee lVaina* in 1997. The cut turned the 1000 hectare *Beel* into a tidal basin, allowed sediment deposition into the land, has increased the cross-section of the *Hari* river downstream till closing in 2001 (Mutahara, 2018). This proved that temporary tidal basins could seriously benefit rivers. At present, this public initiative to improve drainage has almost achieved the intended goal by raising around 600 ha of land by an average of about 1.0 m (Gain et al., 2017a).

The Asian Development Bank (ADB), Bangladesh Water Development Board (BWDB) and other agencies in the end acknowledged (around 1980-2000) that Tidal River Management (TRM), the process of temporary inundating floodplain in order to prevent drainage congestion, is a better strategy for mitigating waterlogging than engineering-based solutions (Gain et al., 2017a).

Implementation of TRM, a CLA strategy in *Beel Kedaria*

For the first time, the authority has undertaken Tidal River Management based on learning, donor influence and the conclusions of an Environmental Impact Assessment that proposed a 'rotating basin' approach in 1998 (Mutahara, 2018). One temporary tidal basin in *Beel Kedaria* was under tidal influence from 2002 to 2005 through opening the existing regulating gates instead of making a new cut in the embankment. TRM had to be suspended mainly for two reasons: (i) the outcome for sediment deposition on land, and drainage of the river was not as expected (ii) landowner's demanded compensation for crop loss but the authority did not pay (Mutahara et al., 2015).

Implementation of TRM, a CLA strategy in *Beel Khuksia*

The authority has cut embankment and opened *Beel Khuksia* at polder 24 in November 2006, one year later than planned because of local resistance. Farmers claimed payment in compensation for the loss of their crops and livelihood. The compensation 'by cash and free fishing' was complex for small and marginal farmers due to administrative issues. Originally, the closing was planned in 2010 but eventually, the delayed closing was done by local people in 2013 (Mutahara, 2018). The evaluation revealed that the river functioned well and parts of the *beel* raised well. But because the TRM operation lasted longer than planned this hampered effectiveness. Major problems were related to a lack of openness and transparency in the discussions with the local community about proposed mechanisms as for example compensation, location of the cut point etc. (Mutahara et al., 2017).

Implementation of TRM, a CLA strategy in *Beel Pakhimara*

In an ongoing project, discussions about TRM implementation started in 2011 in *Beel Pakhimara* at *Tala Upazila* of *Shatkhira* district (Gain et al., 2017a). Compensation to the local people for maintaining agricultural land and the peripheral embankments was still an issue. Lack of trust in the land office, targeted compensation to the landowners but not the landless people who lose their jobs during TRM were and still are the major conflicting issues. Moreover, unplanned construction of a canal causes severe erosion. As a result, it took four years to start the TRM operation in 2015.

Case summary

This case history demonstrates that, initially, the top-down planning system was resistant to accept the voice of the local community and that it displayed a considerable lack of understanding of local social-ecological dynamics (Mutahara et al., 2017). This is shown as the 'traditional policy response' loop in Figure 2.6. The figure summarizes how the combination of CLA response and traditional policy response has emerged into a new policy response. It shows that the community response as a public cut of the embankment was the trigger for the emerging policy response loop, i.e., the tidal river management approach. Over time, authorities were forced and learned to accept the community-supported TRM approach to solve waterlogging problems. However, these developments were accompanied by communication gaps between the local community and authorities, and conflicts among shrimp and rice farmers.

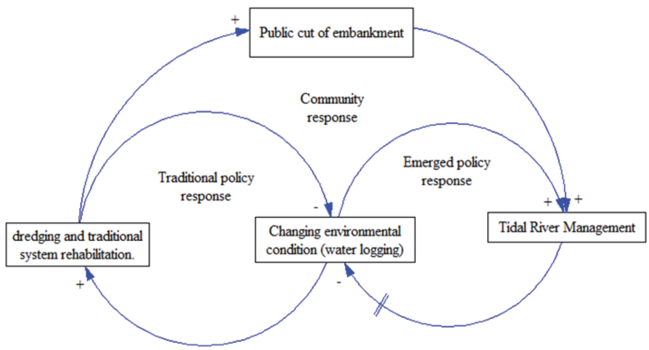

Figure 2.6: Co-evolution of TRM in policy and community response to waterlogging[11]. The traditional policy response loop has triggered a community response loop with 'the public cut of embankment' which contributes in the emergence of a new 'Tidal River Management' policy response loop to waterlogging.

[11]The concept of 'shifting the burden archetype' of system dynamics are used to illustrate the three response loops for the waterlogging problem

Although the intuitive response of the community was successful, the government-operated TRM implementation still lacks a transdisciplinary approach of collaborative working, interdisciplinary research and iterative learning with implementation; many governances and social-ecological challenges remain (Gain et al., 2017a). Implementation of TRM causes structural changes in the social-ecological system which creates different dimensions and perceptions of the local community to deal with by the implementing agency. The challenges that pertain to the TRM practice now are, however, of social and political rather than physical nature. The experts of key planning and implementing agencies have reflected critically on the social, ecological and physical suitability of current TRM approach and suggested for a careful choice with more action research and design (stakeholder consultation, 2016-17). Clearly, this case shows that a sustainable policy design needs to address various types of stakeholder interest, and that this is a challenge in a rapidly changing social-ecological system such as the livelihood adaptation of the local community.

2.4 Discussion and conclusion

This study examines the impact of uncertainties in CLA on the success of (top-down) delta planning and management. The case studies are focused on CLA in response to salinity and waterlogging and its complex interaction with polder management in southwest delta of the Ganges-Brahmaputra in Bangladesh. The results illustrate in two cases how CLA has developed differently than delta planners expected during planning, and that this has a remarkable impact on the success of delta management.

In case 1, the development of shrimp farming was not anticipated by the planners. As a result, conflicting livelihood preferences emerged between shrimp and rice farmers to adapt to salinization and other relevant factors. Specifically, the growth of shrimp cultivation leads to a change in the functionality of polders and had significant impacts on the outcome of the establishment of polders. The CLA was heterogeneous in nature and was determined by many inherent and external driving factors in the social and natural contexts. Ignoring the dynamics of the natural production system, the social power system and the role of culture, the polder management strategies have contributed to the malfunctioning of the polders as unintended outcomes. Multiple livelihood preferences existed but planners failed to grasp the need of all water users (shrimp, capture fishing etc.) with respect to polder management. Instead, they focused on the dominant trend (rice production) only.

In case 2, despite the participatory approach taken from the beginning, it was a public cut by the local community that triggered the emergence of Tidal River Management (TRM). This resulted from social (un)acceptance of traditional structural engineering solutions by the community, and failure by the planners to take the community preference into account from the very beginning of the project. Eventually, under the influence of donors and strong public protest, the community preferred solution referred to as TRM was taken over by the authority. However, the following process of TRM designing and implementation was fraught with a number of challenges including the physical boundary of TRM management, demand for compensation mechanisms, and problematic cooperation between the local community and implementing authority.

In both cases, the community was perceived as a homogeneous group by the implementing agencies and this was counter-productive; it lead to a process of participatory exclusion, marginalization of socially vulnerable groups and capture by social elites.

Our study confirms that adaptation is a process over time and can follow alternative pathways (Dewan et al., 2015; Kabir et al., 2016;Mutahara, 2018). The ADM approach is developed to deal with this uncertainty (Bloemen et al., 2019; Haasnoot, 2013;Zevenbergen et al., 2018).

We conclude that the uncertainty in CLA can have a significant impact on the success or failure of a given delta management strategy; therefore, we recommend that this uncertainty should be taken into account in long-term plans. Moreover, in developing (top-down) delta plans, such as BDP 2100, it is beneficial to pay more attention to the variety of local preferences and possible adaptation decisions. While exploring community perceptions, preferences and plans through research (e.g. by interviews and surveys) may help as a first step, a more inclusive and transdisciplinary participatory approach is recommended, aiming at co-development or co-design with the community.

Given the complexity of the socio-ecological adaptation processes, however, an inclusive and transdisciplinary participatory approach will not eliminate the fundamental uncertainties in anticipating how communities will adapt in the future. Therefore, CLA might be considered as an explicit uncertainty for relevant sectors while developing long-term delta plans such as BDP 2100. This fits perfectly with the Adaptive Delta Management (ADM) approach and can be implemented by developing a range of possible scenarios describing pathways for CLA, in addition to scenarios in uncertain exogenous factors such as climate change and economic development. The scenarios will improve with the incorporation of CLA and therefore serve as a useful tool for long-term planning. For example, the measures in BDP 2100 can be designed while acknowledging that future conditions including CLA might be very different from current conditions. In such a way, more robust plans can be developed that include CLA monitoring and options for plan adaptation depending on how the preference and standard of the local community for life and livelihood evolve over time.

Chapter 3

The Cognitive map based Unframed Scenario Approach

Case Application for the Rice Farmers of Polder 30 and 31

This chapter has been published in the International Journal of Sustainable Development & World Ecology in 2019 as:

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

U. Kulsum[a], J. Timmermans[b], M. S. A. Khan[c] and W. Thissen[b]

[a]Delft University of Technology, Netherlands and Institute of Water and Flood Management, Bangladesh; [b]Delft University of Technology, Delft, The Netherlands; [c]Institute of Water and Flood Management, Dhaka, Bangladesh

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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The Cognitive map based Unframed Scenario Approach

Case Application for the Rice Farmers of Polder 30 and 31

3.1 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 pre-cautionary short – term action while keeping adaptation options open, and continuous monitoring of actual developments (Lempert, 2003; Walker et al., 2013; Walker et al., 2001).

Bangladesh is one of the countries moving towards that approach as part of the Bangladesh Delta Plan 2100 (BDP 2100) (GED, 2018). With wide stakeholder engagement, the approach taken has a top-down character, i.e., policies are developed at 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 response of local community at an uncertain direction which is illustrated by recent experiences in southwest Bangladesh. As documented (Dewan et al., 2015; Gain et al., 2017b; Nowreen et al., 2014), 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' (Kabir et al., 2016; Nowreen et al., 2014). 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 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 Chapter will, first, briefly introduce six key concepts: community livelihood adaptation and adoption, uncertainty and scenarios, mental model and cognitive map (Section 3.2); next, the approach design, data collection, and analysis will be presented in Section 3.3; The test using a case study follows in Section 3.4; Section 3.5 reflects on the strengths and weaknesses of the approach, and Section 3.6 concludes with suggestions for further research and improvement.

3.2 Concepts and methods

3.2.1 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 (Dewan et al., 2015; Parry et al., 2007; Scoones, 1998;Scoones, 2009). 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’, 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).

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 (Börjeson et al., 2006; Haasnoot, 2013; Maier et al., 2016; Rotmans et al., 2000) can be combined.

3.2.2 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 analyse 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 (Börjeson et al., 2006; Maier et al., 2016;Rotmans et al., 2000).

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 (Maier et al., 2016; Parker et al., 2015). 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 policy maker. But the strategic scenarios incorporate policy measures under control of the policy maker. 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 chapter takes explorative approach from the view of a national or regional policy maker, 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.

3.2.3 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 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, 1976), 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.

3.3 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 3.1, 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.

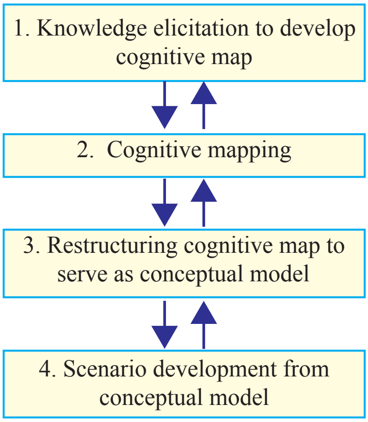


Figure 3.1 The designed approach to explore uncertainties in CLA for ADM

3.3.1 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 set of open questions to stimulate the discus-sion, 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 statistical significance of the sample. Data saturation means data collection can be ended when the researcher thinks no new concepts or links are captured.

3.3.2 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 individu-al 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 cogniti 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 cognitive map in *vensim* (Pruyt, 2013b) 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.

3.3.3 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.

3.3.4 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 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.

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

The southwest 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, 2011b). 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 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 3.2 shows the study area.

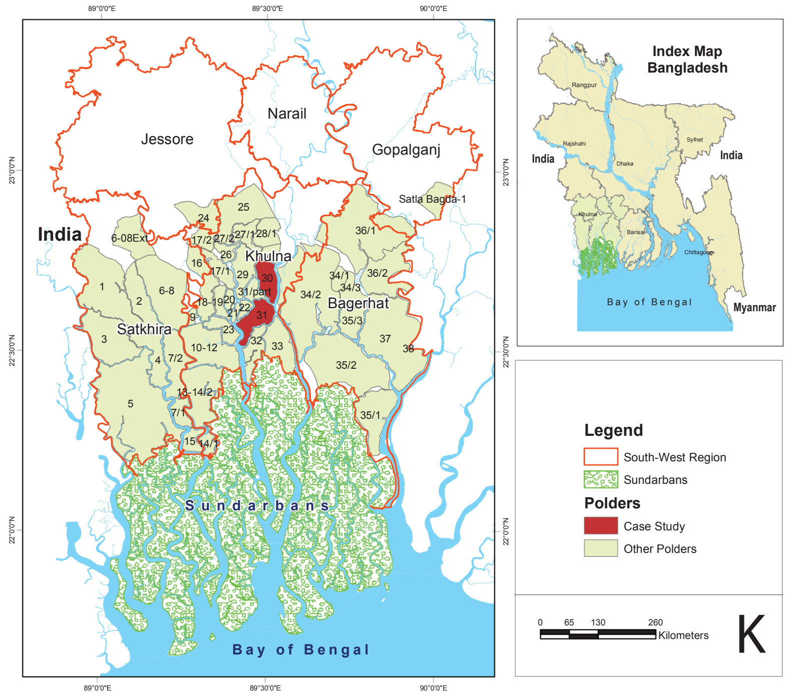


Figure 3.2 The study area: polder 30 and 31 in southwest region of Bangladesh

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.

3.4.1 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 haveparticipated 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/elderly), 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 was 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 3.1 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.

3.4.2 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 was analyzed through a number of themes: goals, actions/decisions, concerned conditions/situations, external drivers, management options, perceived learning and communication gap. The concepts 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 'influential people's influence… no influence' After validation, the cognitive map was updated accordingly.

The cognitive map in Figure 3.3 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 to 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 was 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 3.4.

3.4.3 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 3.5: the cognitive map (restructured) to serve as a conceptual 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 feed back into the iteration of the same process at the next cropping season and into the next year.

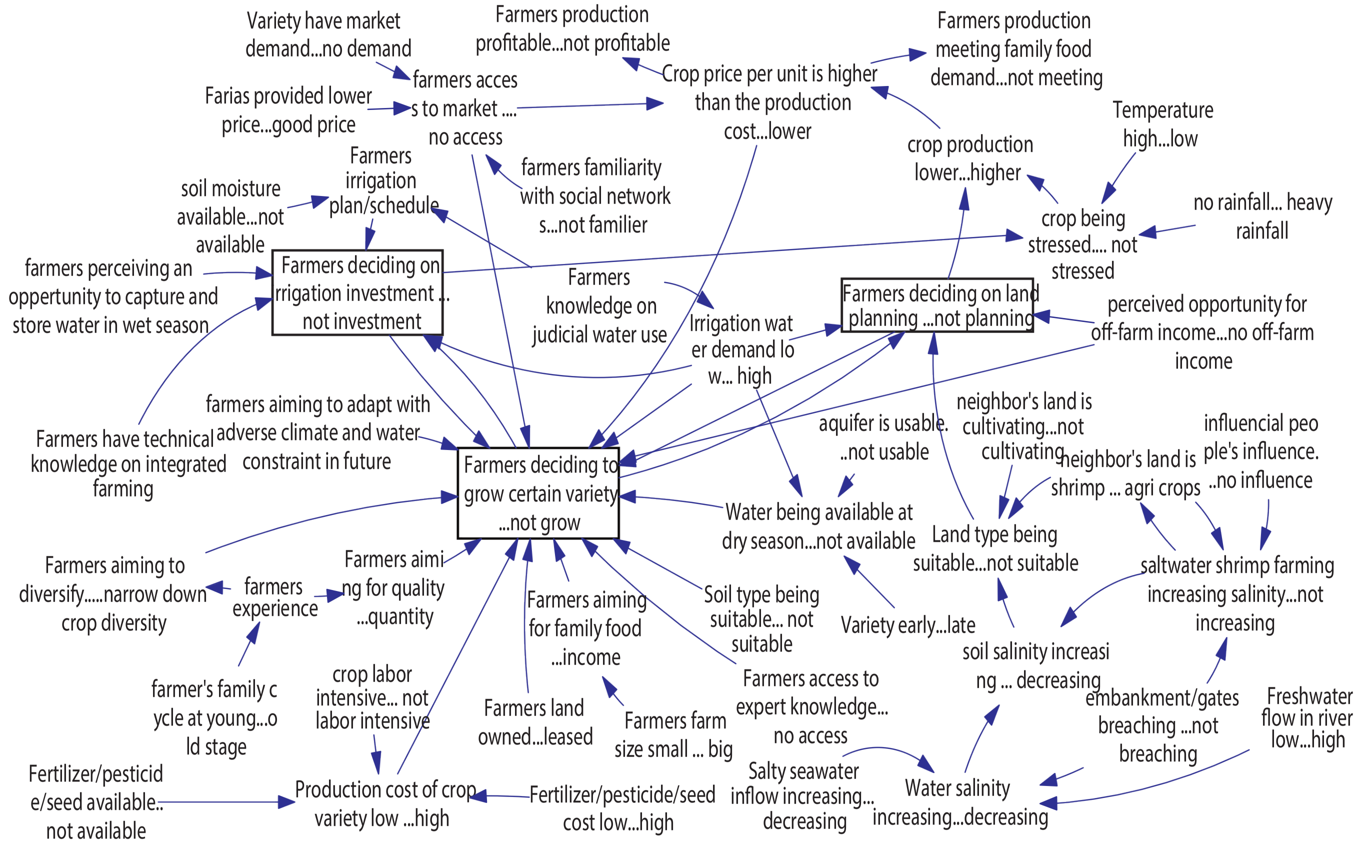


Figure 3.3 Cognitive map of farmer's community for strategic cropping decision in dry season. ("…" should be read as "rather than" to express the contrasting pole). The rectangles represent farmer's decisions, the arrows represent causal links and the rest are conditions.

Figure 3.4 The conditions and relationship in the strategic decision on crop variety

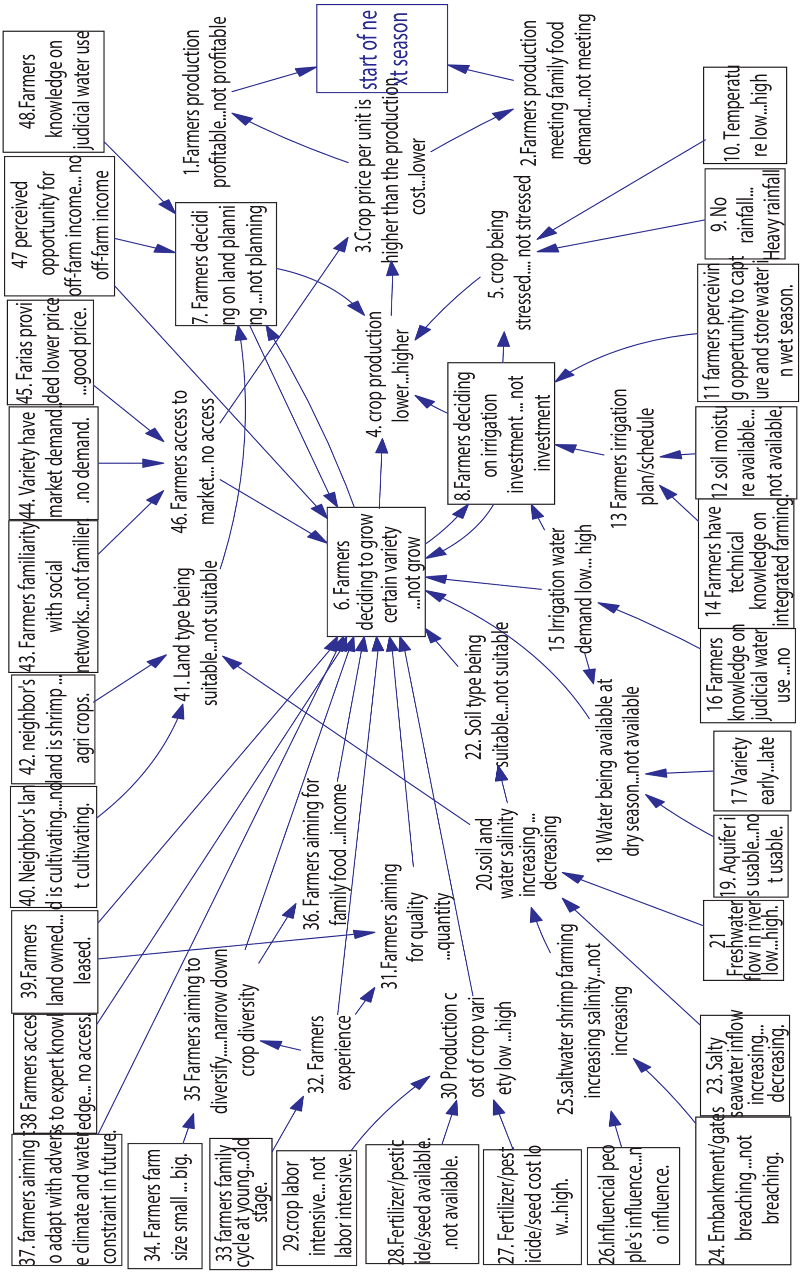


Figure 3.5 The cognitive map (restructured) to serve as a conceptual model

3.4.4 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 3.5 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.

3.5 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?

3.5.1 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 farmer's 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' adaptation scenario. Both are derived from the combination of relevant external factors and conditions illustrated in the conceptual model (Figure 3.5). In each of these main scenarios, we distinguish between a numbers of different farmer types/situations. The numbers in the text refer to the corresponding numbers in figure 3.5.

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 constraint 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 for 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 elderly 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 on 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 elderly (33) and experienced farmers (32) who feel as 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) inspite 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 interest to grow this local salt-resistant variety along with the new salt-resistant variety.

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 don't 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 elderly farmer's family members (mainly young labor force) (33) perceive a better opportunity to go for income (36) to a nearby city or other region (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 *rabicrops*. 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 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 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 is comfortable with known variety inspite of the production loss or have income from shrimp or have oppertuntiy in income with lower irrigation or perceive fallow is 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 3.6 Livelihood adaptation pathway map: Farmer's possible response to salinization shows the variety of livelihood adaptation pathways in 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 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 pathways by the farmers within 2050, as the adaptation decision of farmers are embraced with a number of uncertain factors.

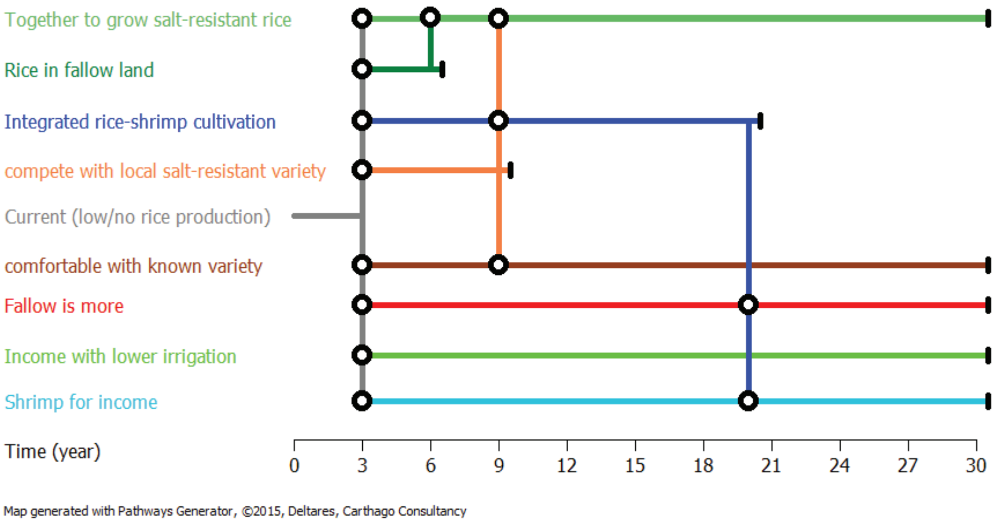


Figure 3.6 *Livelihood adaptation pathway map: farmers possible response to salinization.All are for illustrative purposes only. The black (round) transfer stations illustrate the livelihood adaptation decision from one to other by local farmer communities. The black terminal has illustrated the condition in which a livelihood is not suitable anymore.*

However, farmers may switch from one livelihood to another over time that may lead to hero adaptation also. The local salt-resistant rice variety may seem to be more familier 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 occur. The planners may prepare with 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 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.

3.6 Discussion: Reflecting on the application of the approach

To be robust against any uncertain development of CLA, the design of delta management strategy need to understand and account how local people, particularly the farmers, make agricultural adaptation decisions in their social-ecological system. This chapter 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.

3.6.1 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 bi-polar statement in the cognitive map makes 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 in 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.

3.6.2 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 with the farmers' adaptation decision making captured in this approach may seem too much to deal with by the policy-maker for adaptive delta management.

3.6.3 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 offer a useful approach to collect and apply basic data obtained in a qualitative way.

3.6.4 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.

3.7 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.

Chapter 4

The MOTA based Framed Scenario Approach

Case Application in Polder 30

An earlier version of this chapter has been presented in the 7th International Conference on Water and Flood Management (ICWFM), IWFM, BUET, Dhaka, Bangladesh in 2019 as

Kulsum, U., Timmermans, J., Thissen, W., & Khan, M. S. A. (2019). Exploring community livelihood adaptation under uncertainty for adaptive delta management: a case of polder-30 near urban influence in southwest Bangladesh.Dhaka, Bangladesh, ICWFM, 2019.

4

The MOTA based Framed Scenario Approach
Case Application in Polder 30

4.1 Introduction

Delta communities are facing a multitude of challenges with uncertain climate and socio-economic change and are in autonomous adaptation of their livelihood (Kulsum et al., 2019). Accounting for the complex and dynamic decision making process of community livelihood adaptation is always a challenge in (adaptive) planning and implementation. Inspired by adaptive delta management (ADM), our approach explores the community livelihood adaptation (CLA) under uncertainty, thinking in terms of multiple possible future scenarios for sustainable delta development.

The cognitive map-based unframed scenario approach in chapter 3 has shown its ability to explore how a farmer community's cropping decisions for adaptation are influenced by a variety of triggering factors. The approach is practical for the purpose of in-depth analysis, illustrating and presenting factors and relationships for one specific decision domain, i.e the cropping decision of a rice farmer community in the case of Chapter 3. However, while this approach can be followed for exploring any other decision process in principle, its use for multiple domains of livelihood adaptation (i.e agricultural, non-farm, migration etc.), might have practical constraints in terms of required time and effort.

