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Why uncertainty in community livelihood adaptation is important for adaptive delta management: A case study in polders of Southwest Bangladesh

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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.

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; DeltaProgramme, 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

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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[1] (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 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[2] 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.

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 (Fig. 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 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 1).

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 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

[1] 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).

[2] 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.

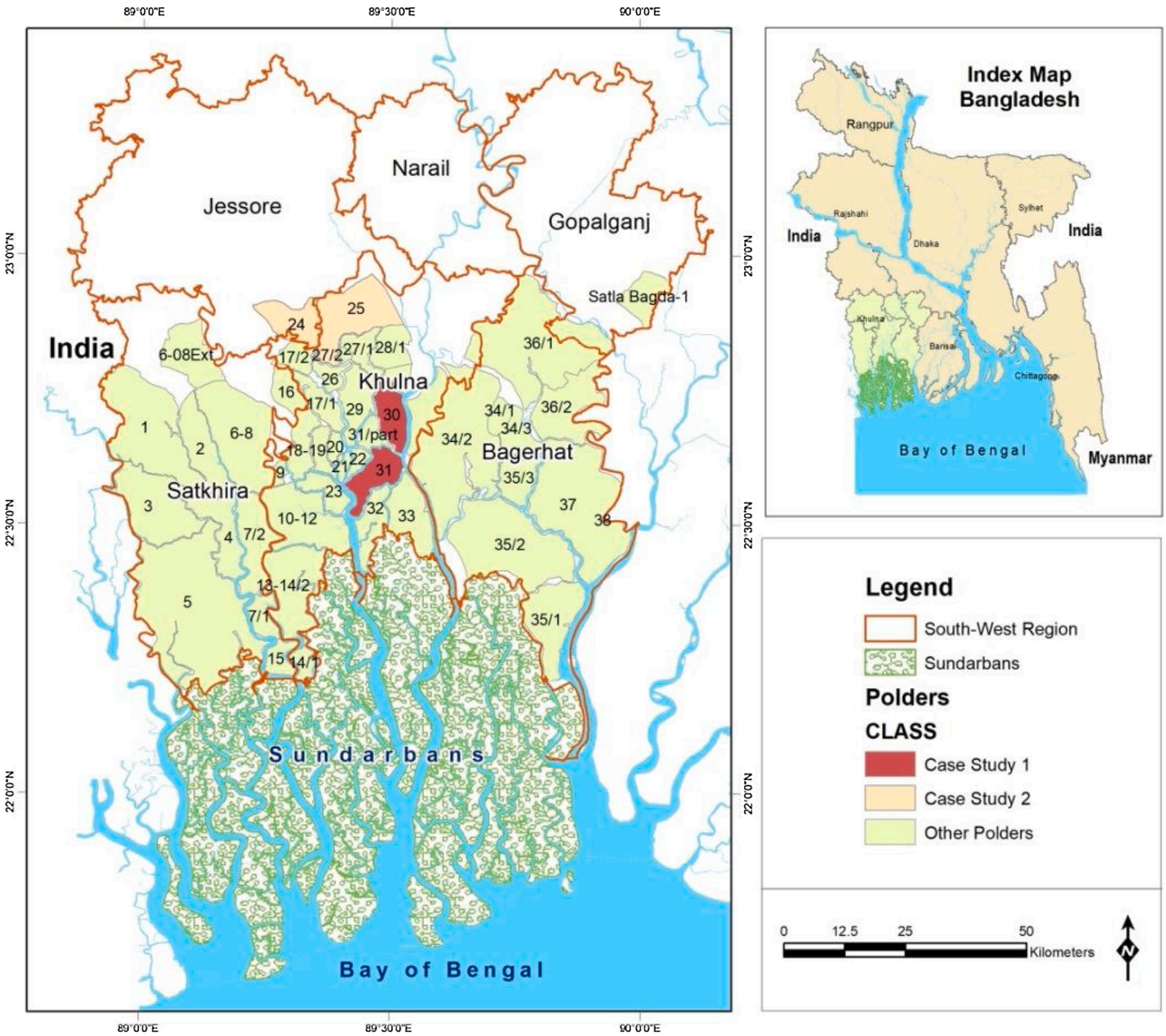

Fig. 1. The study area showing Case 1 (polder 30 and 31) and Case 2 (polder 24 and 25).

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.

3. Results

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 Fig. 1. The region covers around 16,135 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).

Since 1960, this region has seen five distinguished transitions in the water/land management regime (Fig. 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 developments in 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. Fig. 2 (based on literature in Table 1) illustrates the historical timeline of transitions and shifts in delta management including the key objectives, system concerns, and driving factors.

Between 1960 and 1975 the natural tidal system of this region was transformed into a 'polder' enclosure system with 139 polders (GED,

Table 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 document review, two FGD with the water user group, consultation with ten policy experts	(Gain et al., 2017b)
2	Shifts in water governance	44 interviews with policymakers, researchers, consumers, and NGO workers	(Chan et al., 2016)
3	Shift towards Integrated Water Resource Management (IWRM)	Policy document review, interview/survey of ten key policy experts	(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, key informant interview	(Dewan et al., 2015)
6	Adaptation Tipping Point in delta management and community engagement	Literature review	(Kulsum et al., 2017a)
Case 1: Livelihood adaptation in agriculture: Polder 30 and 31			
	Shrimp culture versus crop diversification in two villages at polder 31	Literature review, Village census (310 hh), KII	(Kabir et al., 2016)
	Community water management and cropping system synchronization in polder 30	Farmer interview (37)	(Mondal et al., 2015)
	Factors affecting farmers adaptation in Sathkhira	Survey (100 farmers)	(Uddin et al., 2014)
	Situation analysis polder 31: community-based water management	Seven Focus Group Discussions and fourteen Key Informant Interviews (KIIs)	(Bakuluzzaman, 2012)
	Rice versus shrimp in polder 31	Farmer interview (120)	(Fatema et al., 2011)
	Rice to shrimp in southwest	60 sample plots: Land use/land coverage, crop area, and yield data	(Ali, 2006)
Case 2: Tidal River Management :Polder 24 and 25			
1.	Social learning in TRM	Mixed-method of RWMA[a] participatory approaches: 15 Focus Group Discussion, 3 local stakeholder meeting, 20 institutional surveys, 1 regional stakeholder workshop, 210 Individual interviews	(Mutahara, 2018)
2.	TRM: shift in polder management	Literature review and document review	(van Staveren et al., 2017)
3.	TRM as Transdisciplinary approach	Mixed method: qualitative case study, two workshops, site visit, and literature review	(Gain et al., 2017a)
4.	Local stakeholder perception on TRM	Literature review and 61 Individual interview	(Karim and Mondal, 2017)
5.	TRM in the frame of stakeholders	RWMA participatory approaches: participatory maps, 42 semi-structured interviews, 21 open interviews, 100 document review	(de Die, 2013)

[a] Rapid Water Management Appraisal.

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 *Aila* in 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[3] 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 6.8 mm, 3.7 mm and 4 mm per year, respectively (GED, 2018a). All these challenges have influenced the transitions in the southwest region polders we studied.

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. Fig. 3 presents the major features of the Polder 30 and 31.

The Polder 30 is located in *Batiaghata*, *Gangarampur*, and *Surkhali* Unions of *Batiaghata* Upazila. An embankment of ~40 km length protects an area of 6455 ha, with 66 % Net Cultivable Area (NCA), 29 % settlements, 4% water bodies (*Khal*) and 1% roads (CEGIS, 2015). About 9490 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 30–49 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 Kazi Bacha*) (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 30–49 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).

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