Based on the experience in chapter 3, three key challenges need to be addressed to develop an improved or alternative approach:

1. ***Practicality in terms of time and effort:*** The unframed approach of scenario development combined with cognitive mapping ended up with a

rich diversity of concepts that is challenging to the analyst as well as to the policymaker in terms of practical requirements of time and effort.

2. ***Decision domain:*** In the case of chapter 3, only one cropping decision is explored (the dry-season cropping decision of rice farmers), but in reality farmer's households make more livelihood adaptation decisions than their cropping decision in the dry season. While the approach, in principle, could be applied to such other farmer decisions as well, including the variety of decisions in a similar way will significantly add to the complexity and require significant effort and time.
3. ***Future-oriented scenario development with actors:*** In the case of Chapter 3, the actors' (farmers') perceptions on uncertainties and their decision preferences are based on their experience from past years to present, while the result is applied to future developments. It might be better to explore how farmers themselves perceive *future* developments of uncertain factors and their future adaptation decisions.

To address the challenges stated above, this chapter reports on the development and application of an approach combining framed scenario development with a conceptual model based on the Motivation and Ability (MOTA) framework. While the number of contextual variables may be reduced (first point) by adopting the framed scenario development method, covering all possible livelihood adaptation options (second point) for different scenarios may still be challenging in terms of the variety of arguments, factors and aspects that have to be taken into account. We therefore, first, explored the possibility of the MOTA framework to serve as a general conceptual framework for modeling actor's adaptation decision making that could reduce model complexity by aggregating the richness of factors and concepts of actor decision making into a simplified model. We also decided to move to participatory future oriented scenario development as suggested in the third point above. The approach is tested in the case study of the livelihood adaptation of farmer communities at polder 30, around 26 km south, near the urban influence of Khulna city in southwest Bangladesh.

The remainder of this chapter presents the MOTA framework for modeling CLA in 4.2, followed by the design of the approach and methodological steps in section 4.3. This is followed by testing the approach in case study of livelihood adaptation decision of rice and integrated farmers in polder 30 (section 4.4). The reflection on the conceptual model and approach to support ADM is in section 4.5; finally concluding remarks in section 4.6.

4.2 The MOTA framework for modeling CLA

4.2.1 History and variations of relevant frameworks

Scanning recent literature on specific relevant applications and history of related concepts in our field, the Motivation, Opportunity and Ability (MOA) conceptual framework (Rothschild, 1999), Fogg's Behavioral Model (Fogg, 2009) and the Motivation and Ability (MOTA) conceptual framework (Phi et al., 2015) stand out. We will explore these further in the subsections below.

The Motivation, Opportunity and Ability (MOA) conceptual framework of Rothschild (1999) assumes that motivation, ability and opportunity are fundamental for the action of an individual or community. Self-interest is a strong component of motivation i.e. individuals are highly motivated when they can see their self-interests are well-served. The lack of opportunity[12] however can restrict the behavior/action of an individual or community. Ability (skills or proficiencies needed) to act can be greater when expectancies of personal achievement are high. However, insufficient abilities can have a negative influence on the choice for an action.

Fogg's Behavioral Model (FBM),(Fogg, 2009) understands human behavior as a product of three factors: motivation, ability and trigger, where each of these have subcomponents. Motivation can be internal or external. Three core motivators are pleasure/pain, hope/fear and social acceptance/rejection. The ability includes factors that express how easy or difficult it is for an actor to implement an action. The abilities and motivations vary by the individual and by the situation. A trigger is all about an incentive to action while the actor has sufficient motivation and ability. It is important that all three elements: trigger, motivation and ability occur simultaneously for any action to happen.

[12] Situations in which the individual wants to act but is unable to do so because there is no mechanism in hand

The Motivation and Ability (MOTA) framework of Phi et al. (2015) introduces the integrated relationship of motivation, ability and trigger for action. The framework uses Fogg's behavioral model to enrich concepts from existing actor models for public policy analysis (Phi et al., 2015). Most of these models seek to explain actor behavior by looking at the key notions of perceptions, resources and interests (Hermans and Thissen, 2009). Abilities are similar to the 'influence', 'power', 'capacity' or 'resources' in other actor analysis methods and recognized under three categories: financial, technical, and institutional. In addition to ability, motivation is the next pre-condition for a specific action. Threats ('pains', or costs) and opportunities ('pleasures', or benefits) are simply considered as two opposite motivators. Perceived opportunities or threats caused by a situation explain the actors' motivation to act. Triggers are events that cause actors to consider a change in their action.

Threats ('pains', or costs) and opportunities ('pleasures', or benefits) are simply considered as two opposite motivators. Perceived opportunities or threats caused by a situation explain the actors' motivation to act. Triggers are events that cause actors to consider a change in their action.

The MOTA framework combines the concepts of FBM and MOA to represent the subjective rationality of action. We will further discuss the existing applications of this framework and analyze its potential applicability for our purpose.

4.2.2 Knowledge from recent applications of MOTA

Phi et al. (2015) have used the MOTA conceptual framework based on motivation and ability of actors to assess plan implementation maturity. Its first application was to assess MOTA scores for direct implementation and societal adaptation of two flood risk management alternatives in Vietnam. They compare the motivation and ability scores of government actors for direct plan implementation and of societal actors (community, group of citizen) for subsequent societal adaptation. This first application did not have a transparent procedure to derive a motivation score from triggers and perceived opportunity (threat). The authors argue that the MOTA concepts help in understanding the differentiated motivation and ability of actors for a plan where conventional planning methods implicitly assume 100% probability of success and 100% of goodwill or support in involved actors.

Nguyen et al. (2019b) have applied the MOTA framework in understanding and evaluating stakeholder attitudes towards four retrofitting responses to urban flood risk: a conventional drainage system, local detention facilities, rainwater harvesting and green roofs in Ho Chi Minh City. The MOTA scores analysis shows that the stakeholders' motivation and ability to implement the retrofitting responses varied. This application offers "insights from a different perspective on planning processes and contributes towards narrowing down the gaps between '*what we want*' and '*what we can'* in the plan implementation".

Nguyen et al. (2019a) have applied the MOTA framework in a bottom-up approach to understand the motivations and abilities of local farmers to change livelihoods in Vietnam's Mekong Delta (VMD). The normalized MOTA scoring (-1 to +1 scale) is calculated by multiplying the Motivation score with the Ability score, each of which is collected separately. Results showed that farmers' motivations and abilities to change livelihoods vary substantially among different groups, driven by their perceptions on triggers and opportunities. The authors argue that acknowledging this diversity is essential to the development of agricultural transformation plans. Based on the analysis, recommendations are made to support knowledge, skills and financial capacities of communities, and for other interventions to reduce the risks of the new livelihood.

Arora (2018) has included the MOTA framework as part of a multi-method conceptual approach for implementation programming in Strategic Delta Planning. The author used the MOTA framework to structure the data collected in semi-structured interviews and to analyze the positions of regional authorities for the Mekong Delta Plan in Vietnam. The author concludes that this actor behavior framework can specify the nature of measures required by the actors or the lack thereof.

Korbee et al. (2019) have applied the MOTA framework to assess the implementation feasibility of the Mekong Delta Plan in Ben Tre province, Vietnam. The study concludes that the framework is useful as a tool to reveal diverging motivations and a perceived lack of ability among government actors at local and regional level; and that it can help manage implementation processes for strategic delta planning.

It can be concluded that the practical utility of the MOTA framework in identifying the differentiated motivation and ability of various actors for a set of alternative planning options has been established in the current applications (Arora, 2018; Korbee et al., 2019; Nguyen et al., 2019a; Nguyen et al., 2019b; Phi et al., 2015). For analytical assessment, the motivation and ability data for a set of actions is collected separately where the normalized MOTA score is derived from multiplication of motivation and ability scores. As such, the MOTA score provides a snap-shot of motivation and ability of actors for specific actions at the present situation and recurrent MOTA score analysis for the future is suggested. None of the applications attempted to derive motivation scores directly from triggers and perceived opportunities or threats yet. While the MOTA authors emphasize the conceptual innovation of the method they acknowledge its analytical limitations, and emphasize its utility for getting a broad-brush image of the situation, only.

4.2.3. How MOTA can fit conceptually?

The MOTA framework fits conceptually and it provides a way to simplify the reality. The potential strengths of MOTA framework in application for our purpose include:

1. Like the cognitive mapping model, the framework can explain the action of actors and underlying processes of decision making;
2. It seems possible to derive the condition for specific actions of a range of actors, also for future conditions represented as scenarios;
3. The MOTA score representing the relative preference of actors for actions can provide a signal to the policymaker

The rich concepts in the rice farmers' decision making on dry season cropping, presented in figure 3.5 of chapter 3 can be grouped into the key elements of MOTA framework and used in explaining relationships. The farmers' ***action*** in this case is to grow a certain variety; and plan land and irrigation investment for that variety. The ***external triggers*** can be from water availability/management (embankment gates breaching…not, salty seawater inflow increasing…not, aquifer usable…not, freshwater flow in river increasing…not), the weather/climate system (no rainfall… heavy rainfall, temperature low…high), the market system (variety cost/labor intensive…not, variety early…late, inputs available in market…not, have market demand…not, *farias* provide good price…not), neighbors cropping (cultivating… not, shrimp….rice, influential peoples' influence…not) and so on. The ***outcome*** as 'crop production lower…higher' and 'crop price lower…higher' may have a potential influence as ***internal triggers*** to change in ***perceived opportunity/ threat*** and abilities. The higher ***motivation*** can be influenced with (aiming for family food…income, aiming for quality…quantity, aiming to diversify… narrow down crops, aiming to adapt with adverse climate/water condition…not). The ***abilities*** can be farm size small…large, farmers family cycle young…old, land owned… leased, farmers knowledge and experience in judicial use/technology…not, access to social network/institutions/expert knowledge…not, off-farm income opportunity…not etc. Triggers may have a potential influence on the ability. The zero adaptation or hero adaptation of the variety by the farmers' community (largely depends on the integrated relationship of subcomponents) can be explained thereof. Concluding, all the detail in chapter 3 can be mapped onto the simpler, aggregated MOTA components, but in the process the deeper insights of reasoning might be lost, for example, why certain factors are seen as opportunity/ threats, or why certain abilities are more relevant than others for a specific action.

4.2.4 Conceptualization of CLA under uncertainty in MOTA framework

The conceptual model based on the MOTA framework (Phi et al., 2015), as shown in figure 4.1, describes the choice of the community livelihood adaptation (CLA) action as the causal consequence of triggers, motivation and ability; where the outcome in terms of contribution to family food/income and livelihood sustainability (at a future moment in time) is the result of the chosen action. The triggers in this model are the events and/or factors that cause actors to perceive opportunities or threats in terms of how a situation is contributing to achieve their aims (or outcome); the perceived opportunities or threats, in turn, influence the motivation of actors for specific livelihood adaptation actions.

Figure 4. 1 Conceptual model for exploring CLA under uncertainty

The abilities may have potential influence on the motivation through perceived opportunity/threat as higher ability may influence the perceived opportunity positively. The triggers may also have potential influence on the abilities. Motivation and ability can trade off and a high enough motivation can cause the choice of actions for which ability is low (Fogg, 2009); an actor selects the preferred livelihood adaptation action from a set of available actions based on the highest combination of motivation and ability. The conceptual components of the MOTA framework: trigger, motivation, ability and action are elaborated based on relevant scientific literature.

Triggering factors are either sudden events or gradual trends (a change in the value of factor) that cause actors to change their motivation and (maybe) ability to consider a change (triggers) in their routine action (Phi et al., 2015). Sometimes, a small change in a triggering factor is all that requires performing a certain action for people who already have sufficient motivation and ability (Fogg, 2009). Triggering factors can be internal and external to the system. The internal triggering factors for example can come from the outcome of earlier year production. The external triggering factors may range from a change in policy strategy, a new agricultural technology, to changes in rainfall pattern and extreme climatic events like a tidal storm or flood. For the triggers to change, sometimes timing is considered as the more important aspect than scale and intensity (Fogg, 2009).

Motivation is related to the reasons of action which are related to an actor's goals[13]. A situation presents a certain opportunity (or threat) in terms of a range of outcomes affordable from that situation (Ostrom, 2005). From a rational actor perspective, motivation of an actor depends on his or her perception (positive/negative) of outcomes offered by that situation; this is the subjective rationality based on the actor's own definition of the situation (Boudon, 1994; Timmermans, 2004). The resulting motivation can be explained with two opposite motivators: perceived opportunities (pleasure/ hope/ social acceptance) or perceived threats (pains/ fear/ social rejection) based on (Fogg, 2009; Phi et al., 2015). The motivation can be high or low depending on the perception. Moreover, the perceived opportunity or threat can be different based on characteristics of individuals; which is individual's motivating factors can be self-determination[14] (i.e aiming for family food) or intrinsic[15] (i.e preference for crop diversification) characteristics of individuals (Binney et al., 2006; Ryan and Deci, 2000). Motivating factors can also be extrinsic[16] (i.e. to access subsidy for crop) (Reeve, 2014; Ryan and Deci, 2000). The proximity (short term/long term) and timing of perceived opportunities/threats further matter in motivation (Fogg, 2009; Phi et al., 2015).

Abilities, another pre-requisite for action, in this model are qualifying conditions that are relative to the required capacities for specific livelihood actions. The abilities depend on the financial, technological and institutional conditions of the actor. Different categorizations of resources and abilities are used in various frameworks. For instance, abilities are similar to the concept of livelihood assets and access to the transforming structure and processes in the sustainable livelihood framework (DfID, 1999). Abilities according to the MOTA framework can be of three types. *The financial ability* is the ratio of the amount of money available to the actor (including access to loans) for a specific (livelihood adaptation) action and the amount required for that action. This availability of required money for action can be assessed in terms of full ownership, partial ownership/ loan, full loan for the action. *The technical abilities* are both physical/ecological resources and knowledge/experience resources for an action. *The institutional abilities* refer to access to resources through social networks and the governance system.

[13]https://en.wikipedia.org/wiki/Motivation accessed on 22 August 2019
[14]Self-determination theory proposed as being primary motives in human
[15]Intrinsic motivation theory maintain that person who are motivated by the task itself, perform well for longer
[16]Extrinsic motivation theory explains that individuals can engage in activities or adopt behavior for incentives/ external rewards.

The choice of actions, livelihood adaptation actions in our case, taken by the actor (from a set of possible actions available) is directly influenced by motivation and abilities based on their perception on triggering factors and abilities (Fogg, 2009; Phi et al., 2015). This is in line with other actor models presuming some level of rational behavior of an actor (Hermans and Thissen, 2009). The action occurs when the combination of motivation and ability for an action crosses a certain threshold (Fogg, 2009; Phi et al., 2015).

Outcomes are the result of chosen action and may have potential influence as trigger for example the outcome in terms of production or harvest of earlier year for the future (next year) action, shown as a feedback loop in figure 4.1.

4.3 Design of the approach and methodological steps

To explore CLA under uncertainty, our MOTA conceptual model-based framed scenario approach has two distinctive parts as shown in figure 4.2: i) conceptual model development based on the MOTA framework (with relevant concepts) that combines model development with a participatory framed scenarios approach; ii) the model application in an illustrative policy implementation that combines livelihood adaptation pathways and policy adaptation pathways[17]. Our methodological steps have combined different approaches in which each approach has its own purpose.

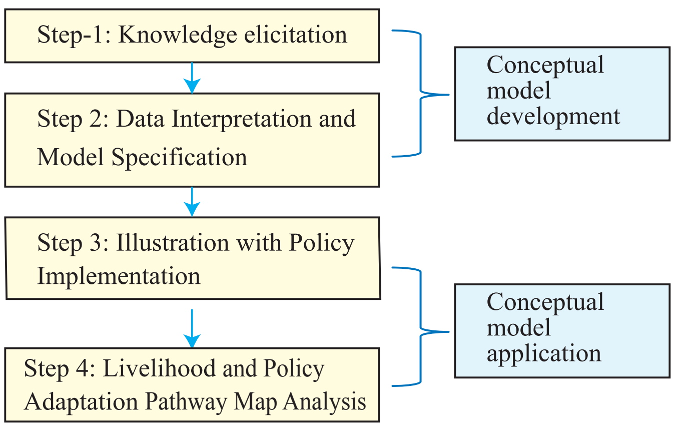


Figure 4. 2 Methodological steps of exploring CLA under uncertainty for ADM

Literature suggests that the CLA in southwest region of Bangladesh has not complied to the policy implementation due to (one of the main reasons) the top-down decision making approach of delta management (Dewan et al., 2015; Mutahara,

[17] *we refer to the adaptation in policy strategy by the policymaker in response to the new situation.*

2018). Therefore, to address the knowledge gap in integrating the bottom-up stakeholder perceptions with top-down policymaker perspectives in adaptive delta management, we base our participatory model development on a participatory process on the perception of local farmers and stakeholders. The purpose of the framed scenario approach is to limit the participatory scenario development around two dominant uncertain external triggering factors. The model application uses an illustrative (adaptive) delta management policy with the perspective of policymaker. When we address adaptation pathways, we distinguish between the livelihood adaptation pathway to represent farmers livelihood adaptation response; and the policy adaptation pathway to represent the policy adaptation strategy of a governmental policymaker. The methodological steps are discussed in the subsections below.

4.3.1 Knowledge elicitation

For conceptual model specification, we use a participatory scenario development workshop following the scenario logic approach (Schwartz, 1996); in this commonly used approach the scenarios develop around usually two key factors. The participant selection from the relevant actors follows the research objective. After sharing the objectives during the workshop, the discussion structures along: (i) identification of the key trends and issues that are important for their decision but not under their control, (ii) making consensus of two most important but external issues/trends as factors (iii) the stories and relationship development around two factors into two divergent axis of the matrix (iv) identification of adaptation action per scenarios (v) identification of motivation and abilities for action.

Semi-structured interviews are beneficial to supplement with the data of the abilities and motivation of individual households of the communities. GIS mapping adds the data on the geo-spatial feature including the agricultural land, access to irrigation, roads etc.

4.3.2 Data Interpretation and model specification

The data interpretation and model specification follows the conceptual model of figure 4.1. The dataset on scenarios and relevant narratives should be interpreted as different realizations of triggering factors (external to farmers) for a certain period of time (for example 30 years up to 2050). The data on abilities from respondents is interpreted and categorized by the researcher into Financial, Institutional and Technical (FIT) abilities (Phi et al., 2015). The motivation and abilities for livelihood adaptation identified by the participants are utilized to explain the rationality of the farmer's livelihood adaptation actions under the scenarios.

4.3.3 Illustration with policy implementation

For illustration with policy implementation, we follow the concepts of the adaptive policymaking approach (Kwakkel et al., 2010; Walker et al., 2001). First, the main problems are identified from the policymaker perspective. The policy objective is set to address the policy problem and a basic plan of policy strategies is implemented illustratively. Based on the policy objectives, the policy strategy of BDP 2100 is chosen. The new situation as a result of the policy implementation is assumed. The scenarios developed in the earlier step are used to represent possible impacts of the policy strategy on the triggering factors and its influence on the perception (threat/opportunity), motivation and abilities of actors for adaptation action. Then actions under scenarios are analyzed and presented in the next step.

4.3.4 Livelihood adaptation and policy adaptation pathway maps

In this research, we make a distinction between two adaptation pathways: (i) the farmer's livelihood adaptation pathway representing the farmers' livelihood adaptation response, and (ii) the policy adaptation pathway representing the anticipated policy adaptation of the policymaker. To illustrate these two pathways, we first assumed implementation of a (hypothetical) basic plan with specific policy objectives in line with BDP 2100 for the Coastal Zone hotspot. Then, we analyzed the livelihood adaptation response of farmers' community (based on the conceptual model) and visualized it in a livelihood adaptation pathway map. In correspondence with the livelihood adaptation action, we then developed a plan of policy adaptation and presented it in a policy adaptation pathway map with anticipated policy adaptation actions. We identified signposts, i.e., the conditions that should be tracked in order to determine whether the plan is meeting the conditions for its success. Critical values of signpost variables (triggers[18]) beyond which additional actions should be implemented are specified also.

[18] *Triggers in adaptive policymaking specifies the condition under which a pre-specified action to change the plan is to be taken*

4.4 Testing the approach in case study: livelihood decision of rice and integrated farmer

Polder 30 with an embankment of 40.27 km length is located in *Batiaghata*, *Gangarampur*, and *Surkhali* Unions of Batiaghata Upazila of Khulna District. This polder near Khulna city covers an area of 6,455ha, with a Net Cultivable Area (NCA) of 4,240 ha (66%), settlement 1900 ha (29%), water bodies (*Khal*) 250 ha (4%) and roads 65 ha (1%) (CEGIS, 2015). The polder is located in the southern hydrological zone of the country, actually lower than the highest tidal water levels observed in Rupsa-Pasur River. Around 60% of the land parcels of the area have elevation between 1.33 to 1.54 m above Mean Sea Level (MSL), whereas 40% have elevation are more than 1.54 m above MSL. As the areas have a very minor downward slope from north to south, it draws water from the up-stream basins to the Rupsha-Pasur River through the peripheral rivers (*Sholmari*, *Salta*, *Jhopjhopia* and *Kazibacha*). The area constitutes of one agro-ecological zone, namely the Ganges Tidal Flood Plain (AEZ-13) (CEGIS, 2015).

At present, the double cropped area is about 94% of the NCA and cropping intensity is 194% (CEGIS, 2015). Crop damage in this polder is mainly due to salinity, drainage congestion, siltation and heavy rainfall. The total NCA is under poorly drained condition i.e. the soil remains under water from 15 days to 7/8 months. The removal of water in/after the wet season is the main constraint for growing crops in the dry season. Over the period of 1973 to 2009 soil and water salinity have been increasing. In 1973, 48% of total NCA was very slightly saline (4.1-8.0 DS/m) and 52% was slightly saline (8.1-12 DS/m), which has increased to 81% slightly saline (8.1-12 DS/m) and 19% moderately saline (12.1-16 DS/m) (CEGIS, 2015).

In polder 30, about 9,490 households have a total population of 38,240 of which 18,940 are male and 19,300 are female (BBS, 2011). About 38% of total population is in the main working force of age group 30 to 49 years (BBS, 2011). At present, 83% of the population is engaged in the agricultural sector, 13% in the salaried service sector and only 4% in industry (includes petty trade, handicraft, other manual sector) (BBS, 2011). The relatively large agricultural workforce includes farmers 42%, agricultural laborers 28%, fishers 25%, day laborers and other 5% (CEGIS, 2015).

Therefore, in our case study, we focused on the farmers' community who are facing salinity and drainage constraints along with other triggering factors. The present situation of rice farmers and integrated farmers based on the data of 20 participants in workshop and interview is summarized in the subsections below.

The rice farmers in *Gangarampur* village at figure 4.3 (right) are in between the *Amtola* river and *Kodaldaha* canal. About 90% of the farmers have been living in the area for 40 to 70 years and 10% for 40 years. They have two cropping seasons: *Aman* rice in the wet season and *Boro* rice or Rabi crops (lentil, sesame, water-melon, vegetables etc.) in the dry season. They depend on the *Kodaldaha* canal for irrigation in the dry season. Three Shallow wells equipped with pumps provide another source of irrigation water. Farmers usually don't irrigate with *Amtola* river water because the river water becomes saline in the dry season. In extreme shortage of irrigation water, they store river water in the canal for three/four days before irrigation. March-April in the dry season is the most irrigation water scarcity period as all land needs irrigation and the water in the river, canal etc. dries up.

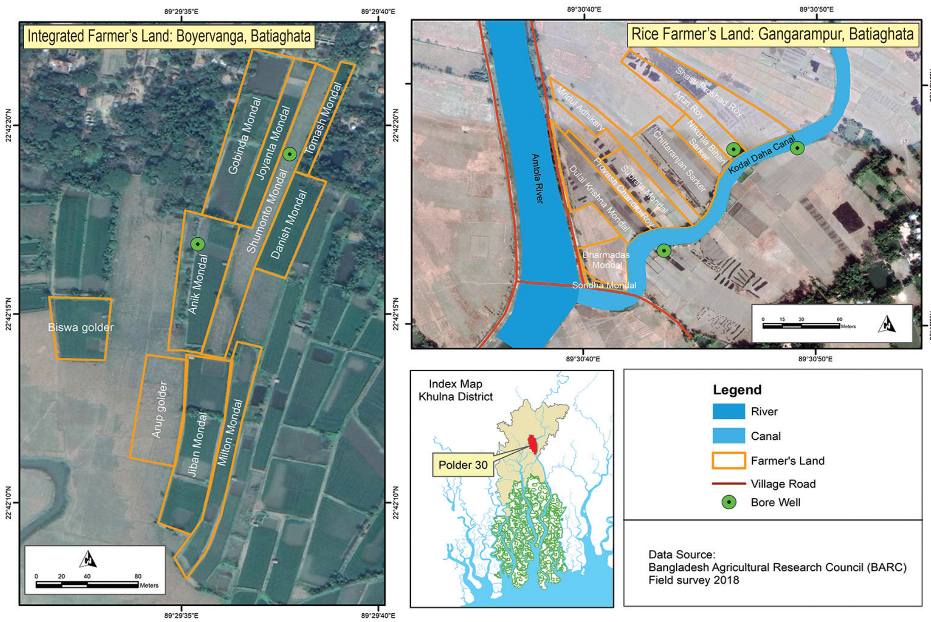


Figure 4. 3 Rice and integrated farmers' community at the study area in polder 30

The integrated farmers in *Boyervanga* village of *Batiaghata* at figure 4.3 (left) are in the interior location - far from canals or rivers. They have transformed their land into *ghersuitable* for integrated farming as shown in figure 4. 4 (a and b) cross sections of the *gher*.

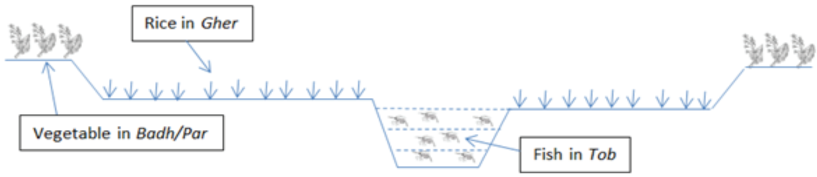


Figure 4.4a cross section of the *gher* in the dry season

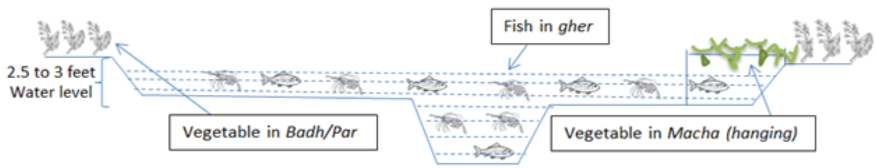


Figure 4.4b cross section of the *gher* in the wet season

Figure 4. 4 Cross sections of ghers

During the dry season they cultivate *Boro* rice in the *gher*, shrimp post larvae in the *tob* (the small relatively deeper part in the *gher*) and vegetables in the *badh* (embankment). During the wet season, they cultivate shrimp, fish in the *gher* and vegetables in the hanging *macha*. Water from two shallow wells is the main irrigation water source in the dry season. For fishery, the rainwater in the wet season is the main source of water. They also preserve rainwater in the small pond/*tob* (reservoir) in their own land for dry season fishery. March-April in the dry season is the most irrigation water scarcity period for *Boro* rice cultivation.

4.4.1 Step 1: Knowledge elicitation

Three methods were used to collect data to develop the conceptual model from the farmers' perception: participatory scenario development workshops, semi-structured interviews and GIS mapping (GPS data of agricultural land with farmers)

In polder 30, we identified a community of 10 rice farmers at *Gangarampur* village and a community of 10 integrated farmers at *Boyarvanga* village of *Batiaghata* Upazila under *Khulna* District. The farmers were selected based on (a) have rice/shrimp 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/elderly), and male/female (at least two women farmers who are actively involved). A local key-informant NGO has supported the participants' selection, the arrangement of the scenario workshops and individual interviews.

Participatory scenario development workshops

For our purpose, the participatory scenario development was designed based on the scenario logic approach (Schwartz, 1996). The objective of the scenario development was to (1) explore future possible developments of key triggering but uncertain factors (ii) identify farmer's adaptation action under each scenario (iii) identify the motivation and ability for scenario specific livelihood adaptation actions. see appendix 4.1. Our exploratory scenario development adopted the forecasting (starting in the present with future inference) approach (Van Notten et al., 2003). For practical reasons, the number of scenarios is limited to 4, (3+/-1) as recommended in (Kok and van Vliet, 2011). The storyline and relationships around two key triggering factors are built into two divergent axes of a matrix following the scenario logic approach (Rounsevell and Metzger, 2010; Schwartz, 1996).

We performed three scenario workshops at the study area in polder 30 in 2018. The workshops were with 10 rice farmers, 10 integrated farmers, and 15 local stakeholders. see appendix 4.3. The local stakeholders included a representative from a local elected body, agriculture officer, fisheries officer, livestock officer, representatives of the water management committee, gate operator, NGO representative, teacher, businessman etc.

At the scenario development workshops, the objective was shared after introduction. The participants were requested to discuss and list out the factors, conditions or trends that were not in control of the farmer's hand but important for an agricultural livelihood in recent years. The farmers community identified about thirty triggering factors or trends in this polder, see appendix 4.2. Then, from the comprehensive list of factors and trends, they were requested to reach consensus among themselves to prioritize two factors that are most important but uncertain for their agricultural livelihood. The participants were then requested to develop four coherent stories of future development using these two factors till 2030. We placed the two factors into x and y-axis, the four scenarios were placed at four quadrants accordingly. After developing scenarios, they identified their livelihood adaptation plan for each scenario. Finally, they identified the key motivation and abilities for their livelihood adaptation. They also developed some actions that are beyond their capacity and for which involvement of local government and policy makers is required to improve the condition for livelihood sustainability.

Semi-structured interviews

After each scenario workshop, we conducted 20 individual interviews with the same rice and integrated farmers to collect data on socio-economic condition, livelihoods and abilities of individual households. Based on the preliminary data of farmers (cognitive map in chapter 3), a semi-structured and pre-tested questionnaire was developed and used to get data of individual farmer's. The data includes socio-economic condition, current livelihood resources, abilities for action and perception on uncertain factors, their motivation and livelihood adaptation action in the future. see appendix 4.1.

GIS mapping of the agricultural land

During interviews, we went to the house and agricultural land of all participating farmers; observing their current livelihood, cropping pattern and collecting GPS data of their agricultural land for developing a GIS map. The map in Figure 4.3 shows their land location.

4.4.2 Step 2 Data Interpretation and Model Specification

4.4.2.1 Triggering factors in the scenarios

The rice farmers developed four scenarios using two key triggering factors as shown in figure 4.5 below: irrigation water availability and agricultural technology availability. These two most uncertain and important factors for their agricultural livelihood are placed on the x- and y-axis respectively. Four coherent stories of possible future development of irrigation water and agricultural technology are represented in four quadrants accordingly

Availability of agricultural technology (low-high)

Water constrained scenario • ***Water availability: poor quantity and quality*** *Water salinity increases because of poor water management and degrading infrastructures, canals are not dredged. Availability and storage of irrigation water is low.* • ***Agricultural technology availability: high*** *Agricultural skill and knowledge increase. High-tech irrigation technics, saline tolerant and low water demand varieties of crop; the quality inputs, seeds, organic/chemical fertilizers and pesticides they require are available in the market at competitive prices.*	***flourishing scenario*** • ***Water availability: good quantity and quality*** *Water salinity reduces because of improved water management and infrastructure. freshwater flow and storage for irrigation increases* • ***Agricultural technology availability: high*** *Agricultural skill and knowledge increase. High-tech irrigation technics, saline tolerant and low water demand varieties of crop; the quality inputs, seeds, organic fertilizers and pesticides they require are available in the market at competitive prices. ICT based agribusiness is expanding.*
Stagnant scenario • ***Water availability: poor quantity and quality*** *Water salinity increases because of poor water management and degrading infrastructures, canals are not dredged. Availability and storage of irrigation water is low. Farmers quarrel and steal irrigation water at night.* • ***Agricultural technology availability: low*** *Agricultural skill and knowledge is in constrained, lack of access to the Govt. agro-department. Lack of quality seeds, fertilizer, pesticides in the market. Production cost increases; production and net benefit reduces.*	***Agro-tech constrained scenario*** • ***Water availability: good quantity and quality*** *Water salinity reduces because of improved water management and infrastructure. freshwater flow and storage for irrigation increases* • ***Agricultural technology availability: low*** *Agricultural skill and knowledge is in constrained, Lack of quality seeds, fertilizer, pesticides in the market. Production cost increases; production and net benefit reduces.*

Availability of irrigation water (poor-good)

Figure 4.5 Triggering factors in scenarios considered by rice farmers

Market system (unfavorable-favorable)

Water Constrained scenario • ***Water drainage: poor*** *Water drainage delays because of poor water management, degrading infrastructure and siltation. Canals are not dredged.* • ***Market system: favorable*** *Access to market increases. Roads and transportation are good. Improved technology, inputs (fish fry, feed etc.), cold storage etc. are available in the nearby market at competitive prices. A good relation exists with shrimp processing companies, farias (local traders) and other relevant market actors for quality fish production and high market value. Government rules and support for exporting and international market*	***Flourishing scenario*** • ***Water drainage: good*** *Adequate water drainage because of improved water management and infrastructure. Canals are dredged. Have sufficient reservoir for storing irrigation water* • ***Market system: favorable*** *Access to market increases. Roads and transportation are good. Improved technology, crop variety, inputs (fish fry, feed etc.) are available in the nearby market at competitive prices. A good relation exists with shrimp processing companies, farias (local traders) and other relevant market actors for quality fish production and high market value. Government rules and support for exporting and international market.*
Stagnant scenario • ***Water drainage: poor*** *Water drainage delays significantly, waterlogging condition persist longer because of poor water management, degrading infrastructure and siltation. Canals are not dredged. (ghers washed out and people forced to live on embankment)* • ***Market system: unfavorable*** *Access to market is low. Roads and transportation are poor. Improved technology, inputs (fish fry, feed etc.), cold storage is scarce and costly in the nearby market. Lack of good relations with shrimp processing companies, farias (local traders) and other relevant market actors. Lack of Government rules and support for exporting and international market.*	***Market constrained scenario*** • ***Water drainage: good*** *Adequate water drainage because of improved water management and infrastructure. Canals are dredged. Have sufficient reservoir for storing irrigation water* • ***Market system: unfavorable*** *Access to market is low. Roads and transportation are poor. Improved technology, inputs (fish fry, feed etc.), cold storage is scarce and costly in the nearby market. Lack of good relations with shrimp processing companies, farias (local traders) and other relevant market actors. Lack of Government rules and support for exporting and international market.*

Water drainage (Poor- good)

Figure 4.6 Triggering factors in scenarios considered by the integrated farmers

The integrated farmers developed four scenarios as shown in figure 4.6 below. The two most uncertain and important triggering factors for their agricultural livelihood are water drainage, and the market system, and these are placed in the x- and y-axis respectively. Four coherent stories of possible future development of water drainage and market system are in four quadrates accordingly.

In all scenarios developed by rice and integrated farmers, extreme weather (i.e. very high temperature in summer) and abrupt/uneven rainfall pattern are taken into account. Water management in all scenarios refers to the water infrastructure management (i.e embankment, sluice gates, canals, rivers etc.) by Government Authority (i.e BWDB/ LGED) and other projects but does not include the irrigation water management of farmers at their own land.

It is important to note that the importance of triggering factors for rice farmers and integrated farmers are context specific and pertinent to their own current livelihood situation. Therefore, the same scenario at a polder can have different implications for the choice of livelihood action of different actors.

4.4.2.2 Livelihood adaptation under scenarios

In the scenario workshop session, after developing scenarios the farmers have imagined what livelihood they would choose under that scenario.

The livelihood adaptation actions considered by rice farmers

Under stagnant scenario of low agricultural technology and irrigation water availability, the livelihood adaptation actions considered by rice farmers are: shrimp farming, off-farm livelihood and migration to cities/areas for a job/labor; as shown in figure 4.7. The elderly farmers tend to continue rice and low water demanding Rabi crop for family consumption at possible scale. The younger farmers mostly perceive opportunities and are motivated to shift into shrimp farming, off-farm livelihood and migration to cities/areas for labor/job. They also perceive that the adverse conditions may encourage the farmers' cooperatives to strongly appeal to the government for more support in agricultural technology and irrigation water.

Under the *water constrained* scenario with poor irrigation water availability and high agricultural technology, the possible livelihood adaptation actions considered are: high-tech/cost irrigation technologies, restoring water reservoir, efficient irrigation water use, *Rabi* crop, saline resistant rice crop, agribusiness, crop diversification, off-farm livelihoods. The farmers motivate to continue the current agricultural livelihood by mitigating the irrigation water scarcity by adopting irrigation technologies (including high-tech and expensive ones) as for example desalinization, deep bore wells in combination with restoring of water reservoirs (on-farm/pond etc.). They can adopt knowledge/techniques and use to increase irrigation efficiencies. Based on abilities and perceived threats for crop loss, the Boro rice cultivation may shift to the *Rabi* crop, and/or saline resistant rice varieties. Specifically the young farmers also perceived opportunities for additional income in agribusiness and off-farm livelihoods in addition to agricultural adaptation. The farmer's cooperative is seen as an opportunity to influence ability and motivation of farmers in their choice of livelihood adaptation action.

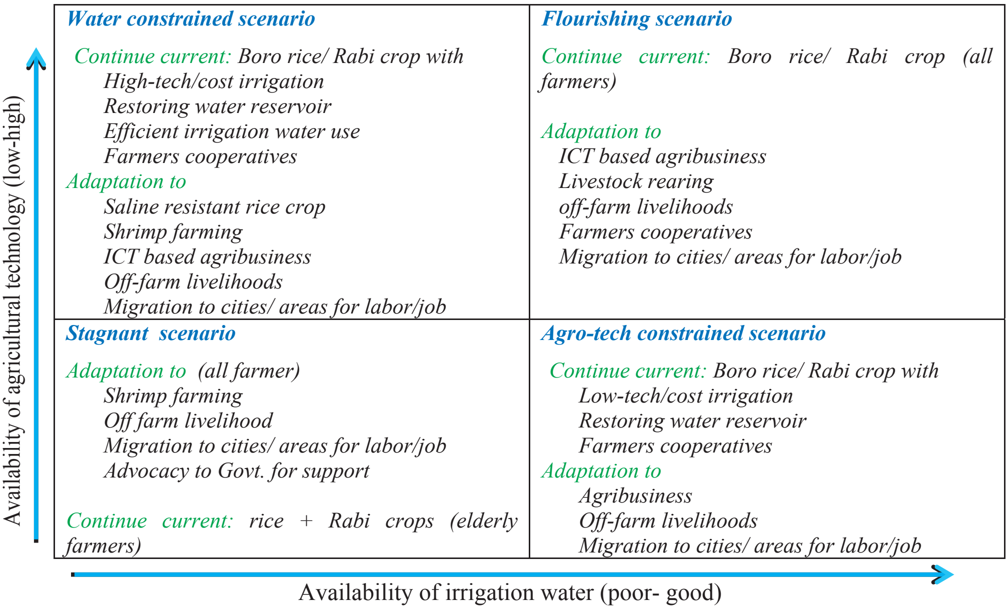


Figure 4.7 Livelihood adaptation action under scenarios by rice farmers

Under *agro-tech* constrained scenario of low agricultural technology and good irrigation water availability, the livelihood adaptation action considered is: off-farm livelihood, migration to cities/other areas for labor/job. Mostly the elderly farmers perceive opportunities from the good irrigation water availability to continue *Boro* rice and *Rabi* crops in their traditional way. The young farmers perceive low opportunities from low availability of agricultural technology, and are therefore motivated to switch to off-farm livelihood, or migration to cities/other areas for labor/job. Young farmer also perceive low opportunity in ICT based agribusiness; thus depending on their ability some farmers may get involved in traditional agribusiness. All farmers perceive opportunity in farmer cooperative for advocacy to government and other organizations for increasing availability of agricultural technology.

Under the *flourishing scenario*, the farmers, both young and elderly, see possibilities to remain in agricultural activities, but also perceive opportunities from other relevant livelihoods for additional or alternative source of income/food. As irrigation water is available, the *Boro* rice cultivation remains the main crop. Moreover based on abilities and perceived opportunity, farmers engage with *Rabi* crops, ICT based agri-business, livestock rearing, crop diversification, off-farm livelihood etc. They also perceive opportunities in their own farmer cooperative. For irrigation, farmers perceive low opportunity in investing in irrigation techniques (high/low-tech). Increasing the capacity of water reservoirs (on-farm/pond) is perceived sufficient as irrigation water is available in canals/rivers/shallow bore-wells. They perceive opportunities from ICT based agribusiness in adapting machines/tools/techniques that make their agricultural activity easy and simple. The educated young and women farmers all perceive opportunity and engage in expanding ICT based agribusiness.

The livelihood adaptation considered by integrated farmers

Under the stagnant scenario, the livelihood adaptation actions considered are: shrimp/ fish farming, migration to another region and tidal river management as shown in figure 4.8. The perceived threats from poor water drainage and unfavorable markets motivate farmers to shift from their current integrated crop intensification[19] system. Based on ability and perceived opportunity, the farmers are motivated to shift to shrimp/ fish farming. At this worst condition of waterlogging, farmers perceive no opportunity from their land and perceive migration to another region as an opportunity for livelihood and living. On the other hand, they perceive tidal river management as an opportunity to revive their land for agricultural activity again. They also perceive the farmers' cooperative as an

[19] intensification Involves various crop production with higher level of input and output per cubic unit of area

opportunity for strong advocacy to government and non-government organization for improving water drainage and markets.

Market system (unfavorable -favorable)

Water Constrained scenario	**Flourishing scenario**
Continue current: integrated farming with adaptation of- *ICT based market* *Raising gher embankment* *Waterlogging resistant variety* *Saline resistant variety* *Farmer cooperatives*	*Continue current: integrated farming* *Farmer cooperatives*
Stagnant scenario	**Market constrained scenario**
Adaptation to - *Shrimp/ fish farming* *Migration to citis/other areas for labor/job* *Tidal River Management (TRM)* *Advocacy to govt./ NGOs for support*	*Continue current: integrated farming with adaptation of -* *liaison/ advocacy with government and other market actors* *improve market linkage (local/international)* *Farmer cooperatives*

Water drainage (Poor- good)

Figure 4.8 Livelihood adaptation actions under scenarios by integrated farmer

Under the *water constrained scenario* with poor water drainage but favorable market conditions, the livelihood adaptation actions considered are ICT based market, raising *gher* embankment, adapt to a waterlogging resistant variety, adopt a saline resistant variety within the existing integrated farming system. The farmers perceive an opportunity for intensification of crop production in their current integrated farming system, so they tend to improve conditions for continuation of current system. The farmers also perceive opportunities in for example ICT based markets. Their ability for marketing of their product increases with direct link and use of ICT (mobile phone/internet) to track the demand of the product, market-place, market price etc. The perceived threat from poor drainage motivates farmers for adaptation actions such as raising gher embankment, waterlogging, and adopting resistant and saline resistant varieties. The farmers' cooperative is instrumental as means for advocacy to the government for improving water drainage.

Under the *market constrained scenario* of good water drainage but unfavorable market, the livelihood adaptation actions mentioned are: continue integrated farming with liaison/ advocacy with government and other market actor, and improve local/national/international market linkage. Good water drainage motivates farmers to continue the integrated cropping intensification system. Farmers also perceive opportunity in enhancing natural food production. For improving both local and international markets, the farmers perceive opportunity in making liaison and advocacy with Government and other market stakeholders. The farmers' cooperative is perceived as an opportunity for making markets favorable as for example collecting/producing quality fish fry, feed etc.

Under the *flourishing scenario* of good water drainage and favorable market conditions, the farmers are motivated to continue the integrated cropping intensification system. Mostly the young farmers are motivated to get involved in the agricultural activity with the support of modern agricultural and communication technology available in the markets. They also perceive an opportunity for raising *Gher* embankments as part of their ongoing *gher* management. All farmers perceive opportunity in this sustainable and environment-friendly farming system that enhance natural food production and bring sustained wellbeing in the family.

In concluding, the livelihood adaptation actions of rice and integrated farmers are specific to their perception of triggering factors. This perception is different for the young and elderly rice farmers whereas the perception of all elderly and young integrated farmers is aligned. The livelihood adaptation decision also depends on the requirements of the possible available livelihoods.

4.4.2.3 Abilities for livelihood adaptation

Abilities of rice farmers

The current abilities of rice farmers for their current livelihood i.e rice farming were identified and analyzed, leading to the observations that follow. *Financially*, 90% of farmers are capable to fully own and 10% are capable to partially own/loan for investing in *Boro* rice cultivation. As the money required for rice cultivation is segregated over the season, the farmers get time to arrange the money. The financial abilities to adapt *Rabi* crop require around the same amount but adapting to shrimp farming requires a higher amount of initial investment.

The technical abilities reflect higher knowledge/experience on varieties and cultivation techniques for elderly farmers than that of younger farmers. The *technical knowledge and experience* of farmers' family from their current livelihood has a critical role in adaptation. According to respondents, the rice farmers' family based on family size, cycle (young/old) etc. involves as much as eight livelihoods. The crop agriculture on own or rented land is their main livelihood. The other livelihoods include: fish/shrimp farming, kitchen gardening, small business (grocery, tea-stall etc.), professional work (teacher etc.), livestock/poultry rearing, day/wage labor, transport services (rickshaw/van/cart/ motorcycle) and self-employed (tailoring/carpenter etc.). The livelihood diversity supports a higher ability to transfer resources for adaptation. The *physical/ecological resources* include land ownership, type of ownership (own/leased), leasing type (crop based/fixed term), availability/ownership of transferable[20] resources/ equipment (fruit trees, livestock, agricultural tool, transport means, cell phone, sewing machine etc.). All farmers have owned their land. About 70% farmers are smallholder (<2.5 acres) and 30% are medium-size farmers (2.5 to7.4 acres). About 60% of the household members have 8 to 14 years of schooling and were involved in earning for the last 12 months. The 60% farmers in the age group of 47 to 60 years were also involved in earning for the last 12 months.

The institutional abilities refer access to formal and informal institutions, local organizations, service providers, neighboring farmers, markets etc. in the society to share accessible resources for their own livelihood need. The farmers who are in a farmer's cooperative specifically the lead farmers have a good relation and access with local agriculture department, NGOs, service providers, and markets. The relationship/ dependency with neighboring farmers is a critical ability for crop adaptation based on land type; as they rely on each other for coordinated input, irrigation, pest and harvest management for successful yield.

Abilities of the integrated farmer

The current abilities of integrated farmers for current livelihood action i.e integrated farming were identified and analyzed. Financially, at present, 60% of the farmers are capable to invest with full own fund whereas 40% are capable in partial own/loan funding. These abilities may change over time.

The *technical abilities* in terms of knowledge and experience of both the young and elderly farmers are well; the young are more involved in rice variety/irrigation and similar techniques. As with rice farmers, the *technical knowledge and experience* of farmers' family from their current livelihood has a critical role in

[20]Transferable resources are easy to use or convert to cash for livelihood activities

adaptation. According to respondents, the integrated farmers' family based on family size, cycle (young/old) etc. involves as much as five livelihoods. The integrated fisheries/crop/vegetable on own or rented land is their main livelihood. The other livelihoods include: small business (grocery, tea-stall etc.), professional work (teacher etc.), livestock/poultry rearing, day/wage labor, and self-employed (tailoring/carpenter etc.). The livelihood diversity supports a higher ability to transfer resources for adaptation. The *physical/ecological resources* include land/pond ownership, type of ownership (own/leased), availability of transferable resources/ equipment (fruit trees, livestock, agricultural tool, transport van, solar panel, call phone etc.). About 90% of the integrated farmers own their land. About 60% are small farmers (<2.5 acres) and 40% are medium farmers (2.5 to7.4 acres). About 60% of the household members have 10 to 14 years of schooling who were involved in earning for the last 12 months. The 60% farmers in the age group of 24 to 50 years were involved in earning for the last 12 months.

The institutional abilities are the same as for the rice farmer community. The relationship/ dependency with/in neighboring farmers is a critical ability for crop adaptation based on land type; as they rely to each other in coordinated input, irrigation, pest and harvest management for successful yield. About 60% of households had shortage of food for 2 to 4 months due to lack of work opportunity and failure in shrimp/fisheries; their coping mechanisms was to lend from neighbors/relatives.

4.4.2.4 Motivation for livelihood adaptation

For an adaptation actionto be chosen, the motivation needs to be higher than for keeping the current livelihood, as we observed in the livelihood adaptation action under scenarios at section 4.4.2 of rice and integrated farmers. The motivation is derived from two opposite motivators: perceived opportunity or perceived threat from the triggered condition. The perceived opportunities from the existing condition are observed as the key driver for motivation in the flourishing scenario, while the perceived threat from the existing condition and recurrent loss are the key drivers in motivating farmers for livelihood adaptation action under the stagnant condition. The adaptation action under the two constrained scenarios is shaped by balancing between the threats from the poor condition (i.e. water availability) and opportunities from the good condition (i.e. improved irrigation techniques). If there is a re-current crop production loss at current cropping/livelihood, the farmers perceive availability of new crop/technology as opportunity.

In a quest to find the relationship of the motivation with perceived opportunity and threat, we asked the integrated farmers 'what has motivated them for transformation into the integrated farming system?'. The data shows that the perceived opportunity from the integrated system (rice, shrimp/fish, vegetables) combined with recurrent loss and threat from the environmental condition mostly low water quality for fishery (earlier action) in the dry season motivated the farmers to switch to Boro rice cultivation integrated with vegetable and fish. Adverse environmental conditions such as the lack of sufficient water level (below the standard of 2.5 to 3 feet) and high temperature result in recurrent losses; so knowledge/experience of drying the land and cultivating *Boro* rice in the dry season (that improves the next season's shrimp/fish production) motivated them for change. They also perceived the opportunity of higher production by cultivating *Boro* season rice (around fourth time higher than *Aman* season rice). Similarly, perceived opportunity of year-round vegetables for family consumption and income has motivated them. Framers also mention a preference for crop diversification as a motivating factor. Summarizing, perception of the riskiness of the cultivation under adverse environmental conditions, and perception on the abilities of families, and above all the well-being of future generations motivated them for this livelihood adaptation to the integrated farming system.

The above data show that the livelihood adaptation action can be influenced by the individuals' motivating factors. The rice and integrated farmers perception about the individual motivating factors varies as shown in figure 4.9. The aiming for food and income is the main goal (outcome) for all farmers, no doubt. Moreover, a number of intrinsic motivating factors may have influence on the preference for a livelihood adaptation action. The rice farmer perceives importance (higher to lower) of these factors: preference to adapt adverse environmental condition (1), preference for crop diversification (2), preference from knowledge/experience (3), preference to avoid risk (4), preference for quality (5) and preference for quantity (6); this order of importance is different in perception of integrated farmers as of figure 4.9.

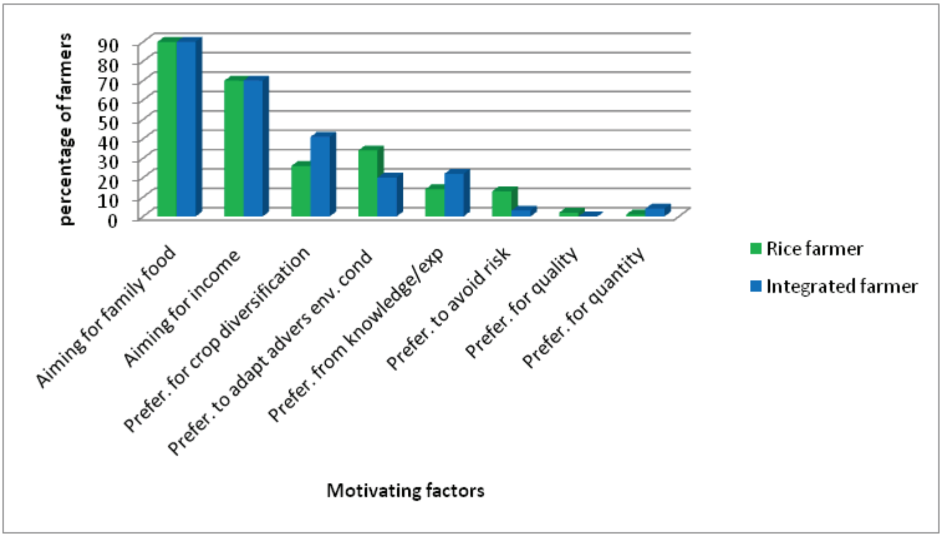


Figure 4.9 Motivating factors mentioned by Rice and Integrated farmers

Mostly the smallholder farmers see cropping as primary source for family food and may therefore perceive threats to their existing livelihood in situations of potential crop loss. In contrast, the larger farmers who see income as their main purpose may perceive opportunities by adapting their livelihood. The farmers who have preference to adapt under adverse environmental condition and have a preference to avoid risk may perceive high opportunities for livelihood adaptation. The experienced elderly farmers and integrated farmers who perceive low opportunity for livelihood change, are more inclined to continue rice and are conformable to switch between known varieties. Younger farmers with less cropping experience, having knowledge of other livelihoods may perceive high opportunity in livelihood adaptation and are motivated to switch faster into another livelihood. Farmers' preference for quality or quantity further influences the perceived opportunity, as farmers prefer quality of rice/yield for family food consumption and quantity of rice/yield for income. The farmers who have a preference for diversification of crop varieties often perceive high opportunity in livelihood adaptation and as leading farmers may be followed by other farmers. The above discussion shows that perceived opportunity or threat depends on the individual's motivating factors that vary also.

The above discussion on motivation concludes that the motivation is influenced with the perceived opportunities/ threats; in terms of how a situation (of triggering factors) is contributing to their aim (desired outcome) for a specific livelihood action. The motivation is also influenced with their perception of abilities for the possible available livelihood adaptation action and individuals' motivating factors.

4.4.2.5 The conceptual model of polder 30: case of rice and integrated farmer

Figure 4.10 specifies the triggering factors, motivation, abilities, actions and outcomes of rice and integrated farmers as discussed above. The triggering factors under four scenarios have influenced the farmer's perception, motivation and abilities for action.

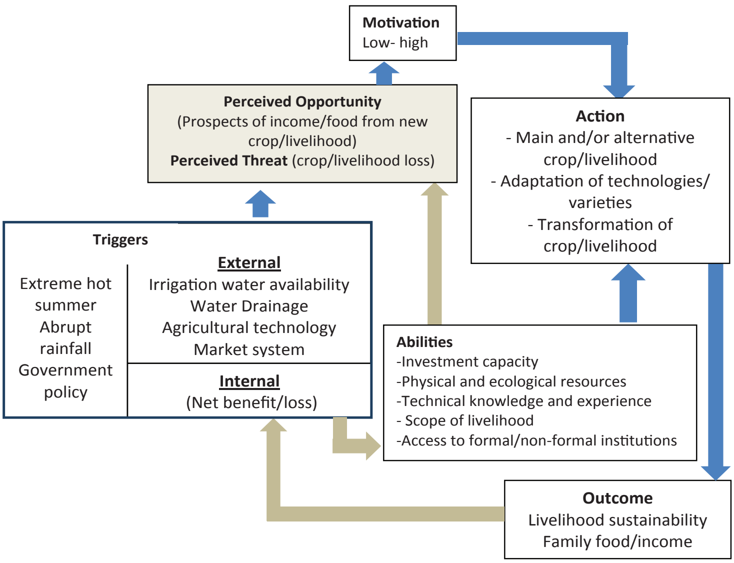


Figure 4.10 The conceptual model of Polder 30: case of rice and integrated farmers. *Blue and grey lines represent influence and potential influence respectively. The grey box of perceived opportunity/-threat represents the subjective perception of actors about the influence of triggers. The triggers can be internal (poor outcomes), or external, influenced by external driving events/trends. The other boxes represent key elements in decision making on livelihood adaptation.*

As conditions change (for worse), the livelihood adaptation action of both rice and integrated farmers gradually ranges from (i) continue main livelihood (*Boro* rice cropping/ integrated farming) and/or adaptation of other crop/livelihood for alternative income/food, towards (ii) adaptation of technologies for improving conditions (water availability, agro-technology etc.) and crop varieties (stress resistant variety); and finally (iii) transformational[21] adaptation of cropping/livelihood (shrimp farming/ migration/ off-farm/TRM).

[21]Transformation involves a long-term system-wide change and hard to return original.

The integrated farmers perceived opportunity and are more inclined to continue their current cropping system under three scenarios until the stagnant scenario. The rice farmers mostly elderly tends to continue rice farming in all three scenarios until the stagnant scenario, while young tend to adapt another livelihood as main or alternative to all scenarios. This broad pattern of livelihood adaptation of rice and integrated farmers may vary based on differentiated ability and motivation of farmers within their community over time.

In concluding, the analysis above has shown that the farmer's arguments for choosing a specific livelihood can be conceptualized in terms of the MOTA framework: a combination of triggering factors (in terms of scenario), motivation, and abilities lead to the choice for an adaptation action; through which the outcomes are produced (figure 4.1). The triggers influence perceived threats/opportunities, motivation and abilities for adaptation action; the framework can represent the relation in both the cases of rice farmers and integrated farmers (figure 4.10) in Polder 30.

4.4.3 Step 3: Illustration with Policy Implementation

In this illustration, with the word 'policymaker' we refer the government actors in strategic policymaking and local implementation in general. We assume that the main problem identified, from a policymaker perspective, is reduced crop production and loss of livelihood due to shortage of irrigation water, increased salinity, drainage congestion, climate variability etc. To address this policy problem, the policy objective is to enhance the crop production and livelihood sustainability. Under illustrative policy strategy, the government wants to diminish drainage congestion with restoration of rural river/canals and improve livelihood. For that, we assume that the government has a basic plan to i) re-excavate rivers/-canals locally ii) renovate gates, increase/ repair the embankment iii) promote a saline resistant early rice variety and some new variety of *Rabi* crops (sunflower, sugar beet etc.) including training on farming technique and improving market conditions (subsidy at inputs and fare price of product) for livelihood support of coastal inhabitants.

As a result of policy implementation, we assume that the improved water management has diminished drainage congestion; more irrigation water is available for cropping at dry season. The saline resistant early variety, less water-demanding crop varieties (sunflower, sugar beet etc.) and techniques are available with improved market for the farmers. The scenarios developed by the farmers in figure 4.5 and figure 4.6 that are external to them can be seen as the space of policy interaction with the local system for policymaker. How this works out depends on a variety of factors. Firstly, it depends on the impact of the policy strategy on triggering factors/trends at any of the scenarios. Secondly, how the policy strategy/ design is influencing the perception (threat/opportunity) of farmers and to which extent the farmers are motivated. Finally, we look at how the policy implementation is interacting with the abilities (or gaps in abilities) of farmers for adaptation.

We assume that with the above policy implementation, the flourishing scenario of favorable condition of water availability, drainage, agricultural technology and market is prevailing for the rice and integrated farmers. As of the figure 4.10, the adaptation action of farmer in figure 4.7 and 4.8 is a consequence of perceived threat/opportunity from the triggers, their motivation in terms of high/low and their ability in terms of financial, institutional and technical capacity.

To demonstrate the use of adaptation pathway maps, we postulate a development in which the policy strategy causing favorable conditions at the start will lose its effectiveness in diminishing drainage congestion and supporting technology and market conditions, and other conditions worsen as well. The question then is: what could happen in the livelihood adaptation of the farmer's community when conditions will gradually evolve from very favorable to very unfavorable?

4.4.4 Livelihood adaptation and policy adaptation pathways

The lists of livelihood adaptation action based on data from selected rice farmers and integrated farmers (figure 4.7 and 4.8) are used to generate a livelihood adaptation pathway map. The map presents the overview and sequence of livelihood adaptation actions that include the adaptation possibility of basic plan (of policy strategy) by the farmer community. The livelihood adaptation pathways suggest policy adaptation pathways for the policymaker.

Livelihood adaptation pathways

Figure 4.11 shows the livelihood adaptation pathway map for indicative (hypothetical) time axis from 2018-2050. The map provides the overview or summary of a set of pathways at a qualitative scale (1-10) of triggering condition (favorable -unfavorable), the corresponding motivation and ability at that period. Here, the scale we choose 1 to 10 to represent favorable to unfavorable respectively for worsening trajectory over time is corresponds with the use of pathway generator[22]. The unfavorable condition can be resultant due to uncertain socio-economic development and climate change. The concept of signpost (adaptation tipping point) that explains the need to change action via transfer station is used to form the sequence of livelihood adaptation action. The relationship is explained based on the conceptual model of Figure 4.10. Here, we conceptualized the favorable triggering condition for current livelihood as high availability of irrigation water, good water drainage, favorable market system and high availability of agro-technology. The timing of the adaptation can be earlier or later of the indicative year.

Both the rice and integrated farmers have high motivation to continue their existing variety of *Boro* rice cultivation until the value of 5 and integrated farming until the value of 8 as they perceive opportunity in irrigation water availability and improved drainage in the dry season. Based on motivation and ability at the correspondent condition, they perceive opportunity to grow *Rabi* crops (new variety) in combination with *Boro* rice as alternative food/income source (rice farmers) up to the value of 8.50, and at the land fringe/raising embankment as part of their existing integrated cropping system. However, both farmer communities perceive low opportunity in adaptation to saline resistant early rice variety at the favorable condition (of their own variety) because they perceive threat of crop loss from the new variety, required synchronization with neighbors in cultivation, pest management and harvesting for successful yield.

[22]Pathway generator in the https://publicwiki.deltares.nl/display/AP/Pathways+Generator

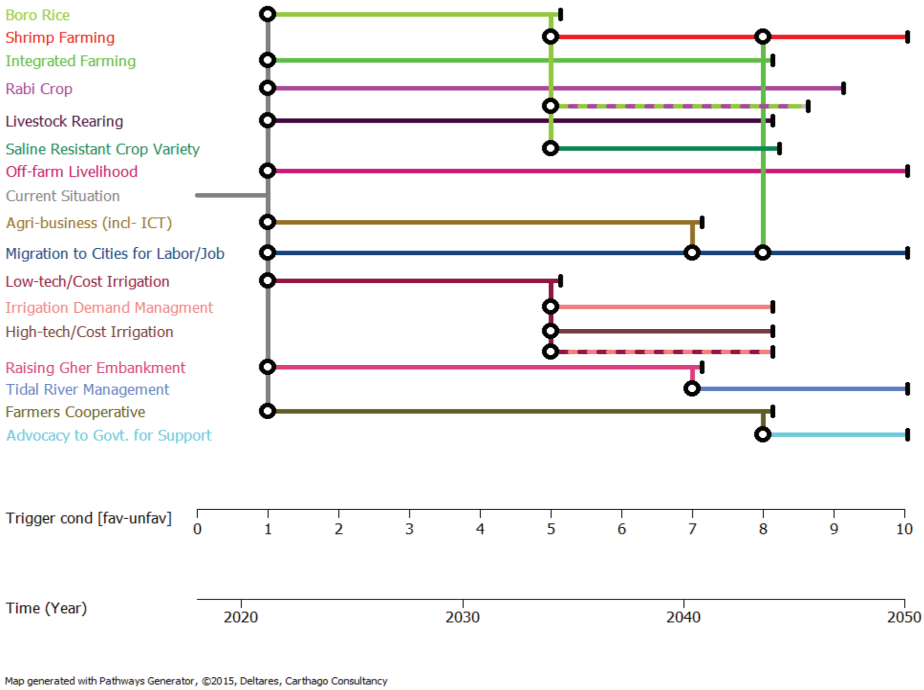


Figure 4.11 Livelihood adaptation pathway map of rice and integrated farmers in Polder 30. The triggering condition axis (favorable to unfavorable) is representing the combined conditions: irrigation water availability, water drainage, agricultural technology and market system of current rice/ integrated farmer. The time axis is indicative (hypothetical) from 2018 to 2050. Time at which a certain condition is reached - if at all - is uncertain also.

The perception may differ based on farmers' ability (land type, land size, access to agro-department etc.) and offered provisions for adopting saline resistant variety (subsidy, training, markets etc.). Some – but not many - farmers can be motivated extrinsically and may adopt saline resistant crops for few years as long as they perceive opportunity from promotional incentives. But, adaptation (long-term) to saline resistant crops largely depends on the perceived threat from conditions (i.e. shortage of irrigation water, high salinity etc.) for existing crops, re-current crop loss, perceived opportunity for saline resistant crop (i.e higher production, resilient, higher market price), farmers preference for adaptation/diversification and differentiated ability over time. The farmers may adapt to saline resistant crop at the value of 5 and continue up to the value of 8.

Besides the above farmer's adaptation to *Rabi* crops and saline resistant early rice varieties promoted by the government strategy, shrimp farming may be perceived as an opportunity. Motivated *Boro* rice farmers (based on ability) at the value of 5 and the integrated farmer at the value of 8 will choose for shrimp farming and continue until the value of 10. Farmers perceive opportunity in livestock rearing until the value of 8. Farmers also perceive opportunity in ICT based agri-business; particularly the young and women have high motivation for this upto the value of 7 based on correspondent ability at condition. Off-farm livelihood and migration to cities (for labor/job) are always perceived as opportunity for alternative income source while they become the main source of income at the unfavorable condition (for agricultural activity) specifically for small farmers. Integrated farmer perceive opportunity in raising *gher* embankment upto the value of 7; and above this condition they have high motivation for Tidal River Management (TRM) as they perceive threats of crop loss from severe drainage congestion.

The farmers continue low cost/tech irrigation until the value of 5 then combine with high cost/tech irrigation and/or shift to irrigation demand management until the value of 8. At the unfavorable condition around value 10 most farmers perceive threat to agricultural activities. Few farmers (mostly elderly), who have no other ability for livelihood, may still perceive opportunity to continue agricultural activity with low or no yield. Above the triggering condition of value 8, the farmers' cooperative turns into the advocacy to government for support.

The illustration above explains the possible sequence of livelihood adaptation actions, critical triggering conditions, differentiated ability and motivation over time. The time period (year) of reaching the triggering condition and correspondent motivation and ability can be earlier or later than indicated in the Figure 4.11 at different realization of future. This exercise indicates that the development and implementation of a basic plan by policymaker may not lead to success, specifically in terms of farmers' adaptation. Farmers have their own perception (opportunity/threat) of triggering conditions, differentiated ability and motivation for a set of available livelihood adaptation actions.

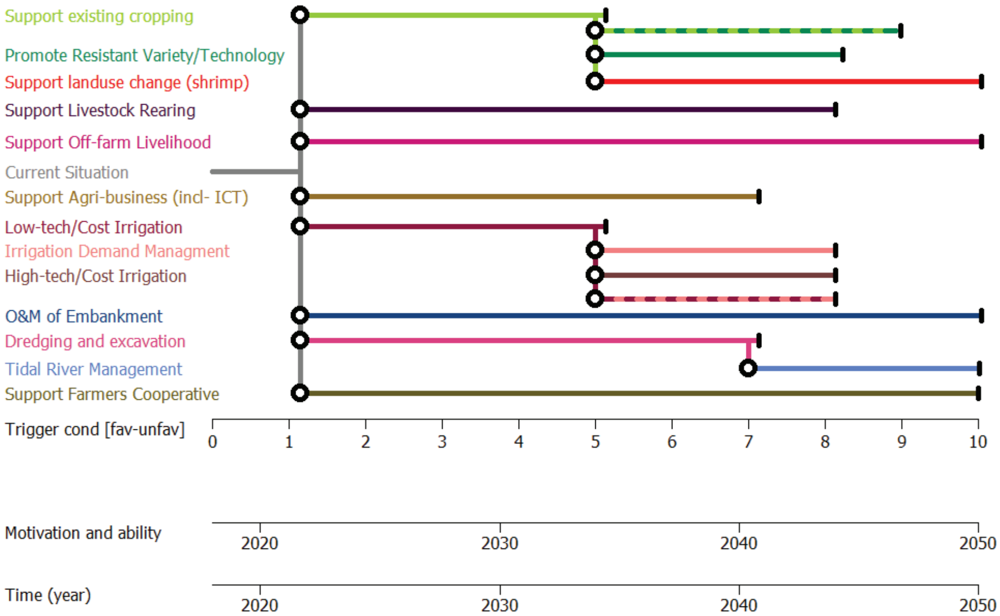
The above adaptation response of farmer community summarizes that the realization of the policy objective 'to enhance the crop production and livelihood sustainability' is specific to the farmers perception and adaptation response to the triggering conditions. At the left, trajectory of favorable condition of current livelihood of actor community may be assured under favorable conditions; however, when an unfavorable trajectory evolves due to uncertain changes in climate and socio-economic development, the farmers' may adapt their livelihood based on their perception on the condition and ability as conditions worsen. This suggests the design and adaptation of a policy in which the livelihood adaptation response of farmer community over time is monitored.

Policy adaptation pathways

The policy adaptation pathways are suggested by the above illustrative livelihood adaptation response at figure 4.11 to adapt the basic policy plan with new information over time as shown in figure 4.12 Policy Adaptation Pathway. The policy strategy can be focused to support/enhance the favorable condition for the broad set of livelihood types with support of existing cropping, O&M of embankment, dredging and excavation, low-cost/tech irrigation and support agri-business.

However, the unfavorable condition due to uncertain socio-economic development and climate change can be resulted. Promotion of resistant variety and technology can be combined with 'support existing cropping' to mitigate or hedge the uncertain adverse effect at the value of 5 while the farmers have preference for adaptation of a resistant variety/technology. Supporting land use change (i.e shrimp farming) can seize the opportunity of saline condition based on farmers' motivation and ability at the same time period. Supporting livestock rearing, off-farm livelihood, farmers' cooperative can serve as a shaping action that can reduce failure or enhance success to have additional livelihood options to cope with constrained situations. Along with Operation and Maintenance (O&M) of embankment, the dredging and excavation can shift into Tidal River Management at the value of 7 to seize the opportunities of the situation and farmers perception for adaptation.

Above all, the basic idea is for the policymaker to focus on the farmer's adaptation response as a trigger for policy adaptation instead of expecting a fixed desired response of farmers to a pre-designed policy strategy.



Map generated with Pathways Generator, ©2015, Deltares, Carthago Consultancy

Figure 4.12 Policy Adaptation Pathway Map. The triggering condition axis (favorable to unfavorable) is representing the combined conditions: irrigation water availability, water drainage, agricultural technology and market system of current rice/ integrated farmer. The time axis is indicative (hypothetical) from 2018 to 2050. Time at which a certain condition is reached - if at all - is uncertain also.

4.5 Reflection on the conceptual model

The conceptual model can cover a wide range of livelihood adaptation actions (as many as farmers can elicit) and support the devel opment of a livelihood adaptation pathway map under scenarios. This may provide holistic and practical information on the broad pattern of community livelihood adaptations under uncertainty for delta management locally.

The MOTA framework based on Fogg (2009) was developed to assess the feasibility of implementation of a specific policy or plan, by exploring the motivation and abilities of stakeholders (Phi et al., 2015). By extending the application of the MOTA framework (conceptually) in combination with a framed scenario approach, it is possible to identify the motivation and abilities of farmer communities (specific stakeholders) for their livelihood adaptation. The approach analyzed uncertainties in term of the development of triggering factors (water availability, water drainage, agricultural technology and market system) in the scenarios. In addition to exploring uncertainties, the approach can explain their influence on farmers' perception (threat/opportunity), their motivation and their abilities for action leading to a qualitative assessment of the probability that specific actions will be taken under a variety of circumstances. The result can be presented in a livelihood adaptation pathway map.

The participatory approach is relying on the perception of farmers and relevant stakeholders locally. Participatory scenario development allows getting the perception of farmers and local stakeholders on uncertainties in terms of important but out of control factors for them. The exercise of scenario development by farmers not only allows them to imagine different possible development directions of factors but also how their actions may be influenced by those conditions. The farmers were able to recognize how their perception of opportunities and/or threats is influencing their motivation and abilities for specific adaptation actions. Besides data collection, the participatory scenario development workshop has increased farmers capacity to think about uncertain changing conditions and how to take an informed decision/ action under that condition. However, the perception of farmers and relevant stakeholders may differ from the perception of policy maker at regional/national scale also. The perception of local stakeholders may vary also. Application is so far limited to the case of two farmer communities in a polder, but its general characteristics provide confidence that is can be applied as well to large varieties of farmers in different social-ecological systems or other livelihood communities.

The approach presents a way to take the subjective nature (perception, motivation) of stakeholders' action into account in the planning and implementation of an adaptive policy strategy. The approach can accommodate the diversity in perception of different communities at the polder scale. As shown in the perception of rice farmers and integrated farmers priorities differ for triggers/scenarios and motivating factors.

In concluding, this participatory MOTA conceptual-model based framed scenario approach is presented as a holistic system analysis approach. The approach enables a policymaker to explore the likelihood of a set of livelihood adaptation actions at different triggering conditions. Through analyzing CLA under uncertainty, this conceptual model based approach offers a way for policymakers to understand how farmer communities respond to uncertainties and how a policy should interact with that local social-ecological system.

4.6 Conclusion

In this research, we presented a conceptual-model based approach to explore community livelihood adaptation under uncertainty. The approach has two distinctive parts: (i) the conceptual model development combines the motivation and ability conceptual framework with a participatory framed scenario approach and (ii) the application of the conceptual model was illustrated in a livelihood adaptation pathway map with the concepts from adaptive policymaking and adaptation pathway. The uncertainties in terms of the development of triggering factors are framed into a limited set of scenarios. The triggering conditions under those scenarios influence the motivation and abilities (through perceived threat/opportunity) for livelihood adaptation action of farmer communities. Finally, the conceptual model based on the case of rice and integrated farmers has been applied to identify the possible farmers' adaptation actions in response to illustrative policy implementation. In this way, the approach can explore community livelihood adaptation under uncertainty to inform policy maker for adaptive planning and implementation.

Thus, the approach may support the planning and implementation of a national scale strategic plan like BDP 2100 at the regional or local scale. The analysis of CLA under uncertainty for planning and implementation of policy strategies, contributes to identify and consider areas for increasing ability/motivation, and this may improve the success (in terms of social adaptability) of a policy strategy. Continuous motioning will be necessary to determine the need and timing for adapting a policy strategy.

Further research and application to a wider variety of stakeholders (farmers at other location, other livelihoods) adaptation action and project beneficiaries at the practical field may help develop the approach for use by policymakers for practical purposes.

Chapter 5

The Extension of the MOTA based Framed Scenario Approach to a Computational Model

Case of Polder 31

Photo courtesy: author (2018)

List of symbols

l	The Livelihood Adaptation Action where l=1…m
t	Triggering Factor where t =1…..n
a	Ability factors where a=1……p
k	Actors type where k= 1…q
l_t	Livelihood Implication value of t
A	Ability score
r_a	Relative Importance Rank of ability factor
r_t	Relative Importance Rank of triggering factor
w_a	Relative Importance Weight of ability factor
w_t	Relative Importance Weight of triggering factor
P_a	Perceived Ability Value from ability factors
O_t	Perceived Opportunity Value from triggering factors
P_{xa}	Normalized Perceived Ability Value from ability factor
O_{xt}	Normalized Perceived Opportunity Value from triggering factor
MOT	Motivation Score
MOT_{min}	Minimum motivation thresholds
A_{min}	Minimum ability thresholds
A	Ability Score
MOTA	Motivation and Ability Score

5

The Extension of the MOTA-based Framed Scenario Approach to a Computational Model

Case of Polder 31

5. 1 Introduction

The community livelihood adaptation to changing conditions has a history of unexpected impact on national policy planning and implementation (chapter 2). In our approach we acknowledge and explore community livelihood adaptation as an uncertainty, going beyond the traditional approach of overlooking the uncertainties. In chapters 3 and 4, our focus was on development and application of conceptual-model based scenario approach for exploring community livelihood adaptation as an uncertainty in adaptive delta management. This chapter explores how to move toward a computational model that might be used as a tool for taking account of the community livelihood adaptation under uncertainty in computer-supported future exploration and adaptive planning and implementation.

The key challenge is capturing the highly qualitative, subjective and rich nature of actor decision-making and translating it into a formal computational framework for supporting adaptive planning and implementation (Elsawah et al., 2015; Nguyen et al., 2019a). In line with this, our contribution is to present a stepwise approach for translating the perception of actors (qualitative and conceptual) into a formal computational model for exploration of possible community livelihood adaptation under different circumstances. We demonstrate how the community livelihood adaptation decision can be represented from a mix of qualitative and quantitative data of local community to simulate their decision making under changing conditions. The result can be integrated with other relevant computational frameworks for future exploration of adaptive planning and implementation.

This chapter reports on the experiments for the case of polder 31. In Chapter 4, we have designed methodological steps with two distinct phases: a conceptual model development from farmers' perception using the MOTA framework, and its application in illustrative adaptive planning and implementation for the case of rice and integrated farmers in polder 30. This chapter focuses on demonstrating the computational framework development of MOTA conceptual model and its application in the case of livelihood adaptation action of both rice and shrimp farmers in polder 31.

The remainder of this chapter first describes the current situation of community livelihood in polder 31 in section 5.2. The methodology and approach are presented in section 5.3. The model development is discussed in section 5.4 and the model application is in section 5.5; the results on community livelihood adaptation action are shown in section 5.6. Finally section 5.7 reflects on the approach, the contribution to adaptive delta management is discussed in section 5.8 followed the concluding remarks in section 5.9.

5. 2 Polder 31: the current situation of community livelihood

Polder 31 with a 47-km long embankment is located in *Tildanga* and *Pankhali* unions of *Dacope* Upazila under KhulZa district; about 40 km south of Khulna city (WARPO, 2018). This polder covers an area of 7529 ha (WARPO, 2018). The polder is surrounded by four rivers; *Monga* in the North, *Badurgacha* in the Northwest, Dhaki in the Southeast and *Shibsha in* the West (Bakuluzzaman, 2012). The polder is located in the southwest hydrological region of the country. The area is within one agro-ecological zone, namely Ganges Tidal Flood Plain (Agro Ecological Zone-13).

In Polder 31, about 7830 households have a total population of 32,576 of which 15,996 are male and 16,580 are female. The population density is 1028 per sq km and average household size is 4.2. Literacy rate is 58.3%. About 27.5 % of the total population is in the main working force of age group 30 to 49 years. About 57% of the population is engaged in the agricultural sector, 41.1% in the salaried service sector and 1.9 % in industry (includes petty trade, handicraft, other manual sector). Men dominate in the agricultural sector (80.1%) whereas women dominate in the service sector (63.8%) (BBS, 2011a). Crop damage in this polder is mainly due to damage of embankment with cyclone and tidal surge (Sidr in 2007 and Aila in 2009), river erosion, siltation, drainage congestion and salinity (Bakuluzzaman, 2012). The salinity is high in the *Tildanga* while moderate to low in the *Pankhali* union.

This polder displays two contrasting dominant agricultural livelihoods in *Pankhali* and *Tildanga*, respectively. In *Pankhali*, the dominant agricultural livelihood (around two third of net cultivable area) is *Boro* rice/*Rabi* crops in the dry season after harvesting *Aman* rice in the wet season. Farmers open the gates in the beginning of the monsoon and close them in the dry season to prevent salt water entry. Around 10% of net cultivable area is in year round mixed (shrimp/prawn/other fish) fish cultivation. In *Tildanga*, around two third of the net cultivable area is in shrimp/fish farming either all the year round or in dry season after harvesting *Aman* rice in wet season. Brackish water is used from the rivers/ canals using the sluice gates (about 18 gates constructed by the BWDB, Third Fisheries Project and Fourth Fisheries Project) (Bakuluzzaman, 2012). *Bororice/ Rabi* crops cultivation is rare. Therefore in our case study, we identified and worked with a community of 10 rice farmers at *pankhali* village of *pankhali* union and a community of 10 shrimp farmers at *Kaminibasia* village of *Tildanga* union. The present situation of rice farmers and shrimp farmers are summarized in below subsections.

The rice farmers at *Pankhali* village of *Pankhali* union at figure 5.1 (left) are near the *Hatkhola Canal*. These are the same rice farmers' community who attended the focus group discussions for the cognitive map based conceptual model (Chapter 3). Out of 10 farmers 3 are women. A total of 70% respondents are from main working age group of 30 to 49 years and 30% respondents' age are more than 50 years. Around 80% of the farmers live in a *semi-pucca* house and 20% have a house of tin-structure. They have two cropping seasons: *Aman* rice in the wet season and *Boro* rice or *Rabi* crops (lentil, sesame, water-melon, vegetables etc.) in the dry season. They depend on the *Hatkhola Canal* connected with the *Monga river* for irrigation in the dry season. Water from three shallow wells equipped with pumps is another source of irrigation. March-April in the dry season is the most irrigation water scarcity period as all land needs irrigation and the water in the river, canal etc. dries up.

The shrimp farmers at *Kaminibasia* village of *Tildanga union* at figure 5.1 (right) are near the canal. Out of 10 farmers, 5 are women. All respondents are from the age group of the main working force from 24 to 50 years. Around 90% of the farmers have a *Kacca*/mud house and 10% have a house of tin structure. They have two cropping seasons: *Aman* rice in the wet season and shrimp/fish farming in the dry season. They maintain narrow channels to bring water in their land from the *Tetultola* canal connected with the *Dhaki river* for shrimp farming in the dry season. March-April in the dry season is the most critical period to maintain the required water depth (2.5 to 3 feet) and quality (i.e water temperature etc.) for shrimp farming, as the water in the canal and river dries up. During this period virus infestation is the major concern.

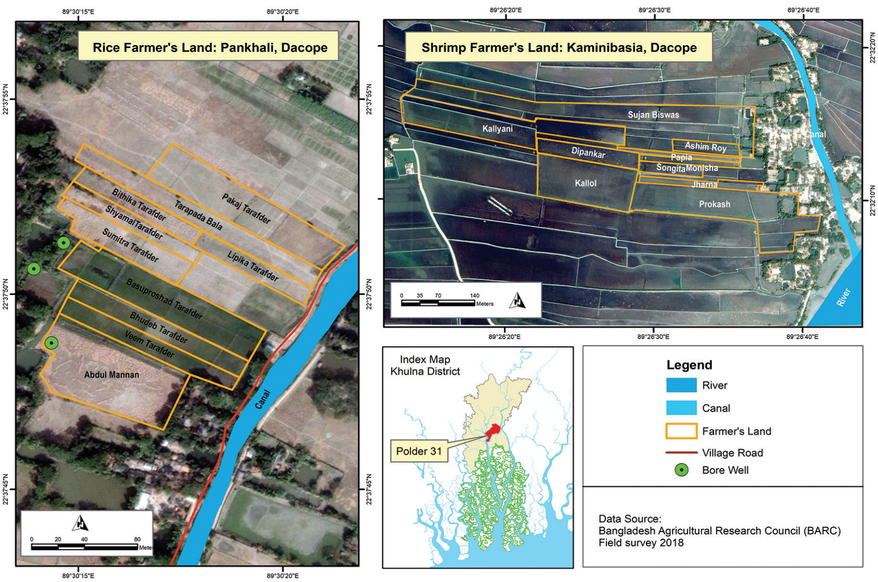


Figure 5.1 Rice and shrimp farmers' community at the study area in polder 31

5. 3 Methodology and approach

To explore CLA under uncertainty, we selected the same participatory model development approach as earlier in Chapter 4. Our approach is based on the Motivation and Ability (MOTA) conceptual model. The MOTA conceptual framework, as descriptive model of (rational) decision making, has been originally developed and applied to assess actor-oriented implementation maturity of policy plans (Nguyen et al., 2019b; Phi et al., 2015) and farmers adoptability (Nguyen et al., 2019a), and has not yet been applied in the wider field. In earlier chapter, we applied this conceptual model to explore the community livelihood adaptation in the case of rice and integrated farmers in polder 30.

For participatory model development, our data collection method from farmer's perception is designed and followed same as chapter 4. We performed three participatory scenario development workshops and 20 individual interviews in 2018. The workshops were with 10 rice farmers, 10 shrimp farmers, and 15 local stakeholders.See appendix 5.1.The local stakeholders included representatives of a local elected body, an agriculture officer, a fisheries officer, a livestock officer, representatives of the water management committee, a gate operator, a NGO representative, a teacher, a businessman etc. We conducted 20 individual interviews with the same rice and shrimp farmers for triangulation of collective data and data on abilities of individual households. Based on preliminary data of the same rice farmers (cognitive map in chapter 3), a semi-structured and pre-tested questionnaire was used for interviews of the farmers. For the interviews, we went to the house and agricultural land of all participating farmers; observing their current livelihood, cropping pattern and collecting GPS data of their agricultural land for developing a GIS map of the community, shown in figure 5.1.

Based on the conceptual model, a set of quantitative equations and simple logical functions are arranged in a computational framework to derive perceived opportunity/threat, motivation and ability for a livelihood adaptation action from the data of triggering factors and ability factors. This computational framework has been implemented in MS Excel to represent the decision making process of the livelihood adaptation action of an actor community at specific conditions. In the case, the data collected showed homogeneity in perceptions and preferred livelihood decision among the shrimp farmers, but significant differences in this respect between the elderly and the young rice farmers. Therefore, for the computations we further subdivided the rice farmer community based on age group. The model result was verified with the farmer's decision on livelihood adaptation under four scenarios as expressed in the workshops, and compared with the past history from available literature.

5. 4 Model Development of Community Livelihood Adaptation under Uncertainty

5.4.1 The conceptual model

The conceptual model based on MOTA framework (Phi et al., 2015), as shown in figure 5.2, explains the choice of community livelihood adaptation (CLA) action as the causal consequence of trigger, motivation and ability; where the outcome in terms of contribution to family food/income and livelihood sustainability (at a future moment in time) is the result of the chosen action. The triggers here in this model are the factors that cause actors to perceive opportunities or threats; in terms of how this situation is contributing to achieve their aim (or outcome); the perceived opportunities or threats, in turn, influence the motivation of actors for specific livelihood adaptation actions.

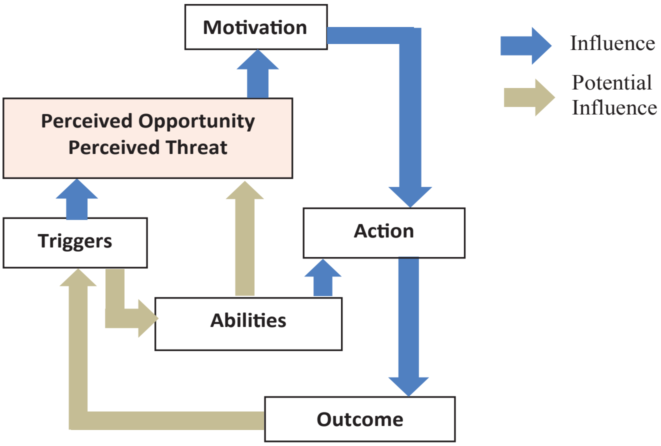


Figure 5.2 Conceptual model for exploring CLA under uncertainty

The abilities, another pre-requisite for action, here in this model are qualifying conditions that are relative to the required abilities for specific livelihood actions. The abilities depend on the financial, technological and institutional conditions of the actor. The triggers may have potential influence on abilities. The outcome may have potential influence as trigger in a next year/in future. Motivation and ability can trade off; a high enough motivation can influence the choice of difficult actions also (Fogg, 2009). On the other hand, the abilities may have potential influence on the motivation through perceived opportunity/threat as a higher ability may influence the perceived opportunity positively. We assume that both the motivation and abilities of an actor need to be equal to or higher than that of a threshold (minimum non-zero) for an action to be chosen under that situation (Fogg, 2009). We assumed that the actor selects the action with the highest combination of motivation and ability as the preferred one from a set of available actions.

5.4.2 Specification of the CLA computational framework from the conceptual model

The developed model is a pragmatic tool for exploring Community Livelihood Adaptation (CLA) under uncertainty. The purpose of the model is to assess the preference of different actors for available livelihood actions as a function of different factors. The attractiveness of livelihood adaptation action l (l=1…m) for actor k (k=1….q) is a function of the values of motivation (MOT) and of ability (A) for that action and for that actor, at a specific scenario. The value of the motivation score is assumed to be a function of perceived opportunity (O_t) as determined by the triggering factors t (t=1….n) and of the value of the ability score (A). The value of the ability score is assumed to be a function of perceived ability (P_a) from the values of ability factors a (a= 1…p). Figure 5.3 below shows how the MOTA score for a specific livelihood action of a specific actor community at a given scenario is computed from the values of the triggering and ability factors.

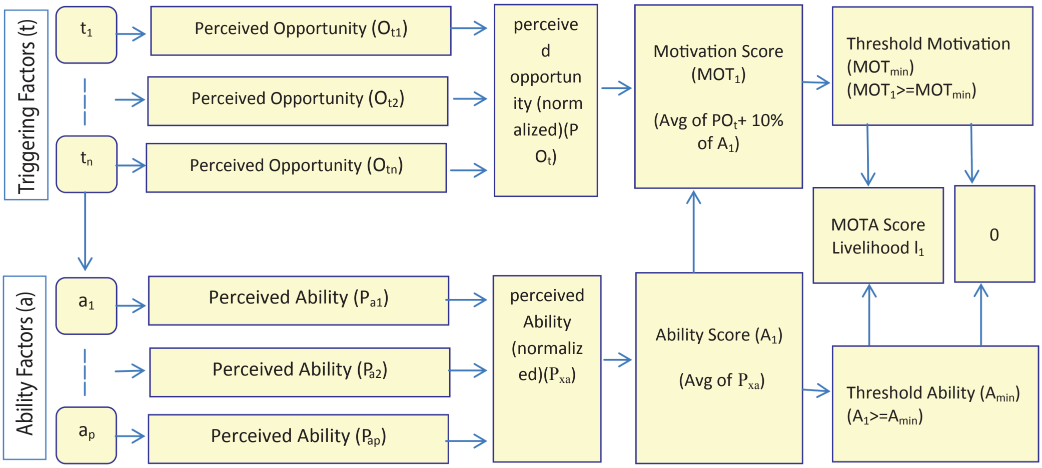


Figure 5.3 Computation of MOTA score for a livelihood action of an actor community at a scenario

We used the same method for calculation of all livelihood adaptation actions for all actor communities for all scenarios. The detailed steps followed in developing the computational framework from the conceptual model in the participatory model development approach are described in subsections below.

Step 1 The purpose of the model is set to assess the preference of different actors for available livelihood actions as a function of different factors. As of model purpose, the input data on triggering factors (t), ability factors (a), and possible livelihood adaptation actions (l) of actors (k) is collected. For livelihood adaptation actions, staying at the same livelihood is included as one of the possible actions.

Step 2 From ability factors to perceived ability and ability score

Step 2.1 The data on the percentage of farmers (at the community) for each of six individual ability factors (a_1,a_2,a_3..) are organized into a scale of five from very high (0.9), high (0.7), average (0.5), below average (0.3) and low (0.1) as shown in table 5.1. For example, the weighted average value 0.52 of ability factor (a_1) in the Table is generated on the basis of data on the fractions of the community having the different ability levels, in the example for (0.2 =20%) of the farmers ability factor (a_1) is at very high (0.9) level. Then, the average is computed as (0.9*0.2+0.7*0.3+0.5*0.1+0.3*0.2+0.1*0.2). Similarly, the weighted average of all other ability factors is calculated to generate the current ability level of the actor community. We have data on the current ability levels for the current livelihood and for reasons of simplicity we used these to calculate the ability level of that actor community for the same action at any of four suitable scenarios

Table 5.1 The distribution of two ability factors for one actor community of 10 farmers

Ability factors	Very high 0.9	High 0.7	Average 0.5	Below average 0.3	Low 0.1	weighted average score
Ability factor 1 (a_1)	0.2	0.3	0.1	0.2	0.2	0.52
Ability factor 2 (a_2)	0.9	0	0.1	0	0	0.86

Note: values represent the percentage of farmers at that category

Step 2.2 The relative importance (r_a) of six ability factors for a specific livelihood adaptation action is ranked with increasing order of importance based on farmer perceptions as expressed in interviews/workshops and our judgment. For example, the importance of ability factors to the rice farmer for rice farming can be investment capacity (ranked 6), technical knowledge (5), access to social group (4), Access to Government, Fisheries/agricultural Department (3), Ownership of livelihood assets (2) and scope of livelihood (1). This order of importance is different for the same rice farmer when an industrial job or other livelihood actions are considered; it is also different for shrimp farmers for other livelihood actions. For Importance weight value (w_a) corresponding to this importance rank of ability factor, we relied on the weight for 6 criteria of Rietveld and Ouwersloot (1990), which focus on the expected values of the weight as best representation of the equally probable distribution of all criteria.

Step 2.3 The perceived ability value (P_a) from ability factor (a_1) is calculated with the multiplication of ability level value (a_1) and relative importance weight (w_a) for livelihood action l_1. Then, the normalized perceived ability value (P_{xa}) from the six ability factors for livelihood action l_1 is calculated with equation (1). Where the P_{min} is the minimum value of P_a, P_{max} is the maximum value of P_a for livelihood adaptation action l_1.

Equation-1

Normalized perceived ability value (P_{xa}) = $(P_a - P_{min}) / (p_{max} - P_{min})$

Step 2.4 The ability score (A) of the current livelihood as for example rice farming for the rice farmers at the selected scenario is used determine the average value of normalized perceived ability value P_{xa}. We choose the average value to represent the ability of the community. Currently the rice farmers choose to stay at rice farming, so at the current condition rice farming is assumed to be their preferred livelihood.

Step 2.5 Based on the conceptual model, the ability score for other livelihoods at the same scenario is derived from (i) the relative requirements for that livelihood action and (ii) the relative importance ranking of ability factors for that livelihood action. The values are assigned and tested based on farmers perception and our judgment to generate the ability score for other livelihood.

Step 2.6 we derived the ability score for all livelihoods at other scenarios based on the assumption in the conceptual model that the triggering factors may have potential influence on the values of ability factors. We assigned the value of ability factors based on farmer perceptions and our judgment.

Step 3 From triggering factors to perceived opportunity and motivation score

Step 3.1 The list of triggering factors that are most important for livelihood adaptation but over which farmers have low or no control (i.e., external factors) is determined. Subsequently, extreme values (high or low) of these triggering factors are used to develop four future-oriented scenarios in a participatory workshop.

Step 3.2 According to the conceptual model, we assume that the influence of the same triggering factor in the same scenario on perceived opportunity of an actor is specific to the livelihood action. For example, farmers perceive low irrigation water availability as a threat for rice farming but as an opportunity for shrimp farming. We considered this influence as livelihood implication (l_t) of individual triggering factor for a specific livelihood action as good, average and poor with corresponding values of 0.8, 0.5 and 0.2. We considered the perceived threat as implicit in the low opportunity. The value is assigned based on farmers' perception and our judgment.

Step 3.3 In this step, we assume that the relative influence of the triggering factors on perceived opportunity is actor and livelihood action specific. For instance, out of five triggering factors, the increasing order of importance for rice farmers can be the irrigation water availability (5), saline water availability (4), availability of agro-technology (3), availability of market (2) and availability of industries (1). But for shrimp farming this order of importance can be different. The importance ranking is based on farmers' perception and our judgment. For transforming this importance rank into a relative importance weight value (w_t), we relied on the weight for 5 criteria of Rietveld and Ouwersloot (1990).

Step 3.4 The Perceived Opportunity value (O_{t1}) from triggering factor (t_1) is calculated with the multiplication of relative importance weight (Wt_1) and livelihood implication value (l_{t1}) for livelihood action l_1. Then, the Normalized Perceived Opportunity value (O_{xt}) from five triggering factors for livelihood action l_1 is calculated with the following equation (2). Where the O_{min} is the minimum value of O_t, O_{max} is the maximum value of O_t for livelihood adaptation action l_1.

Equation-2

Normalized perceived opportunity value $(O_{xt}) = (O_t - O_{min}) / (O_{max} - O_{min})$

Step 3.5 Based on the conceptual model, the ability may have potential influence on the perceived opportunity as higher ability may influence the perceived opportunity positively. Therefore, the influence of the ability score is added to the average of Normalized Perceived Opportunity Value (O_{xt}) from five triggers to generate the Motivation Score (MOT) of livelihood action l_1 of actor k_1. We considered the reinforcing influence of 10% of the Ability score (A) with the following equation (3) to derive Motivation (MOT) score.

Equation-3

Motivation score (MOT) = Average O_{xt} + A*0.1

Step 4 From Motivation score and Ability score to MOTA score of livelihood adaptation

Step 4.1 For calculation of the MOTA score we followed the earlier authors who multiplied the motivation score and ability score to keep the MOTA score at the scale of 0 to 1. The MOTA score of each actor community for each livelihood adaptation action under each scenario is computed according to equation (4) below from the motivation score (MOT) and ability score (A), each of which is calculated separately in the earlier steps 2 and 3.

Equation-4

MOTA Score (for each livelihood adaptation action) = MOT *A

Step 4.2 The livelihood adaptation action with the highest MOTA score at a specific scenario is considered to be the preferred one. For example, the highest score of rice farmers for rice farming confirms that this is their preferred livelihood action. However, some livelihood actions may be considered as not suitable or non-preferred at a specific scenario due to either or both too low motivation and too low ability for that specific livelihood action. A threshold or minimum value of motivation and ability is therefore introduced based on (Fogg, 2009). We considered that for a valid livelihood action, the motivation score is required to be equal or higher than that of the thresholds value 0.35 (i.e minimum 35% motivation) and the ability score is required to be equal or higher than that of threshold value 0.30 (i.e minimum 30% ability). If any of ability score (A) or motivation (MOT) score or both is lower than the threshold value, then the MOTA score will be 0. This implies that the actor does not perceive any opportunity in that livelihood adaptation action at that scenario. This can be applied in the equation (5) below.

Equation-5

MOTA Score = IF (MOT>=MOT_{min}, IF (A>=A_{min}, (MOT*A), 0), 0)

For illustrative purposes, the preferred livelihood adaptation action is considered to be the one with the highest MOTA score whereas the MOTA score of other livelihood adaptation actions represents the range of preference for possible and non-preferred livelihood actions at a scenario. Now, the livelihood adaptation actions of different actor communities under several scenarios can be identified and analyzed.

5. 5 Model application

For demonstrating the computational CLA under uncertainty model, Polder 31 was used as a case, using data from workshops and interviews with two rice and shrimp farmers' communities in Polder 31. The determination of individual components of this conceptual model and implementation in the computational framework as illustrated in Figure 5.4 are elaborated below.

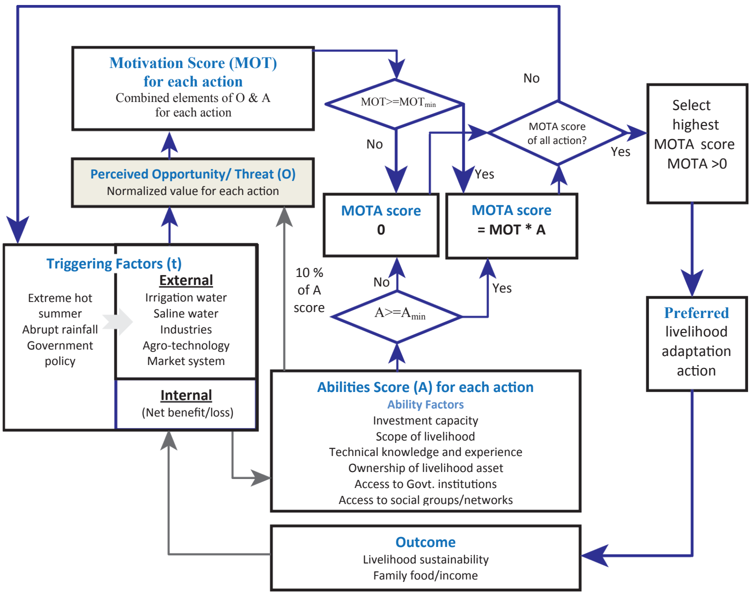


Figure 5.4 The computational flow-diagram of livelihood adaptation decision under a given scenario.The choice of preferred livelihood adaptation is per scenario (a set of triggering factor). For one specific scenario, the values of the set of triggering factors does not change, they change for another scenario. Before MOTA score calculation for a livelihood, it does two logical tests with minimum threshold values of Motivation and Ability respectively, and then calculates the MOTA score. After computation of the MOTA score for each action, the algorithm goes to the next possible action, starting again with the triggers (feedback on top).Finally, MOTA scores for all possible actions are compared, and the highest MOTA score defines the preferred livelihood for that scenario and feeds back into outcome (for a next year).The feedback arrow from outcome goes to the triggering factors for next time period, and has not been implemented in this current version for demonstration.

5. 5.1 Determination of triggering factors for scenarios

The rice and shrimp farmers have developed scenarios separately around the important factors for their livelihood but have low/no control over the factors (external scenarios). The rice farmers think economic development may go into two alternative directions: agricultural or industrial, and these are manifested to them as availability of agro technology or of industries. The four scenarios generated by rice and shrimp farmers are shown in Table 5.2. the analogous choice of names of scenarios are as of chapter 5. We have four alternative scenarios per actor group, each with five triggering factors. The qualitative descriptions of these scenarios can be found in appendix 5.2 and appendix 5.3. For each scenario the values of each triggering factor are defined and fixed based on the farmers' perception and qualitative description of scenarios.

Table 5.2 Scenarios developed by rice and shrimp farmers

Triggering factor (availability)	**Scenarios developed by rice farmers**			
	Water available Agro (Flourish)	Water constrained Agro	Water constrained Industrial	Water available Industrial
Irrigation Water (IW)	High	Low	Low	High
Saline Water (SW)	Low	High	High	Low
Agro Technology (AT)	High	High	Low	Low
Market System (MS)	High	High	High	Low
Industries (IND)	Low	Low	High	High
Triggering factor (availability)	**Scenarios developed by shrimp farmers**			
	Flourish	Water constrained	Market constrained	Stagnant
Irrigation Water (IW)	Low	Low	Low	Low
Saline Water (SW)	High	Low	High	Low
Agro Technology (AT)	High	High	Low	Low
Market System (MS)	High	High	Low	Low
Industries (IND)	Low	Low	Low	Low

5.5.2 Determination of livelihood adaptation action by the farmers

After scenario development, the farmers have indicated which livelihood adaptation action they would choose under each scenario. The broad pattern of livelihood adaptation actions mentioned is i) keep the current main livelihood and adapt one or two additional livelihood to diversify at the flourish condition ii) adaptation of technologies/varieties under the constrained scenario iii) switch to other crops/ livelihoods or choose to leave land fallow under the stagnant condition. This is shown in Figure 5.5.

Market system (unfavorable-favorable)

Water-constrained Scenario Main livelihood Continuation of shrimp (with/without rice) with Techniques of Gher improvement Techniques of water quality improvement Alternatives Fallow land Fish trading and Crab fattening	Flourish Scenario Main livelihood Continuation of shrimp (with/without rice)
Stagnant Scenario Main livelihood Continuation of shrimp (with/without rice) after pause for some years Alternatives Fallow land off-farm livelihood and Fish trading	Market-constrained Scenario Main livelihood Continuation of shrimp (with/without rice) with improving network/linkage with market Alternatives Increase of family fish consumption Drying fish

Water availability (poor- good)

(a) Livelihood adaptation action of shrimp farmers under four scenarios

Development (Industrial -agricult ural)

Water-constrained Agro Scenario *Main livelihood* *Rice farming (elderly)* *Rabi crops (all)* *Shrimp (with/without rice) (young)* *Alternatives* *Agro-processing industries (young)*	***Flourish Agro Scenario*** *Main livelihood* *Rice farming (all)* *Alternatives* *Rabi crops* *Agro-processing industries (young)*
Water-constrained Industrial Scenario *Main livelihood* *Rice cropping (elderly)* *Shrimp (with/without rice) (all)* *Industrial job/labor (young)* *Fallow* *Alternative* *Sale of agricultural land* *Non-agricultural alternative occupation* *Migration to other areas, region or country*	***Water Available Industrial Scenario*** *Main livelihood* *Rice cropping (elderly)* *Industrial job/labor (young)* *Alternative* *Sale of agricultural land* *Non-agricultural alternative occupation* *Migration to other areas, region or country*

Water availability (poor- good)

(b) Livelihood adaptation action of rice farmers under four scenarios

Figure 5.5 Livelihood adaptation action of shrimp and rice farmers under four scenarios

All shrimp farmers continue shrimp farming under all conditions. Under the constrained condition, the shrimp farmers continue shrimp farming with the adaptation of technology/variety for water/market constrained condition. Under the stagnant condition they keep land fallow for some season/year with off-farm livelihood, fish trading.

Among rice farmers, the elderly continue rice farming as main livelihood under all four conditions; they adapt *Rabi* crops under flourish and water-constrained agro conditions; Shrimp (with/without rice) and/or fallow under water-constrained industrial conditions. However, the young rice farmers continue rice along with *Rabi* crops, Agro-processing industries under flourish and include Shrimp (with/without rice) under the both the water-constrained agro and the water-constrained industrial condition. They perceive opportunities in switching to industrial job/labor, along with sale of agricultural land, leave land fallow, non-agricultural alternative occupation, and migration under water available industrial conditions.

Based on the above data, we considered five main livelihood adaptation actions for demonstration of the computational model in polder 31: 1. Rice farming, 2. Rabi crop, 3. Shrimp (with/without rice), 4. Industrial job/labor and 5. Fallow. However, this list can vary and be larger also.

We observed that the perception of young and elderly rice farmers can be significantly different while the perception of young and elderly shrimp farmers was aligned during the scenario development workshop. Therefore, for demonstration of the model, we considered three categories of actors: i) elderly rice farmers ii) young rice farmers iii) shrimp farmers.

5.5.3 From ability factor to perceived ability value and ability score

For demonstration purposes we selected two ability indicators per ability type (financial, technical and institutional), and prioritized them based on the dataset of ability factors of 10 rice farmers and 10 shrimp farmers as shown in Table 5.3 below for shrimp farmers. The values in the table are based on data specified in appendix 5.4, and they reflect the values for shrimp farming under the water constrained scenario. The relative importance rank (r_a) and importance weight (w_a) for the six factors are generated as explained above under step 2.2 in section 5.3; the perceived ability value (P_a), normalized perceived ability value (P_{xa}) and ability score (A) for shrimp farming under the water constrained scenario are derived as explained in steps 2.3 and 2.4 respectively.

Table 5.3 Ability score of shrimp farmer for shrimp farming under water constrained scenario

Ability Factors	a	r_a	w_a	O_a	O_{xa}	A
Investment capacity	0.52	6	0.41	0.21	1.00	0.450
Scope of livelihood	0.86	4	0.16	0.14	0.62	
Technical knowledge	0.56	5	0.24	0.13	0.60	
Ownership of livelihood asset	0.56	2	0.06	0.03	0.10	
Access to govt. Fisheries/Agro D.	0.48	3	0.10	0.05	0.17	
Access to social groups/networks	0.48	1	0.03	0.01	0.21	

Next, as explained in step 2.5, the ability level and importance weight for Rice farming, *Rabi* crops, Industries and Fallow under the same scenario are assigned. As the ability factors are representing the average ability of the shrimp farmer's community, the ability factors are changed relative to the livelihood adaptation actions only. Under this scenario, the required abilities are the same for the Rice and *Rabi* crops, the technical knowledge needs to be higher for industries while all/some of the ability factors can be lower for fallow land.

The importance of the six ability factors is livelihood action and actor specific. For example, for adaptation to rice and *Rabi* crops by shrimp farmers under the water constrained scenario, the importance of access to social groups/networks is 2^{nd} highest and the scope/ diversity of their current livelihood is lowest while the other four abilities have the same importance as for shrimp farming. For industries, the technical knowledge is the highest important ability factor. Similarly as of step 2.6, the value and relative importance rank of ability factors are assigned to generate ability scores for all livelihoods under the other three scenarios.

For rice farmers, the current abilities are considered for the water-available agro scenario and the data on ability factors of elderly and young farmers are utilized for rice farming as livelihood option. We followed the same steps to generate the ability score of rice farmers for other livelihoods at the same scenario and all livelihoods at other three scenarios.

5.5.4 From triggering factors to perceived opportunity value and motivation score

From data about the triggering factors, the livelihood implication (l_t) of each triggering factor for each livelihood adaptation action under each scenario is assigned based on step 3.2. For example, the high availability of saline water is perceived poor (0.2) for rice farming but good (0.8) for shrimp farming. For shrimp farmers, the perceived livelihood implication of the triggering factors under the water constrained condition for shrimp farming is shown in Table 5.4. The perceived opportunity value is derived as explained in step 3.3 and 3.4. The motivation score is derived based on step 3.5.

Table 5.4 Motivation score of shrimp farmer for shrimp farming under water-constrained scenario

Triggering factor	Scenario			r_t (5-1)	w_t	O_t	O_{xt}	MOT
	availa bility	l_t	l_t value					
Irrigation (IW)	Low	Good	0.8	4	0.26	0.21	0.88	
Saline water (SW)	Low	Average	0.5	5	0.46	0.23	1.00	
Agro technology (AT)	High	Average	0.5	3	0.16	0.08	0.24	0.510
Market system (MS)	High	Good	0.8	2	0.09	0.07	0.20	
Industries (IND)	Low	Good	0.8	1	0.04	0.03	0.00	

In this scenario, the shrimp farmers perceive low availability of irrigation water as good; low saline water (i.e below the standard amount for shrimp farming) is average; high agro technology is average; high market system is good; and low industries (push to continue shrimp) is good for shrimp farming. The relative importance of triggering factors for shrimp farming is, in descending order (high-low), saline water, irrigation water, agro-technology, market system and industries for shrimp farming. The resulting motivation score for shrimp farming under the water constrained scenario is 0.510.

Similarly, the motivation score is calculated for five livelihood actions for three types of farmers under the four scenarios identified by each farmer category. The data shows that the perceived opportunity and motivation is also influenced by motivating factors of individuals such as preference of crop diversification, preference to adapt with adverse climatic condition, preference for quality or quantity etc. These individual preference factors however have not been included in the present initial exploration of the potential of a computational model.

5.5.5 From motivation and ability score to MOTA score of livelihood actions

Based on step 4, The MOTA score for each livelihood adaptation action is calculated from the motivation score and ability score in excel with an "IF" Function as of equation 5 at step 4.2. The MOTA score of shrimp farmers for five livelihood adaptation actions under the water constrained scenario is used to identify the preferred livelihood adaptation action. As of step 4.2 the auto generation of preferred livelihood adaptation action based on the highest MOTA score is defined by using the following "VLOOKUP" function in excel as of equation (6).

Equation-6

VLOOKUP (MAX (Range of MOTA Score), MOTA Score: Livelihood Actions, 2, FALSE)

Under the water constrained scenario, the preferences of shrimp farmers for five livelihood adaptation actions based on the computed MOTA scores are shown in table 5.5: below. The result shows that, according to the model, shrimp farming is the preferred livelihood action for shrimp farmers while fallow land can be a possible option but rice farming, Rabi crops and industrial job are identified as non-preferred at all as a consequence of not meeting a threshold value for motivation and/or ability.

Table 5.5 MOTA score of shrimp farmers for five livelihood adaptation action under the water constrained scenario

<table>
<tr><th>Livelihood action</th><th>MOTA score</th><th>Preferred Livelihood Action</th></tr>
<tr><td>Rice farming</td><td>0.000</td><td rowspan="5">Shrimp</td></tr>
<tr><td>Rabi crops</td><td>0.000</td></tr>
<tr><td>Shrimp</td><td>0.230</td></tr>
<tr><td>Industrial job</td><td>0.000</td></tr>
<tr><td>Fallow</td><td>0.145</td></tr>
</table>

5.6 Results

The results of the pilot computational CLA under uncertainty model for shrimp farmers and rice farmers of polder 31 under four scenarios are shown in figure 5.6 and figure 5.7 respectively. The results indicate the preference range of livelihood adaptation actions as preferred, possible and non-preferred for two communities of rice (elderly and young) and for the shrimp farmers under several scenarios.

The result for shrimp farmers in figure 5.6 shows that shrimp farming is the preferred livelihood action under three scenarios while fallow land is preferred in the stagnant scenario. The other spectrum of the preference includes the Rabi crops and industrial jobs which are estimated as non-preferred for all scenarios. The list of possible actions at the stagnant condition includes shrimp farming and rice farming while fallow is the possible livelihood action under the water constrained scenario.

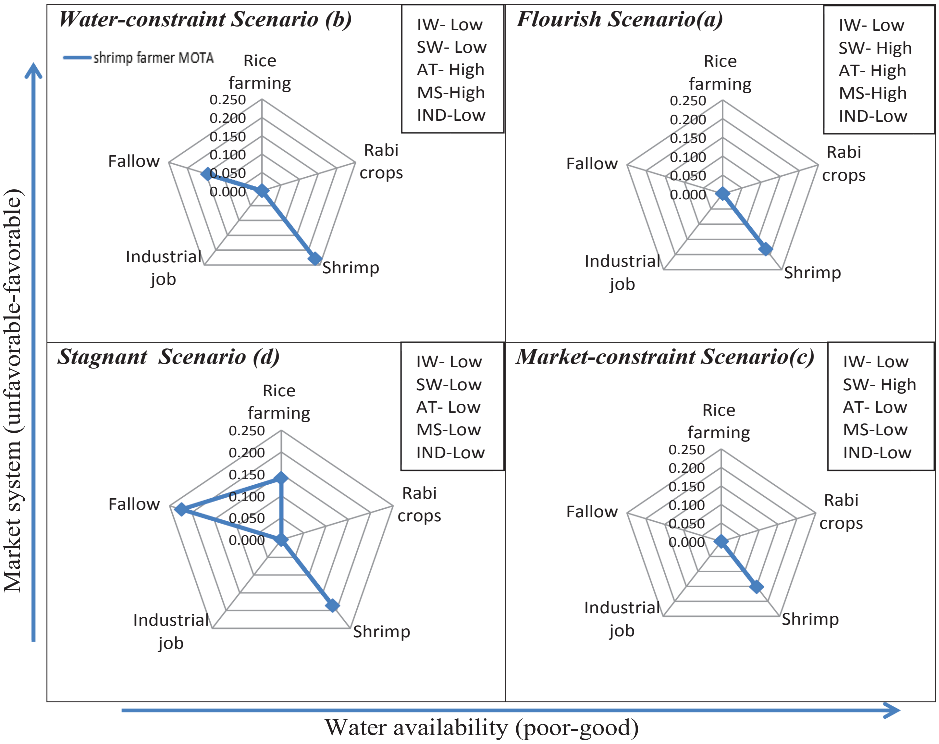


Figure 5.6 The result of CLA under uncertainty model for shrimp farmer in polder 31

The analysis of the motivation and ability scores for the shrimp farmer community in the model shows that the motivation score of the non-preferred livelihood adaptation actions was lower than the threshold under flourish, water-constrained and market-constrained scenario, while the ability score was higher than that of threshold. Under the stagnant scenario, the ability score was lower than that of the threshold while the motivation score was higher than the threshold. This is representative for the shrimp farmers at the case study area of polder 31.

The results of CLA under Uncertainty computational model for the elderly and the young rice farmers of polder 31 under four scenarios are shown in figure 5.7.

Under the water-available Agro-scenario, as of figure 5.7 (a), the preferred livelihood action of both elderly and young farmers is rice. Possible livelihood actions for both are Rabi crops while industrial job are possible for the young. Shrimp farming and fallow (by both) and industrial jobs (elderly only) are considered non-preferred because either motivation or ability is lower than the respective threshold.

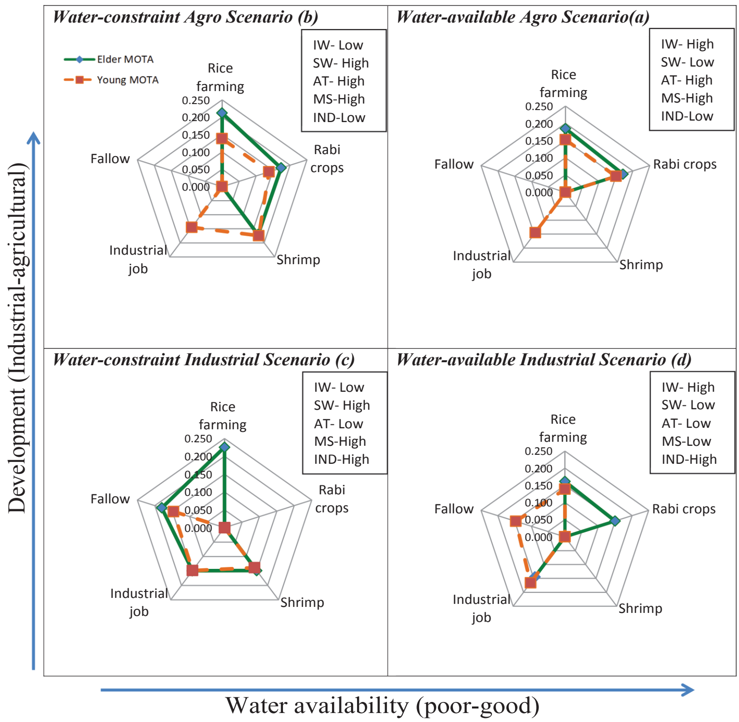


Figure 5.7 The result of CLA under uncertainty model for elderly and young rice farmers in polder 31

Under the water-constrained Agro-scenario, see figure 5.7 (b), the preferred livelihood action of elderly rice farmers is rice whereas that of the young ones is shrimp. Possible livelihood actions are Rabi crops for both, shrimp for the elderly and industrial job for the young. Fallow (by both) and industrial job (elderly only) are considered non-preferred due to either lower motivation or abilities than that of the thresholds.

Under the water-constrained industrial-scenario, see figure 5.7 (c), the preferred livelihood action of the elderly is rice whereas that of the young is industrial job. Possible livelihood actions of elderly are fallow land, shrimp and industrial job, while shrimp and fallow land for the young. Rabi crop (by both) and rice (young only) are considered non-preferred due to lower motivation scores than that of the thresholds.

Under the water-available industrial-scenario, see figure 5.7 (b), the preferred livelihood action of the elderly is rice whereas that of the young is industrial job. Possible livelihood actions of young rice farmers are fallow and rice, and Rabi and industrial job for the elderly. The motivation score of the young for Rabi crop and shrimp farming is lower than that of the threshold; therefore these two are classified as non-preferred action. The motivation score for the elderlys for fellow and their ability score for shrimp farming are below the thresholds, thus these two actions are classified as non-preferred.

The model result on livelihood adaptation action is in accordance with the preferences for livelihood adaptation under different scenarios as expressed by the farmers in the scenario workshops, as illustrated in figure 5.5. The results also show that the same computational procedure is applicable to generate meaningful results for subgroups of actors within a community.

5. 7 Reflections on the computational CLA under uncertainty model

The case of rice and shrimp farmers in polder 31 shows that the computational CLA under uncertainty model with MOTA concepts and scores can reproduce the preferences for livelihood adaptation actions under several scenarios of triggering conditions. The results correspond well with the observed community livelihood adaptation actions.

The quantification and analytical approach of the CLA model is based on the farmers' perception, reasoning and expert judgment, and somewhat subjective specific to the context. The method offers a systemic approach of reasoning and consistency for the simplified representation of community livelihood adaptation decisions in reality. Our exercise demonstrated how the data on external triggering factors and ability factors based on actors' perception, expert judgment and logical reasoning can be used to estimate motivation and ability for livelihood adaptation actions under a set of specific conditions.

Initially we wanted to derive decisions for two communities: shrimp farmers and rice farmers. During the analysis of data from the workshops we observed a clear deviation in perception and livelihood decision between elderly and young rice farmers. Therefore we decided to calculate their decision separately which worked well and demonstrates that the approach can deal with heterogeneity and model subgroups distinguished based on criteria such as land size, age, and gender.

The computational approach can be extended and elaborated further. First, the outcome (net benefit/loss) of one year can act as a trigger for a subsequent year, the timescale may vary and thereby the model can be extended to a dynamic model simulating community livelihood adaptation over time. This can provide learning for agent-based modeling and integration with physical system modeling

Another issue that came up relates to the influence of individual motivating factors (characteristics) such as preference of crop diversification, preference to adapt with adverse climatic condition, preference for quality or quantity etc. These have not been included in the present model, and it may be worthwhile to explore further disaggregation of the model by including these as separate motivating factors and perhaps subdivide the community according to differences in these factors.

The data on triggering factors are subjective from farmers' perception. The mix of quantitative and qualitative data with existing socio-economic data of the Bangladesh Bureau of Statistics (BBS) is used to develop five value classes for the ability factors; the percentage of households at each class is collected and this has been used to compute a weighted average of the individual ability of that community. In this way, the model is based on existing available data (as for example BBS, ESPA Delta etc.) at polder or larger scale. However, the uncertainty in access to context specific data may be a problem. Several other pragmatic assumptions were made in the model, for example, the addition of 10% of the ability value to account for the influence of ability on motivation (through perceived opportunity/threat), and the assumptions on the differences in influences of triggering factors on the perception of opportunities or threats offered by different livelihood actions. The impact of these and alternative assumptions needs further analysis.

For model validation, the standard method to validate model using independent data was not used for model estimation or calibration could not be used within the case studies. Model results however correspond with the historical evidence from existing literature about the ways in which the rice and shrimp farmers' community have responded to the changing conditions in the polders in the past. This does admittedly not ensure that the model can produce a reliable range of livelihood adaptation action for unknown cases. The approach is vulnerable to the generally recognized limitations of actor analysis approaches: difficulties in obtaining information on the actors' 'true' characteristics and perceptions, difficulties in interpretation of the actor's expressions, and contextual and time dependency of the actor's preferences, perceptions, etc.

In this perspective, our experimental model is mainly tuned to the main livelihood adaptation actions to get a sense of key possibilities of livelihood adaptation and the needs to perhaps improve policies, and should be seen as a pilot to demonstrate the feasibility of the approach.

Another issue requiring further attention is the computation of the MOTA score as a multiplication of motivation score and ability score. Literature suggests that motivation has a higher influence than ability on the decision to action (Fogg, 2009). Multiplication does however not account for this; actually, ability influences the MOTA score both directly and indirectly, as it is also assumed in the model that ability affects motivation. Clearly, it is recommended to further explore this issue, requiring empirical research on the relations between the key concepts ability, motivation and (probability of) decision, as well as and testing the use of other formula's to compute the MOTA score.

In concluding, the CLA under uncertainty model like other models offers a simplification of reality and our quantification effort is an exploration how it could be done. The model is highly aggregated, perhaps too much (aggregated) to capture the real mechanisms. Further elaboration and explorations are needed.

5.8 Perspective on contribution and further research to Adaptive Delta Management

The model development and application exercise shows that our approach of logical reasoning, decision rules and theory motivated relations derived from farmer's perceptions can be quantified in a way that might be coupled to the physical system modeling for overall integrated analysis. This approach can use existing socio-economic data structure; therefore existing available data along with participatory focus group discussions with actors' community are useful at polder scale. This could be scaled up to regional or national levels. We suggest further work to explore integration with other policy-oriented exploration models, and use to design policy adaptation pathways, including but not limited to the topics below:

1. Validation and extension

It is worthwhile to explore further applications and extensions. First, use of the computational model for cases of other farmers in a variety of conditions and for other actors/livelihood community in a variety of conditions could help validate the model for practical application to real world policy problems. More detailed factors and relations, and other relations could be explored as argued above. Depending on complexity, it might be worthwhile to use another modeling platform for simulation which might be more practical in terms of time and effort. Last but not least, and in line with the focus on uncertainties, future exploration using the model should not only take into account the uncertainties in scenarios but also the uncertainties in the model itself.

2. Towards a dynamic model

Further experiments could also be focused on extending this step towards a dynamic model to simulate the development of community livelihood adaptation action over time. According to the conceptual model, the outcome of the chosen action (under the prevailing conditions) is then fed back as internal trigger (net benefit/loss), to influence abilities and possibly motivation for the next year. This iteration can be implemented in MS Excel manually to observe the result and/or in other simulation platform, for example the exploratory system dynamic modeling. Another extension could be to simulate (in a dynamic way) the implementation of adaptive policies in interaction with community adaptation responses, and thereby explore the impact of alternative adaptation options and trigger values for adaptive policy design.

3. Modeling complexity of the community

An alternative platform for model-based research on community livelihood adaptation is offered by Agent Based Modeling (ABM) (Mascarenhas et al., 2013; Ng et al., 2011). Different from cognitive mapping and MOTA as we used them, ABM takes a more fine-grained disaggregated approach, and strongly focuses on and simulates the interaction between actors. Therefore, it is worthwhile to explore the use of ABM, in particular for situations where actor interactions within a community are crucial. Data for modeling individual actors might be similar to the approaches we used here.

4. Integration with physical system models

Future research could also focus on how to integrate this type of model with the physical system modeling approach; specifically with the theory-motivated Integrated Assessment Meta Model (IAMM) approach (Haasnoot, 2013) and Delta Dynamic Integrated Emulator Model (ΔDIEM)(Nicholls et al., 2016). This could contribute to analyse the interactions of the socio-economic and human system with the physical system in an integrated way; extending this to the regional and national scale needs for further research, however.

In concluding, the computational model can contribute by simulating livelihood adaptation action of a local community for a possible range of scenarios. The computational model can repeat, easily modify and test for alternate assumptions, various situations however at a cost of specific data requirement. The results can serve as an indication of the possible livelihood adaptation of the local community under future changed conditions and why this may emerge. With this information, policy makers can anticipate, and adapt their policy to promote the desired livelihood adaptation action by influencing triggering factors, ability factors and thereby motivation.

5.9 Conclusion

In this chapter, we presented a computational extension of participatory model development to demonstrate how the exploration of community livelihood adaptation under uncertainty could be supported with the power of computers. Based on the conceptual model, the data of local rice and shrimp farmer communities at polder 31 were used in a computational framework to simulate livelihood adaptation action from triggering factors and ability factors under eight scenarios. The model results are analogous to the farmers' expressed perceptions on their preferred livelihood adaptation action under specific scenarios. The model result can have useful implication in livelihood adaptation planning and adaptive delta management. Further development, research and empirical application for other livelihood community and at various scale is required. The future exploration should also focus on the integration of this approach to other modeling approaches in order to explore uncertainties in a broader sense, and to help develop policy adaptation pathways for application in real-world adaptive delta management.

Chapter 6

Comparative Analysis and Synthesis

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Comparative Analysis and Synthesis

6.1 Comparative analysis

This research has presented two model-based scenario approaches to explore community livelihood adaptation under uncertainty for adaptive delta management. The first one combines an unframed scenario approach with a cognitive map based conceptual model that is utilized to explore the farmers' livelihood adaptation pathway and develop guidance for policy adaptation. The second approach combines a framed scenario approach with a conceptual model based on the Motivation and Ability (MOTA) conceptual framework, which is utilized to explore the livelihood adaptation pathway and policy adaptation pathway[23]. The second approach is further extended into demonstration of a computational model. Development and application of both approaches have some commonalities and differences. The key features of both approaches are presented in table 6.1.

For evaluating the approaches based on experience of application in the cases of farmer community we choose a closed questions approach as method (Guillaume and Jakeman, 2012; Haasnoot, 2013). While scientific and engineering models are often validated based on the capability to reproduce (within specified limits) real-world values, our model as a policy model simulates future situations which cannot be observed at present (Haasnoot, 2013) and can only be compared with similar observed historical phenomena. Therefore, we evaluate our approaches based on the criteria of functionality, credibility, communicability, practicality, generalizability and computational potential, as introduced in Chapter 1.

[23]As explained before, we distinguish two types of adaptation pathway: the farmer livelihood adaptation pathway to represent farmers' livelihood adaptation response and the policy adaptation pathway to represent the anticipated policy adaptation response of a policymaker

Table 6.1 Key features of the approaches and the cases in which they are applied

no	Features	Approach 1	Approach 2
1	Overall approach	Cognitive map-based unframed scenario	MOTA conceptual model-based framed scenario
2	Models and Decision theories	Cognitive map to represent descriptive mental models of decision logic	Motivation and ability (MOTA) framework rooted in rational decision making theories
3	Methods of presenting decision	Livelihood adaptation pathway map of farmer	Livelihood adaptation pathway map of farmer and policy adaptation pathway map of policymaker
4	Policy strategy of BDP 2100 for illustration	Grow salt-resistant crops	Diminish drainage congestion and improve livelihood
5	Actor community	Rice farmer in polder 30 and 31in southwest Bangladesh	Rice, integrated and shrimp farmer in polders 30 and 31in southwest Bangladesh
6	Livelihood domain of actor decision	Cropping decision in dry season	All types of livelihood adaptation decision (cropping, off-farm, migration etc.)
7	Data collection method	Focus Group Discussion, Interview, crop calendar	Scenario development Workshop, Interview, GIS data of cropland
8	Data collection and scenario development process	The data collection of farmers perception on present decision making, past experience and future situation is collected with 'open questions' as input to conceptual model development; then adaptation responses were developed by the researcher from the conceptual model and presented in the farmer livelihood adaptation pathway map.	The data collection of farmers perception was done in a future-oriented participatory way. Four external future-oriented (until 2050) scenarios around two dominant external factors were developed jointly with the farmers; the data were used to specify the conceptual model which was then used to develop the farmer livelihood adaptation pathway map
9	Scenarios	Forward looking (present to future) developed by researcher	Forward looking (present to future) developed by farmers
10	Scenario type	Scenarios are contextual for farmers while strategic (hero, resp. zero adaptation) for policymakers.	Scenarios are external for farmers while strategic for policymaker
11	The stories in scenario	The stories of different reasoning about relevant factors by farmers and about adaptation possibilities of the policy strategy	The stories of different realization of external factors (including policy) to develop conditions for framers; and farmers reasoning (perceived opportunity/threat) from that condition to possible adaptation.
12	Farmers livelihood adaptation pathway map	Possible farmers' response in livelihood adaptation to the policy over time and condition	Possible farmers' response in livelihood adaptation based on triggering condition, motivation and ability over time. (policy is part of triggering condition)
13	Policy Adaptation Pathway for policymaker	Based on experience, a guidance of policy adaptation for policymaker is provided	Based on experience, a policy adaptation pathway for policymaker is suggested to monitor and update the basic plan.

The remainder of this chapter presents the overview and evaluation of the two approaches based on the research experience as described in the preceding chapters, and using the criteria as specified in Chapter 1, section 1.4.1 followed by synthesis and conclusion.

6.2 Cognitive map-based Unframed Scenario Approach

6.2.1 Overview of the approach

This overview presents our experience in the case of the rice farmer community in polder 30 and 31. For more details, see chapter 3.

The approach

This four-step iterative approach is based on a participatory cognitive mapping technique (Elsawah et al., 2015) to elicit, represent and analyze the mental model of actors rationales when making their adaptation decisions. The case of rice farmers who make strategic cropping decisions for the dry season in polder 30 and 31 at the southwest coastal region of Bangladesh is used to illustrate the designed approach. In step 1, Participatory Rural Appraisal (PRA) techniques are used to elicit knowledge on how they make the cropping decision: focus-group discussion, semi-structured interviews and crop calendar. In Step 2, a group cognitive map of the rice community is developed with nodes (concepts/constructs) and arrows (causal/belief) based on interview transcripts and validated with the same farmers. In step 3 the cognitive map is restructured to serve as the conceptual model and identify the exogenous triggering factors for decision making, both contextual (e.g changes in climate conditions) and internal (e.g experience, aim and interests). In step 4, in the case application, the policy strategy 'grow salt-resistant crops' of the Bangladesh Delta Plan 2100 is used as a starting point, Then, the possible response of farmers based on the rich variety of triggering concepts and reasoning (perceptions) about the situation (Kelly, 1955) is described, and the result is presented in a livelihood adaptation pathway map.

The resulting conceptual model for the case

The conceptual model shows that the rice farmer community at dry season makes three interlinked strategic decisions about crop variety, investment in irrigation water and land planning to achieve two types of goals: meeting family food demand and making profit. A decision as for example about the crop variety is influenced by a total of 29 triggering factors or conditions. The yearly decision leads to meeting the goals or not; that result feeds back into the iteration of the same process at the next cropping season and year.

Illustration with policy strategy

The possible adaptation response of one strategy of BDP 2100 for salinization 'Expand the cropped area with salt-resistant varieties for the coastal area' is illustrated. The conceptual model provides the rules to explain how different farmers in a unified small community act based on their reasoning (perception) about a situation or conditions. Eight possible adaptation responses of the rice farmer community to this policy are presented in a livelihood adaptation pathway map. The reasoning of different farmers on the situation results in different responses, for example together to grow salt-resistant rice; rice in the fallow land; remaining comfortable with the known variety; fallow is more etc. The conclusion is that some farmers might exploit the opportunities provided by the policy, other farmers might be reluctant. The extent to which this will happen depends on around 48 factors (total factors that influence three decisions). Therefore, the adaptation process of farmers is uncertain, and so is the extent of policy impact. The delta planners may improve the design and implementation of a policy strategy if they are aware of the variety of possible adaptation responses. For example, by adapting the policy they may prevent certain otherwise unexpected responses or they can be prepared for a future situation in which the unexpected response would occur.

6.2.2 Evaluation of the approach

1. Does the approach deliver the intended results on CLA as uncertainty in terms of possible adaptation responses to a policy strategy?

The approach has developed eight possible adaptation responses to the policy strategy based on the perception of rice farmers. The farmers' livelihood adaptation pathway map presents varieties of livelihood adaptation responses under the condition of increased water and soil salinity (low-high) at the qualitative scale of 1 to 10 until 2050. An example of zero adaptation response can be 'fallow is more' where the large farmers may be reluctant to invest in salt-resistant rice due to low productivity of land; elderly farmers may have a lack of labor force; the young farmers may perceive better income opportunities in cities or other regions; the small landowners may perceive higher risk of pests, rats and cattle attack when cultivating at small-scale; even leasing for salt-resistant rice may be discouraged because of poor land type. Therefore the cultivation of salt resistant rice may be perceived as non-suitable by farmers. Besides, due to low productivity the integrated rice/ shrimp farmer may shift to 'fallow is more' if conditions get worse. This exploratory analysis suggests ways to improve the design and implementation of a policy strategy, based on awareness of the variety of possible adaptation responses of farmers.

The multi-method approach works well because the unframed scenario approach is open to capture a rich variety of triggering factors responsible for possible adaptation response; the cognitive map structures and presents all the triggering factors and relationships as conceptual model; and the adaptation pathway presents the logical sequence of livelihood adaptation response. However, the rich variety of qualitative data of triggering and other factors may be perplexing, and provides a challenge to human cognition if it is necessary to clearly model and explain a situation. This can be a drawback of the approach.

Concluding, the approach has delivered the intended results on community livelihood adaptation for the selected case and policy.

2. Does the model-based approach provide a credible representation of the community livelihood adaptation based on best available knowledge?

The cognitive map based model defines a highly complex map of 48 factors and 62 relationships that derive three inter-connected strategic decisions on crop variety, investment in irrigation water and land planning of rice farmers for the dry season. The highly complex map with map density (ratio of factors and linkages) 1.29 represents a complex system while a ratio between 1.15 to 1.20 defines a complex map (Eden, 1992). The extent of adaptation to a salt-resistant variety by rice farmers depends on many factors and relationships, many of which are uncertain. So the adaptation process of farmers is uncertain, and so is the extent of policy impact. The credibility of the approach is rooted in the trustworthiness of the statements by the farmers, and further supported by the fact that the possible livelihood adaptation pathways resulting from the model–based approach corresponds with the actual history of the rice farmers, and with the history of rice farmers as reported in available scientific literature (Bakuluzzaman, 2012; Fatema et al., 2011; Kabir et al., 2016; Nahar, 2016).

3. Is the approach development process transparent and communicable to relevant actors, policymakers?

The unframed scenario process is transparent and reflects and uses the terms and language used by the farmers themselves. Despite the complexity, the modeling process structures the large number of factors in a simplified way for easy understanding of relevant actor, policymaker and researcher. The graphical format and day to day languages of relevant actors in the cognitive map and in the adaptation pathway make it easy-to-explain tools to communicate and learning. Clarity and transparency exist in the modeling process as the modeler can share the output of any step with actors and policymakers, which allows revisiting of earlier steps.

4. Is the approach practical to use in terms of time and effort?

The experience in designing and testing the approach in the case of the rice farmers' cropping decision in the dry season points out that:

i. It requires significant time and careful effort to elicit and represent the farmers mental model in a cognitive map;

ii. The approach is practical for the purpose of in-depth analysis, illustration and presentation of factors and relationships for one specific decision domain (cropping decision of rice farmer community in the case).

iii. The same procedure for one decision domain may be used to study decision making about the full range of possible livelihood adaptations (for example to non-farm activities, migration etc.) but the required time and effort would be significant, and the complexity challenging.

5. Can the approach be applied to a variety of situations and actor types?

The approach can, in principle, be applied for any similar purpose of specific decision domain, for a variety of situations and actor types.

6. Does the approach have potential for linking up to a computational modeling framework for future exploration?

In principle, the decision rules generated by the approach can be used as a basis for a computational model that can generate adaptation responses as a function of external and policy conditions. This model could then be linked to other models that, for example, generate the hydrological conditions as a function of time and water management strategies. The level of detail, however, may be a drawback.

Concluding, the approach is useful in structuring the cognitive and qualitative nature of the farmers' decision-making process; helps in understanding the dynamic interactions of farmers' decisions with other actors, their environmental attributes, and market traits. Thereby, a better insight can be gained on the possible response of a particular actor community for a specific policy strategy under future changing conditions, and this can sup port adaptive planning. Acknowledging the fact that actors' perceptions are actor, situation, and time-dependent, the transparent progression of this approach makes it worth applying it to enhance learning and engagement of relevant actors in policy design and implementation processes.

6.3 MOTA conceptual model-based Framed Scenario Approach

6.3.1 Overview of the approach

This overview summarizes our experience in the case of rice and integrated farmer community in polder 30 for the approach, conceptual model and policy illustration. For detail see chapter 4.

The approach

The four-step approach has two distinctive parts. First, the data on farmer perceptions are collected in a workshop and interviews, and these data are used to specify the conceptual model according to the motivation and ability (MOTA) framework. Then, the conceptual model is used to explore the possible livelihood adaptation response. While the case application in first approach focused on the cropping decision of rice farmers, the case application of this approach is focused on all possible livelihood adaptations (i.e cropping, non-farm, migration etc.) of the rice and integrated farmer community in polder 30. In step 1, we focused on the knowledge elicitation in a Participatory Scenario Development workshop, individual interviews and in using and collecting GPS data of the agricultural land. In step 2, the conceptual model is specified with collected data which is ready for use. In step 3, implementation of a basic plan with a policy strategy (in the case, and as example: 'diminish drainage congestion and improve livelihood') is translated into factors affecting the farmer's situation. In step 4, the conceptual model is used to illustrate the possible livelihood response in the farmers' livelihood adaptation pathway map which, in a sense, provides the awareness of and insights for the basis to update the basic plan and to develop a policy adaptation pathway.

The resulting conceptual model for the case

The conceptual model assumes that a combination of triggers (irrigation water, water drainage, agro-technology and market system) affect the farmer's motivation and abilities, and these in turn determine the adaptation action, if any; The conceptual model is generic and has been specified for both the cases of rice farmers and integrated farmers in polder 30. In the case, four scenarios are distinguished: flourish, water constrained, marketconstrained and stagnant. The livelihood adaptation action of both rice and integrated farmers depends on the scenario, and ranges from (i) continue the main livelihood (Boro rice cropping/ integrated farming) and/or adaptation to other crop/livelihood for alternative income/food under the flourish scenario, towards (ii) adaptation of technologies for improving conditions (water availability, agro-technology etc.) and crop varieties (stress resistant variety) under the constrained scenario; and finally (iii) transformational[24] adaptation of cropping/livelihood (shrimp farming/ migration/ off-farm/TRM) under the stagnant scenario.

Illustration with policy strategy

This illustration is comprised of two steps of policy implementation, identification of the community livelihood adaptation response of farmers and generation of the policy adaptation response for policymakers as described above. In the case, the role of the conceptual model is similar to the earlier approach that provides the rules to explain how the rice and shrimp farmers' community act based on their perception. A possible sequence of 16 livelihood adaptation

[24]Transformation involves a long-term system-wide change and hard to return original.

actions based on critical triggering conditions, differentiated abilities and motivations over time is presented in relation to a scenario in which conditions worsen from flourishing to very poor. The exercise suggests a policy adaptation pathway for policymakers. For instance, the promotion of resistant variety/technology can be combined with the 'support of existing cropping' to mitigate or hedge the uncertain adverse effect of an unfavorable condition.

6.3.2 Evaluation of the approach

1. Does the approach deliver the intended results on CLA under uncertainty in terms of possible adaptation responses to a policy strategy?

In the case, the approach has developed a range of possible (16) adaptation responses to the scenarios of changing conditions as well as a policy strategy based on the rice and integrated farmers' perception. The range of adaptation responses covers as many as the farmers may have, including alternative cropping, irrigation, other agricultural livelihoods, non-farm livelihood, migration, lobbying to the Government (i.e through farmer cooperative), and Tidal River Management (TRM). The farmer livelihood adaptation map presents varieties of livelihood adaptation responses under favorable-unfavorable conditions at the qualitative scale of 1 to 10 until 2050. For instance, the farmers may adapt to saline resistant crop at the value of 5 and continue up to the value of 8, based on motivation and ability at the correspondent year. The farmer' adaptation map suggests a policy adaptation pathway of 13 possible policy actions for a policymaker that can be designed, and implemented, based on monitoring farmers' livelihood adaptation actions and critical triggering conditions. Clearly, based on the case experience, the approach delivers the type of results it aimed for.

2. Does the model-based approach provide a credible representation of the community livelihood adaptation based on best available knowledge?

Using the MOTA conceptual model, the data of rice and integrated farmers in polder 30 have been condensed into 6 components: triggers, perceived opportunities/threats, motivation, abilities, actions and outcomes and 8 relationships in terms of influence and potential influence. This presents a simplified representation of the complex and dynamic process of community livelihood adaptation decision making. The combination of components and relationships with logical reasoning and scenario development is able to capture, simplify and reproduce the phenomenon of farmers' adaptation decision making.

The possible livelihood adaptation pathways resulting from the approach resemble the history of rice and integrated farmers in polder 30. The outcomes on livelihood adaptation decision are also similar to the more general historical livelihood adaptation of rice and integrated farmer as reported in available scientific literature (Bakuluzzaman, 2012; Fatema et al., 2011; Kabir et al., 2016; Nahar, 2016). However, the approach is vulnerable because of the limitations of its constituting methods, such as a priori consideration of triggering factors, situation and time dependency of actor perceptions, as well as significant simplification to represent a complex and dynamic decision making process.

3. Is the approach development process transparent and communicable to relevant actors, policymakers?

The approach development process has six steps of model development from farmer perception and illustration with policy strategy from policymaker perspective. The participatory scenario development process with farmers allows them to perceive how different triggering factors may develop in future and can influence their actions at different condition. It is observed that the workshop has increased the farmer's awareness of the possibility of uncertain changing future conditions, and of the ways in which they may take an informed decision/ action under such conditions. The MOTA conceptual model and adaptation pathway offers transparent and communicable model results. The approach helps to identify critical conditions that are relevant in the perception of actors as triggering factors. Clarity and transparency exist in the modeling process as the modeler can share the output of any step with actors and policymakers, which allows revisiting earlier steps if necessary.

4. Is the approach practical to use in terms of time and effort?

The experience in designing and testing the approach in the case of rice and integrated farmers livelihood adaptation action has demonstrated that

i. It is comparatively easy to facilitate and track scenario development around two external triggering factors and to specify the factors and relationships in the MOTA conceptual model; time and effort required are manageable.

ii. The approach is practical for the purpose of exploring diverse livelihood adaptation actions of a diverse actor community.

5. Can the approach be applied to a variety of situations and actor types?

In the case, the approach has demonstrated to be suitable for analyzing the community livelihood adaptation of two major livelihood groups (rice and integrated farmers) at polder scale. The same approach can be applied to other livelihood groups in the polders and at any other location. In principle, for any of similar purpose, the approach can be applied to a variety of situation and actor type at any scale; with the practical consideration of time and effort.

6. Does the approach have potential for linking up to computational modeling framework for future exploration?

The computational potential of this approach is examined in the demonstration at section 6.4 below. See the following section.

We conclude that the approach is useful as a reasonable simplification and specification of relevant factors of the complex decision-making process; it helps in understanding the influence of triggers and abilities on the decision about livelihood adaptation actions. The livelihood adaptation pathway of farmers suggested a policy adaptation pathway for adaptive planning and implementation; in this way, policy strategies may be co-created by the policymakers and local actor communities to be prepare for future changing conditions. The transparent and participatory progression of this approach makes it worth applying to enhance learning and engagement of relevant actors in adaptive policy design and implementation processes.

6.4 Demonstration of MOTA computational model based on MOTA conceptual model

6.4.1 Overview of the approach

This overview presents our experience for the case of rice and shrimp farmers in polder. For details see chapter 5.

The approach

This four-step computational framework is based on MOTA conceptual model with the specific purpose to explore the quantification potential in exploring community livelihood adaptation. The case of rice and shrimp farmer in polder 31 is used to demonstrate the designed approach. In step 1, the objective is set and required data on triggering factors, ability factors and livelihood adaptation actions is collected with participatory scenario development workshop, individual interviews and GPS data of agricultural land. In step 2, the ability score of each actor community for each livelihood adaptation action is calculated from the elements of ability factors under each scenario. In step 3, the motivation score of each actor community for each livelihood adaptation action is calculated from the values of triggering factors under each scenario. In step 4, the overall MOTA score expresses a preference for livelihood adaptation actions each scenario.

The computational model

For demonstration, a set of quantitative equations and simple logical functions are arranged to calculate the motivation score, ability score and MOTA score for each livelihood adaptation action. This mathematical model is implemented in the excel-based computational framework and has ranked livelihood adaptation actions of the actor's community under scenarios. In the case, the values of triggering factors: irrigation water, saline water, agro-technology, market system and industries are distributed into high or low to develop alternative scenarios. Five livelihood actions: rice farming, rabicrop, shrimp (with/without rice), industrial job/labor and fallow under each scenarios of young rice farmer, elderly rice farmer and shrimp farmer is considered.

The livelihood adaptation response under scenarios

The computational model derives scores for a set of available livelihood adapttion actions that can be used to classify the actions as preferable, possible and non-preferable. In the case, the response of shrimp farmers and rice (young/elderly) farmers for five livelihood adaptation possibilities under different scenarios are shown. For example, the result for shrimp farmers shows that shrimp farming remains the preferred livelihood action under three scenarios while fallow land is preferred at the stagnant scenario; Rabi crops and industrial jobs are perceived as non-preferred for all scenarios; possible actions are shrimp firming and rice farming at the stagnant scenario while leaving land fallow at the water constrained scenario. Depending on data availability, the model can be used to assess the preference of actors on livelihood adaptation actions for different communities (shrimp-rice), as well as for sub-groups within a community (young-elderly rice).

6.4.2 Evaluation of the approach

1. Does the approach deliver the intended results on CLA as uncertainty in terms of possible adaptation responses to a policy strategy?

The specific purpose of this exercise is to explore to what extent a computational extension of the MOTA conceptual model can be used to effectively explore the community livelihood adaptation under a variety of conditions. The results show that the computed MOTA score of five livelihood adaptation actions under scenarios can indeed reproduce the preference of elderly rice farmers, young rice farmers and shrimp farmers as preferred, possible and non-preferred livelihood adaptation action.

2. Does the model-based approach provide a credible representation of the community livelihood adaptation based on best available knowledge?

The result of the exercise suggests that the computational approach can reproduce the preferences for adaptation actions under changing parameters in a reasonable way. We emphasize, however, that the model is a simple pilot based on lots of assumptions, and needs to be tested, improved and analyzed further to explore its validity and usefulness in many cases..

3. Is the approach development process transparent and communicable to relevant actors, policymakers?

The approach development process has four easy to follow steps in computational model development. The implementation of this mathematical model with quantitative equations and logical functions in MS excel makes the model transferable to any other relevant modeling platform. The relative simplicity helps in explaining the result.

4. Is the approach practical to use in terms of time and effort?

The experience demonstrates that

i. The data collection in framed scenario logic approach and specification in the MOTA framework is workable

ii. The model can be easily adapted to do many analysis/runs in a short period of time. Effort needed for further development

However, it is emphasized that the current pilot model needs further testing, elaboration and development; when including more complexity, it may be more efficient and practical in terms of time and effort to use another modeling platform for simulation

5. Can the approach be applied to a variety of situations and actor types?

The computational approach seems suitable for exploring community livelihood adaptation of major livelihood groups (rice and integrated farmers) at polder scale, as per our demonstration exercise. The same approach can be applied to other livelihood groups in the polders and at any other location.

6. Does the approach have potential for linking up to a computational modeling framework for future exploration?

Yes, that is why the demonstration experiment was started, and it seems workable. But as mentioned above, further work on the model is needed, for example testing it in variety of livelihoods for many situations, and exploring other mechanisms and assumptions about the (computational) relations between the factors in the model.

This demonstration exercise can be considered as the first static step towards a dynamic model. Summarizing, our exercise shows how the data on external triggering factors and ability factors based on actors' perception, expert judgment and logical reasoning can be transformed into motivation and ability estimates for livelihood adaptation action under a set of specific condition. The model result is representative of the known cases which does not implicitly ensure that the model can produce the possible range of livelihood adaptation action for unknown cases. The computational experiment suggests further work on the details of the model, and exploring the integration with existing model based approaches to enhance learning and engagement of relevant actors in policy design and implementation processes.

6.5 Discussion and conclusions

For exploring community livelihood adaption as uncertainty, this research has designed and tested two model-based scenario approaches. The two approaches are broadly differentiated as cognitive map-based unframed and MOTA conceptual model-based framed scenario approach, each have their own way of scenario exploration, data collection methods, conceptual modeling, and different actor communities and policies were used as case studies.

The first cognitive map-based unframed scenario approach is applied in one specific decision domain of a specific actor community; the cropping decision of rice farmer community at dry season. In our perception, the practical application of this approach in the variety of livelihood adaptation of multi-actor can be a constrained due to required time and effort in managing a rich variety of qualitative data-sets. The case application of MOTA conceptual model-based framed scenario approach can capture the variety of livelihood adaptation action of rice and integrated farmer at once, and requires relatively less time and effort as a result of the limitation of the number of triggers (framed scenario) and the highly aggregated framing of the factors representing the decision making process. As a result of its ability to easily capture a multitude of possible adaptation actions, it does also seem more practical for developing a policy adaptation pathway for policymakers.

Reflecting on differences in the data collection, we distinguish three aspects: (i) the scenario/context development (past/ present in first approach versus present/future in second approach); (ii) the unframed versus the framed character of scenario development; and (iii) the framing of our questions about the rationale for making adaptation decisions (completely open in the first approach and framed by MOTA for triggers, motivators and abilities in second approach). This has some critical impact. For the unframed approach, the completely open questions about the factors for their cropping decision in their past and present experience triggered the participants to go back to that time period (last 30 years). They were trying to remain close to their real past and present experience. Whereas in the second approach, the data collection was about the future (next 30 years), and participants were challenged to imagine different possible future realizations of (only) two key factors and related developments at future. During the scenario development workshop in the second approach, they imagined extreme situations for example a situation in which industries would replace agriculture, or availability of hi-tech irrigation technology such as desalinization. Based on this (limited) experience, the future scenario development by participants (2nd approach) is more productive and creative, and contributes more to awareness of future uncertainties than that developed by researchers and only validated with participants (as in the 1st approach).

Each of the two approaches differs in their combination of methods for scenario development, conceptual modeling and presenting adaptation responses. Other combinations of the same component methods are also feasible, for example, a framed scenario approach might be combined with a cognitive mapping approach to reduce the differentiation into a large number of trigger factors, while keeping the articulation of the farmer's reasoning towards a decision completely open. Similarly, some of the components could be substituted by very different ones, for example by introducing an element of gaming in the workshops, or adopting a different modeling paradigm.

Similarly, for computational purposes a different simulation platform or even a different modeling paradigm (such as Agent-based modeling) might be explored, as well as coupling to or integration with models of physical system. .

In concluding, this research has developed two approaches to support adaptive planning and implementation that can explore community livelihood adaptation (CLA) as uncertainty systematically. Overall, a future oriented participatory scenario development approach seems to be more fruitful than the approach looking at past and present decision making. In practical terms of time and effort, the first, cognitive mapp-based and unframed scenario approach seems to be more suitable to use for one specific (livelihood) decision domain of an actor community, and the second approach is more suitable for exploring all (livelihood) decision domains of an actor community. However, further work is needed to better analyze and assess the pro's and con's of (variations of) these approaches, and possible extensions.

Chapter 7

Conclusions, Reflection and Future Outlook

7

Conclusions, Reflection and Future Outlook

7.1 Overview of the research

The aim of this research is to develop an approach to support adaptive planning and implementation by systematically exploring Community Livelihood Adaptation (CLA) as uncertainty for sustainable delta management.

A strategic planning approach like the one applied in Bangladesh (BDP 2100) combines widespread stakeholder engagement with utilization of available data sources in the formulation of policy strategies; however, policy development is based on fixed – not deeply uncertain - assumptions about the way the local community will respond to the policy measures. Historical examples show that such a strategic planning approach may face implementation challenges as a result of the uncertain response of local communities at the regional or local social-ecological context. Ignoring this uncertainty may result in policy failure; in the same way as policies may fail because of ignoring uncertainty in climate and socio-economic change. Therefore, the research presented in this thesis has focused on designing and testing an approach to systematically explore the uncertainties in community livelihood adaptation under uncertain climate and socio-economic change and that can support adaptive planning and implementation.

Our explorative research built upon relevant theories and empirical cases has resulted in two approaches to address the research objective. Based on experience of the first approach, a second approach is developed and extended to demonstrate a computational model-based version.

This concluding chapter is based on the research that has been presented in the previous chapters. The second part of this chapter presents a reflection on the approach and concludes with a future outlook.

7.2 Answers to the research questions

The key research question is *'What is a good approach to systematically explore community livelihood adaptation under a range of (uncertain) conditions, to support adaptive delta management?'* To answer this main question, the subsections below provide conclusions for the four more specific sub-questions as specified in the introduction.

Question 1: To what extent does CLA have historical importance as uncertainty for (Adaptive) Delta Management?

Before stepping towards developing a new approach, the importance of community livelihood adaptation in (adaptive) delta management was studied, based on literature review, insights from interviews and field observation. Two historical cases of livelihood adaptation of farmer communities confronted with contemporary polder management for salinization and water logging in the polders of southwest Bangladesh since 1960s were studied. The cases demonstrate that historically community livelihood adaptation in polders has been ignored in the development of plans, and this has led to not reaching anticipated policy outcomes of coastal land protection from daily tidal inundation of saline water. For example, the introduction of commercial brackish-water shrimp farming at late 1970s has reversed the functionality of polders from 'controlling the saline water inflow into the polder' to 'allowing the saline water inflow into the polder'. Another example is the evolution of Tidal River Management (TRM) in the late 1980s as a regional policy that allows controlled flooding for land accretion inside the polder and natural dredging of deposited sediment in the river. These findings clearly demonstrate the necessity to further study community livelihood adaptation and to consider it as an uncertainty in developing (adaptive) plans.

Question 2: What theories, methods, frameworks are applicable to explore CLA as uncertainty?

Our literature review of relevant methods for application in the new approach has been focused on methods and theories for (i) scenario development (ii) conceptual modeling of community livelihood adaptation decision-making (iii) data collection and (iv) presenting livelihood adaptation as a function of time and conditions.

Based on the uncertainty literature, our primary literature review for our exploratory research suggests explorative, forward looking scenarios; in which both the unframed and framed scenario development approaches seem applicable. Furthermore, we distinguish between external and strategic scenarios, and use both of them.

The exploration of suitable conceptual modeling methods to describe CLA decision making was done in two steps. First we focused on mental maps and cognitive mapping, commonly used to understand decision making in environmental psychology, behavioral science etc.; After exploring this approach in a first case study, the second step explored the utility of more general frameworks grounded in descriptive decision theories in social science, behavioral science etc.; it was concluded that the Motivation and Ability (MOTA) framework and associated concepts in motivation and livelihood literature offer an interesting potential for application and testing for our purpose.

For data collection about farmers' perceptions and intentions, the participatory rural appraisal methods such as workshops and interviews are appropriate and were used.

For presenting the overview of policy adaptation pathways over conditions and time to policymakers,the recently developed adaptation pathway approach is applicable. As our purpose of presenting the livelihood adaptation response of farmers differs from its original application, we make a distinction between a livelihood adaptation pathway map, and a policy adaptation map.

Question 3: How can an approach be designed and tested to explore CLA under uncertainty?

Two approaches namely a cognitive map-based unframed scenario approach (we refer to it here as the first approach) and a MOTA conceptual model-based framed scenario approach (we refer to it here as second approach) have been developed. The second approach has been developed based on the experience of the first one; however both approaches have their own way of development, combining methods, testing in cases and policy illustration. The second approach is further extended to demonstrate its computational ability which we named the MOTA computational model-based framed scenario approach.

The first approach combines cognitive mapping as conceptual modeling method with an unframed scenario workshop. The modeling steps start with knowledge elicitation, followed by cognitive map development and use of cognitive mapping to derive decision rules. The data collection in the workshop and interviews focuses on the farmers' perception on cropping decisions and triggering factors from past/present experience; which is used by the researcher to develop a cognitive map which is then validated with the farmers. Then based on the decision rules in the conceptual model, the researcher develops the possible adaptation responses of farmers for future conditions. This has two implications. First, the farmers stay close to their real past events and trends; second, the influence of the researcher on the framing of the farmer's perception on triggering factors and decision rules is minimal. Therefore, in the case application, in which the focus was on only one type of decision (on cropping), the completely open discussion resulted in a rich dataset of triggering factors; which was challenging for researchers in developing the cognitive map in terms of time, effort and structuring the rich qualitative data. The result was a complex cognitive map that structures and represents the dynamic decision-making process of farmers' cropping adaptation.

The second approach combines the Motivation and Ability (MOTA) framework as conceptual model with a framed scenario approach. The future-oriented (external) scenarios are developed in a participatory way by the farmers themselves. The modeling steps start with the knowledge elicitation/data collection followed by the specification to derive decision rules. The data collection in the workshop and interviews focuses on the farmer's perception on triggering factors, livelihood adaptation, motivation, abilities and perceived opportunities/threats for future conditions which is used for conceptual model specification. In the case application, based on decision rules in the conceptual model, the researcher has organized the possible sequence of adaptation responses of the farmers. Compared to the first approach (based on farmer's past and present decisions and perceptions), the future-oriented participatory scenario approach seems more productive as farmers are challenged to imagine about any of future uncertain developments of key triggering factors and how their livelihood adaptation shapes for such a possible situation. The structuring of stories around two external triggering factors worked well and was manageable in terms of practical time and effort. In addition to explore uncertainties in terms of triggering factors under scenarios, the approach frames the farmers' perception and decision logic in terms of the influence of the trigger factors on farmers' perception on threats and/or opportunities, their motivation and their abilities for action leading to a qualitative assessment of the probability that specific actions will be taken under a variety of circumstances.

For presenting adaptation responses to a new policy favoring the switch to saline-resistant crops the possible response in the case application of the first approach was organized in terms of zero or hero adaptation, using reasoning and relevant decision rules to derive the response. However, as the cognitive map was derived for the cropping decision only, not all other possible domains of livelihood adaptation i.e., non-farm, migration, community level etc. could be included in the presentation. In the second approach, we chose to use the policy influence of 'diminish drainage congestion and improve livelihood' on the triggering factors as part of the external scenarios for farmers. Then, the possible adaptation response of farmers based on their reasoning of the situation in terms of perceived opportunity/threat and decision rules over time was organized.

Overall, both approaches are, in principle, fit for their purpose. Some key aspects for example the data collection; the use of framed/unframed scenarios, the framing of the decision logic; and the way of organizing the adaptation responses are different and this has impact on the practical usability depending on the specific context. In practical terms of time and effort, the first approach seems to be more suitable to use for one specific (livelihood) decision domain of an actor community and the second approach is more suitable for all (livelihood) decision domains of an actor community

Applications are so far limited to the case of three farmer communities in two polders, but general characteristics provide confidence that the approaches are applicable as well to large varieties of farmers in different social-ecological systems or other livelihood communities.

Concluding, both the approaches are functional in delivering results with their known constraints. They offer systematic structures that capture key features of the community livelihood adaptation under uncertain climate and socio-economic change; that can support adaptive planning and implementation

Question 4: How can this approach be incorporated in Adaptive Delta Management (ADM)?

The approaches can support the policymaker by getting a sense of how the livelihood adaptation action of a local community looks like in different conditions; how different factors influence their adaptation direction; and how a policy strategy may be perceived in this dynamic process. Like a policy game lab, the policymaker and policy researchers can examine the possible adaptation response of a local community before actual implementation of the policy.

The approaches produce results of community livelihood adaptation that show under which conditions and time (can be earlier/later) the community prefers a new livelihood for adaptation and switches from their existing livelihood. This can help the policymaker to develop a suitable policy strategy to influence specific actors and conditions, and/or adapt the policy to community preferences, and this will increase the success of the policy strategy in terms of meeting its ultimate goals. For example, whether the salt- resistant crop will be perceived as an opportunity by the community or not depends on many factors like saline conditions, outcome of their existing crop, coordination among farmers, characteristics (i.e. early or same variety, productivity) of the new crop etc. Another example shows that the integrated farmers are satisfied with their existing livelihood until the most unfavorable stagnant condition of water drainage, market etc. develops. Therefore, adaptation of technologies/varieties to continue their integrated farming is their preference and during the most unfavorable stagnant condition they prefer Tidal River Management (TRM). Hence, under this stagnant condition a policy strategy for TRM can gain the community preference.

The step-wise approach development and application is organized in a clear, transparent and communicable manner that can support repetition of the steps for same cases or any other cases. The use of adaptation pathway method makes the result easy-to-explain for communication and learning.

Unlike some model-based policy approaches that demand high computational and software expertise, these participatory approaches can be used with limited knowledge of computational software or modeling platforms by policymakers as well as researchers. Both national level policymakers who have limited access to local condition as well as local policymakers can benefit from the approach.

A possible more advanced approach is to integrate the computational versions of the models with other computational modeling platforms such as physical system models. This would enable analysts to computationally explore future developments taking the interaction of physical and socio-economic factors into account.

Concluding with respect to our main research question, both approaches developed in this research can support adaptive planning and implementation by systematically exploring community livelihood adaptation (CLA) as uncertainty. In practical terms of time and effort, the first approach is more suitable to use for one specific (livelihood) decision domain of an actor community and the second approach is more suitable for all (livelihood) decision domains of an actor community. The quantification in a computational model could further help the policymaker in visualization and incorporating community livelihood adaptation in adaptive planning and policy implementation. Like other actor-modeling approaches, however, these approaches are based on a simplification of community livelihood adaptation and should therefore be applied with care.

7.3 Reflections and future work

Reflecting on the overall research and its results, a number of limitations come to the front, each leading to an indication of further work.

First, the number of case studies is limited, and application to a wider set of communities with different characteristics is needed to further assess the approaches. The case studies are illustrated with two policy strategies of BDP 2100 for coastal hotspots which can be extended for various policy strategies of BDP 2100 and any other policy strategies.

Second, the two approaches that have been developed and applied differ in several aspects: different scenario approaches have been used, different orientations in data collection (past and present versus future), and different conceptual frameworks. As a result, it is difficult to empirically filter out the impact of each of these changes separately. Future research work could therefore look at other variations of methods in the approaches, for example: combination of a framed scenario with cognitive mapping, or unframed scenarios with MOTA.

Third, only a few levels of detail in modelling the farmers' decision making logic have been explored: the farmer's natural level of detail describing their decision logic, and the highly aggregated MOTA conceptualisation. As indicated in Chapter 6, and also more generally, experimenting with other levels of detail can assist in finding the most appropriate level given purpose and context. This also refers to making (more) distinctions between subgroups in a community based on socio-economic attributes such as age group (elderly and younger), gender (men, women etc), economic status (poor, rich) and different current livelihoods (fisher, farmer, labour) etc.

Fourth, the research has focused on modelling decision making at the individual or collective level only, while other theories and modelling paradigms concentrate on the interactions of actors that affect the collective result. An example in case is agent-based modelling (Mascarenhas et al., 2013; Ng et al., 2011) and it would be interesting to compare application of such a paradigm with the present work

Fifth, the positive experience of developing future-oriented scenarios and adaptation responses together with farmers has triggered the idea to explore changing the data collection setting into a 'serious game' to trigger the awareness, co-design of adaptive policy strategy and co-creation of possible solutions over time.

Sixth, we have used the MOTA framework for a slightly different purpose than for which it was developed and has been used for thus so far, namely as a causal model explaining decision choices as causal consequences of triggers, motivators, and abilities. This is a departure from the direct survey of motivation scores in all other applications of MOTA so far. The experience has identified a few issues for further possible development and refining of the framework. These include the distinction of different types of motivators, and sharpening the relations between ability, motivation and decision. Some authors (Fogg, 2009) suggest that motivation has a larger influence on decision than ability. However, the double impact of the ability score, first by influencing the motivation score, and then by multiplication of the ability and motivation scores to compute the MOTA score that we adopted from earlier MOTA work does not at all reflect this difference, so other operators than multiplication need to be explored.

Seventh, the uncertainty analysis with the computational model has been limited to uncertainties in triggers, i.e., external conditions for the farmers. Given the many uncertain assumptions in the model, an analysis of the impact of the uncertainties in the model needs to be added.

In addition to addressing these various limitations of the modelling and analysis so far, also several extensions are suggested for future work. These include, as discussed in Chapter 5, extension of the current static model to a dynamic model, coupling of the computational model with physical system models, and including the interaction of livelihood adaptation with adaptive policies in the computational model.

Finally, while various parts of the developed approaches can be improved and refined, practical application is highly recommended at this stage. Firstly, because it is better to pay attention to CLA as uncertainty in an appropriate way than not to do it at all; Secondly, because participatory exploration of future developments and possible community adaptations in interaction with possible policies creates an environment for learning by both policy makers and local stakeholders and enhances mutual understanding in policy design.

The systematic and broader use of these approaches however requires an adaptive perspective of policymakers, policy researchers and all relevant decision makers. This needs time and effort for capacity development. With a strategic plan like BDP 2100, the development oriented governance system in a developing country like Bangladesh doesn't move to the adaptive process instantly. This will need time, perhaps ten years, twenty years, or more. Investment in capacity building of current and future policymakers/ decision makers on the advantages and incentives of the adaptive approach to deal with future uncertain climate and socio-economy is essential.

Appendices

Appendix 3.1 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 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 answered 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.

Appendix 4.1 The guiding questions for Scenario workshop and semi-structured Interviews (for chapter 4 and 5)

Introduction

After a short introduction of this PhD research and objective of the scenario workshop and interview, it should 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 future possible developments of key triggering but uncertain factors

1. What is the main source of the livelihood of your family?
2. What are the factors, conditions, trends that important but not in your control for an agricultural livelihood in recent years?
3. Out of the comprehensive list of factors, conditions, trends what are the two most important but not in your control?
   Note: the two most important factors are placed into x and y axis, to have four quadrants for each scenario.
4. How the stories of possible development around these two triggering factors will be in the future (until 2030), imaginefour scenarios?

Part II: to identify the farmer's adaptation action under each scenario

5. What you perceive will be your adaptation action under each of the four scenarios?
6. What you perceive will be the action of the community under each of the four scenarios?
7. What you perceive will be the action of government institutions under each of the four scenarios?

Part III: to identify the motivation and ability for scenario-specific livelihood adaptation option

8. Why do you want to shift/ adapt the selected livelihood strategies under each of the four scenarios?
9. What assets, resources, skills, and networksyou require to adapt/ shift for selected livelihood adaptation under each of the four scenarios?

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. The session closes with providing thanks for their time and contribution.

Appendix 4. 2 Triggering factors and trends during dry season in polder 30

Sln	Triggering factors and trends in dry season	Rice farmer	Shrimp farmer	Local stakeholders
1	Increase of irrigation water shortage	√	√	√
2	Loss of crop production due to changing/ uneven rainfall pattern	√	√	
3	The increase of salinity in river water	√		√
4	The lowering of the freshwater flow in the river	√		√
5	The higher inward pressure of saline water flow from sea	√		√
6	The insufficient drainage with a small number of sluice gates	√	√	√
7	Increasing siltation of river beds increasing drainage congestion	√	√	√
8	Poor water management, no or low sediment management	√	√	√
9	Inlets are inactive, outlets are using for both in and out of the water		√	
10	Encroachment of canals for own benefit increasing waterlogging			√
11	The uneven land elevation in the wider polder			√
12	The conversion of agricultural land into other commercial use			√
13	Industrialization is increasing job opportunity			√
14	The natural resource reserve is reducing			√
15	The continuous reduction of land fertility	√		√
16	The increase rate of pest attack, the increased use of pesticides	√		
17	The outbreak of diseases		√	
18	The increasing rate of production cost	√	√	√
19	The crisis and the high cost of agricultural labor	√		
20	The net benefit per unit area from one crop decreasing	√	√	
21	Diversification of crop is increasing the net benefit of land	√	√	√
22	The vibrant market system relied on transportation and businessman	√	√	
23	The lower quality of production inputs (seeds/fish fry)		√	
24	Market demand of the product during the harvesting period	√	√	
25	Access to agricultural technology have increased	√	X	
26	Lack of technology or improved medicine in the market		√	
27	Hybrid variety increased production but decreased taste/quality	√		
28	The company does not guarantee good quality of product	√	√	
29	The agricultural support from GO and NGO has increased	√		√
30	The local community's recommendation hardly received by BWDB			√

Note: The (√) marked statements are true, (X) marked are not true and blank ( ) represent not elicited.

Appendix 4. 3 Farmers and Stakeholders Consultation

Polder 30: Gangarampur village, Batiaghata, Rice Farmer

No.	Respondent Name	Union	Land (dec)	Latitude	Longitude
1	Shondha Mondol	Gongarampur	12	22.667903°	89.508651°
2	Dhormodash Mondol	Gongarampur	70	22.668220°	89.508709°
3	Dulalkrishna Mondol	Gongarampur	75	22.668750°	89.508832°
4	Provash Chandra Ray	Gongarampur	35	22.669436°	89.508468°
5	Subroto Mondol	Gongarampur	100	22.669022°	89.509097°
6	Mridul Adhikary	Gongarampur	100	22.669357°	89.509100°
7	Chitto Ronjon Biswas	Gongarampur	150	22.669199°	89.509760°
8	Nikunjo Bihari Sarkar	Gongarampur	50	22.669547°	89.509823°
9	Shastiproshad roy	Gongarampur	175	22.669940°	89.510144°
10	Arun Roy	Gongarampur	100	22.669892°	89.509798°

Polder 30: Boyarbhanga village, Batiaghata, Integrated Farmer

No.	Respondent Name	Union	Land (dec)	Latitude	Longitude
1	Shumonto Mondol	Boyar Bhanga	100	22.705408°	89.493851°
2	Gobindo Mondol	Boyar Bhanga	100	2.705574°	89.493542°
3	Joyonto Mondol	Boyar Bhanga	50	22.705775°	89.493842°
4	Anik Mondol	Boyar Bhanga	90	22.704455°	89.493192°
5	Danis Mondol	Boyar Bhanga	50	22.704821°	89.493806°
6	Tomas Mondol	Boyar Bhanga	25	22.705616°	89.494073°
7	Milton Mondol	Boyar Bhanga	70	22.703068°	89.493350°
8	Arup Golder	Boyar Bhanga	70	22.703368°	89.492895°
9	Jibon Mondol	Boyar Bhanga	110	22.703563°	89.493232°
10	Biswa golder	Boyar Bhanga	50	22.704088°	89.492348°

Polder 30: Stakeholders

No.	Name	Profession
1	Sushen Kumar Mondol	Chairman, WMA
2	Nazrul Islam Shekh	Secretary WMA
3	Birendronath Biswas	Gate Operator
4	Shekh Md. Hadiuzzaman	Chairman, Gongarampur
5	Monoronjon Mondol	UP chairman, Sadar
6	Dr. Swapan Kumar Roy	Upazila Livestock Officer
7	Md. Rabiul Islam	Upazila Agriculture Officer
8	S M Amir Ali	Assistant Fisheries Officer
9	Deb Proshad Sarker	ED, LoCOS
10	Ponchanon Mondol	Lecturer
11	Beauty Mondol	Panel chairman, Batiaghata
12	Ranojit Roy	Fish Trader
13	BadalGazi	Fish Trader
14	Molina Rani Roy	UP member
15	Bijoy Krisna Boiragi	Chairman, Angkaria… group

Appendix 5. 1 Farmers and Stakeholders Consultation

Polder 31: Kaminibasia village, Tildanga, Dacope, Shrimp Farmer

No.	Respondent Name	Union	Land (dec)	Latitude	Longitude
1	Kallol Sarker	Tildanga	400	22.537185°	89.437664°
2	Prokash Roy	Tildanga	600	22.536883°	89.439907°
3	Depankar Roy	Tildanga	150	22.537699°	89.437755°
4	Monisha Sarder	Tildanga	66	22.537591°	89.439848°
5	Songita Sarder	Tildanga	66	22.537424°	89.439323°
6	Sajan Biswas	Tildanga	900	22.538112°	89.439076°
7	Papia Roy	Tildanga	50	22.537732°	89.439237°
8	Ashim Roy	Tildanga	75	22.537859°	89.439945°
9	Kollany Roy	Tildanga	500	22.538060°	89.437938°
10	Jhorna Sarder	Tildanga	83	22.537149°	89.440372°

Polder 31: Pankhali village, Pankhali, Dacope, Rice Farmer

No.	Respondent Name	Union	Land (dec)	Latitude	Longitude
1	Pankaj Tarafder	Pankhali	100	22.632080°	89.502230°
2	Tarapado Bala	Pankhali	67	22.631950°	89.502110°
3	Bithika Tarafder	Pankhali	33	22.631970°	89.501780°
4	Lipika Tarafder	Pankhali	33	22.631590°	89.502549°
5	Sumitra Tarafder	Pankhali	50	22.631720°	89.501735°
6	Basu Proshad	Pankhali	100	22.631264°	89.502099°
7	Vudeb Tarafder	Pankhali	50	22.631262°	89.501699°
8	Vim Tarafder	Pankhali	50	22.631109°	89.501619°
9	Mannan Sheikh	Pankhali	125	22.630820°	89.501670°
10	Shyamol Tarafder	Pankhali	33	22.631772°	89.502011°

Polder 31: Stakeholders

No.	Name	Profession
1	Khodabox bala	Gate operator
2	Suvash Chanda Sarker	Headmaster (retired)
3	Mollah Shafiul Islam	FA, DOF, Dacope Khulna
4	John Jack Bala	Motivator, ADRA Bangladesh
5	Bikash Saha	Rice trader
6	Md. Ruhul Amin Gazi	Fish trader
7	Sonaton Mondol	Rice trader
8	Md Nazrul Islam	USS
9	Rina Gain	SAAO, Department of Agri ext.
10	Sk. Abdul Quader	member
11	Ranajit Kumar Mondol	Chairman
12	Bithika Roy	Up Member

Summary of consultation and sharing with key experts

No.	Name	Profession
1	Dr. Shamsul Alam	Member (Senior Secretary), GED
2	Md. Giasuddin Choudhury	Deputy Team leader, *SIBDP,* Dhaka.
3	Md. SarafatHossain Khan	DG, WARPO
4	Dr. Shamal Chandra Das	Superintending Engineer (Civil), Planning 1, BWDB
5	Prof. Umme Kulsum Navera	Professor, Department of Water Resources Engineering, BUET.
6	Engr. AHM Kausher	Hydro-morphology and planning Adviser, CDSP-IV
7	Mr. Saiful Alam	Institute of Water Modelling (IWM)
8	H.S. Mozaddad Faruque	Vice President, BWP
9	Dr Maminul Haque Sarker	Senior Advisor, River, Delta and Coastal Morphology, CEGIS.
10	Dr. Saleemul Huq	Director, ICCCAD, Independent University
11	Mr. Guy Jones	Team Leader, Blue Gold Program
12	Ir. Catharien Terwisscha van Scheltinga	Director, WUR Project Office, Dhaka

Appendix 5. 2 Scenarios developed by rice farmers in polder 31

Availability (Industries-agricultural Technology)

Water-constrained Agro Scenario • ***Water availability: poor quantity and quality*** *Water salinity increases because of poor water management*[1] *and degrading infrastructures, canals are not dredged. Availability and storage of irrigation water is low. The local elected body/ influential peoples are in favor of increasing water salinity.* • ***Agricultural development: high*** *Agricultural skill and knowledge increases. Improved agricultural tools, techniques, resilient crop varieties are accessible to all type of farmers at competitive prices. Low water demanding and high economic value crops are popular. Govt. declares agricultural land which is not allowed for conversion into other purposes.*	***Flourish Scenario*** • ***Water availability: good quantity and quality*** *Water salinity reduces or does not increase because of improved water management and infrastructures, canals are dredged to preserve freshwater/rainwater for agricultural production and environmental conservation. Ground water extraction is regulated. The local elected body/ influential peoples are in favor of maintaining reduced water salinity.* • ***Agricultural development: high*** *Agricultural skill and knowledge increases. Improved agricultural tools, techniques, resilient crop varieties are accessible to all type of farmers at competitive prices. An increase of crop production with rice and off-season multi-cropping of high economic values. Govt. declares agricultural land which is not allowed for conversion into other purposes.*
Water-constrained Industrial Scenario • ***Water availability: poor quantity and quality*** *Water salinity increases because of poor water management and degrading infrastructures, canals are not dredged. Availability and storage of water is low. The industrial water use is the major share than agricultural water use. The industrial pollution of water is major concern.* • ***Industrial development: high*** *The agricultural land converts for industrial and urban development purposes. No land declaration for agricultural use. A few of lands are left for agriculture as the industrial use of land is economically profitable. The rise of shrimp industry. Roads, highways, railways and infrastructure development.*	***Industrial Scenario*** • ***Water availability: good quantity and quality*** *Water salinity reduces or does not increase because of improved water management and infrastructures, canals are dredged. The industrial water use is the major share than agricultural water use.* • ***Industrial development: high*** *The agricultural land converts for industrial and urban development purposes. No land declaration for agricultural use. A few of lands are left for agriculture as the industrial use of land is economically profitable. Roads, highways, railways and infrastructure development.*

Water availability (poor- good)

[1]Refers the water infrastructure management (i.e embankment, sluice gates, canals, rivers etc.) by BWDB/ LGED and other projects that excludes the irrigation water management of farmers at their own land

Appendix 5. 3 Scenarios developed by shrimp farmers in polder 31

Water-constrained Scenario

- ***Water Availability: Poor quality and quantity***
  The amount and quality of saline water at canal is poor because of high temperature, abrupt rainfall, improper water management and infrastructures. Virus infestation is higher.

- ***Market system: favorable***
  Access to market increases. Roads and transportation are good. Improved technology, inputs (fish fry, feed etc.), cold storage etc. are available in the nearer market at competitive prices. A good relation exist with shrimp processing companies, farias (local traders) and other relevant market actor for quality fish production and high market value. Government rules and support for exporting and international market

Flourishing Scenario

- ***Water Availability: good quality and quantity***
  The amount and quality of saline water at canal is good because of favorable weather (moderate temperature, rainfall), proper water management and infrastructures. Virus infestation is lower.

- ***Market system: favorable***
  Access to market increases. Roads and transportation are good. Improved technology, inputs (fish fry, feed etc.), cold storage etc. are available in the nearer market at competitive prices. A good relation exist with shrimp processing companies, farias (local traders) and other relevant market actor for quality fish production and high market value. Government rules and support for exporting and international market

Stagnant Scenario

- ***Water Availability: Poor quality and quantity***
  The amount and quality of saline water at canal is low because of high temperature, abrupt rainfall, improper water management and infrastructures. Virus infestation is higher.

- ***Market system: unfavorable***
  Access to market is low. Roads and transportation are poor. Improved technology, inputs (fish fry, feed etc.), cold storage are scarce and costly in the nearer market. Lack of good relation with shrimp processing companies, farias (local traders) and other relevant market actors. Lack of Government rules and support for exporting and international market.

Market-constrained Scenario

- ***Water Availability: good quality and quantity***
  The amount and quality of saline water at canal is good because of favorable weather (moderate temperature, rainfall), proper water management and infrastructures. Virus infestation is lower.

- ***Market system: unfavorable***
  Access to market is low. Roads and transportation are poor. Improved technology, inputs (fish fry, feed etc.), cold storage are scarce and costly in the nearer market. Lack of good relation with shrimp processing companies, farias (local traders) and other relevant market actors. Lack of Government rules and support for exporting and international market.

Market system (unfavorable-favorable)

Water availability (poor- good)

Appendix 5. 4 Input data on ability factors of 10 shrimp farmers and 10 rice farmers at present condition

Young rice farmer (7 farmers)

Sln	Ability factors	Very high	high	average	b average	low	Total	Wt. ave
		0.9	0.7	0.5	0.3	0.1		
	Financial ability							
1	Investment capacity	0.1	0.3	0.1	0.1	0.1	0.7	0.39
2	Scope of alternative livelihood for income	0.2	0.5	0	0	0	0.7	0.53
	Technological ability (physical and knowledge)							
3	Ownership of livelihood assets (transferable/fixed)	0	0.3	0.1	0.2	0.1	0.7	0.33
4	Livelihood skills and knowledge	0	0.5	0	0.2	0	0.7	0.41
	Institutional ability							
5	Access to Govt. Agri/Fisheries Dept	0	0.1	0.4	0.2	0	0.7	0.33
6	Access to social groups/networks	0	0.1	0.3	0.2	0.1	0.7	0.29

Elderly rice farmer (3 farmers)

Sln	Ability factors	Very high	high	average	b average	low	Total	Wt. ave
		0.9	0.7	0.5	0.3	0.1		
	Financial ability							
1	Investment capacity	0	0.2	0	0	0.1	0.3	0.15
2	Scope of alternative livelihood for income	0.1	0.2	0	0	0	0.3	0.23
	Technological ability (physical and knowledge)							
3	Ownership of livelihood assets (transferable/fixed)	0	0.2	0.1			0.3	0.19
4	Livelihood skills and knowledge	0	0.2	0.1	0	0	0.3	0.19
	Institutional ability							
5	Access to Govt. Agri/Fisheries Dept	0	0.1	0.2	0	0	0.3	0.17
6	Access to social groups/networks	0	0.2	0.1	0	0	0.3	0.19

Shrimp farmer (10 farmers)

Sln	Ability factors	Very high 0.9	high 0.7	average 0.5	b average 0.3	low 0.1	Total	Wt. ave
	Financial ability							
1	Investment capacity	0.2	0.3	0.1	0.2	0.2	1	0.52
2	Scope of alternative livelihood for income	0.9	0	0.1	0	0	1	0.86
	Technological ability (physical and knowledge)							
3	Ownership of livelihood assets (transferable/fixed)	0	0.4	0.5	0.1	0	1	0.56
4	Livelihood skills and knowledge	0.1	0.3	0.4	0.2	0	1	0.56
	Institutional ability							
5	Access to Govt. Agri/Fisheries Dept	0	0.4	0.1	0.5	0	1	0.48
6	Access to social groups/networks	0	0.4	0.1	0.5	0	1	0.48

Table Note:

1. The ability data of households are expressed in % of households in each of five class.
2. The five qualitative classes: very high, high, average, below average, low corresponds with the quantitative value of 0.9, 0.7, 0.5, 0.3 and 0.1 respectively
3. Weighted average are calculated as sum of class value x % of households at that class.
4. The ability factor data is calculated as

Ability Factor 1: The investment capacity

Unit	Very high	high	average	b average	low
% of cost shared for production	full own	70- 99	50-69	30- 49	full loan

Ability Factor 2: Scope of alternative livelihood for income

Unit	Very high	high	average	b average	low
Number of livelihood strategy the hh member involved	5 or more	4	3	2	1

Ability Factor 3: Ownership of livelihood assets (transferable/fixed)

Unit	Very high	high	average	b average	low
Number of livelihood asset owned	Above 12	10 to 12	8 to below 10	5 to below 8	below 5

Ability Factor 4, 5 and 6: Livelihood skills and knowledge, Access to Govt. Agri/Fisheries Dept and Access to social groups/networks

Unit	Very high	high	average	b average	low
Perception in scale of very high (5) to low (1)	5	4	3	2	1

Appendix 5. 5 Photographs of workshops, interviews, consultation and sharing

Scenario workshops in Polder 30

Local stakeholders, Batiaghata May 2018

Integrated farmers, Boyarvanga village, May 2018

Rice farmers, Gangarampur village, May 2018

Scenario workshops in Polder 31

Local stakeholders, Dacope, May 2018

Shrimp farmers, Kaminibasia village, May 2018

Rice farmers, Pankhali village, February 2018

Interview with farmer

Integrated farmer, Batiaghata, May 2018

Rice/ Rabi crop farmer, Batiaghata, May 2018

Rice/ Rabi crop farmer, Batiaghata, May 2018

Consultation and sharing with key policy stakeholders

Let's Talk water, Adaptive Delta Management in Bangladesh, November 2016

Delta Community Meeting, October 2017

ADM project stakeholder consultation, January 2020

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About the Author

Umme Kulsum was born on 11th December 1978 in Khulna, Bangladesh. She completed graduation with a Bachelor in Environmental Science from Khulna University in 2003. Her Bachelor research is on adverse pregnancy outcome of chronic Arsenic exposure in Bangladesh. After graduation, she specialized in climate change adaptation and completed a Masters thesis on strategies for mainstreaming climate change adaptation in Southwest Bangladesh. She obtained Masters in Environmental Science at the same University in 2011.

In 2003 immediately after graduation, she joined Coastal Development Partnership in the role of knowledge management, publishing, and dissemination on the climate change impact, adaptation, and risk reduction for the stakeholders in the 'Reducing Vulnerability to Climate Change' partnership project. Since 2006, she joined Prodipan in a similar role as 'climate change focal point' and promoted as 'Coordinator' for overall coordination of projects in the organization. In 2010, she joined Catholic Agency for Overseas Development in a coordination role of the multi-partners 'Improved Food and Livelihood Security' programme, continues support in programme development, monitoring and impact assessment with the expertise in the application of participatory approaches until 2015.

In 2015, Kulsum commenced her PhD research at the Delft University of Technology, the Netherlands and the Institute of Water and Flood Management, Bangladesh in the 'Adaptive Delta Management' Project. The research focused on developing approaches to support adaptive delta management with a systematic exploration of community livelihood adaptation as uncertainty. Stakeholders expressed interests in application and further development of new approaches in BDP 2100 implementation.

Since 2017, Kulsum is coordinating the 'Delta Community' initiated with a focus on delta research in Bangladesh.

Recently in March 2020, Kulsum has accepted an offer for 'National Climate Change and Risk Management Specialist' of the Food and Agriculture Organization in the 'Community-based Climate Resilient Fisheries and Aquaculture Development in Bangladesh' project. She is hopeful for practical application and further development of her approaches in this role.

She lives in Dhaka with her husband Nur Mohammad, her sons Nahim Wasit and Luban Wasit.

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Long-term planning in urbanizing deltas has to deal with deep uncertainties in socio-economic development and climate change. Adaptive Delta Management (ADM) has been developed as an approach that acknowledges these and similar uncertainties. The Bangladesh Delta Plan 2100 has, in principle, adopted the ADM approach, and it recognizes general uncertainties in (external) physical and socio-economic conditions. It does, however, not acknowledge uncertainties in the way local communities may adapt to uncertain conditions and policy measures. Historical analysis confirms that local adaptation may be different from policymaker's expectations, and that ignoring this may seriously harm the effectiveness of such a planning approach. This research offers two novel approaches for systematic exploration of the uncertainties in community livelihood adaptation under a variety of uncertain future conditions. The first approach looks into the mental model that guides local actors' decision making, while the second approach uses a model describing the impact of (external) triggers on actors' motivation and abilities for a variety of adaptation actions. While both these approaches might be improved, case study applications in the polders of southwest Bangladesh illustrate their utility as instruments to create awareness of possible developments and to act as vehicles for participatory learning by both policymakers and local communities.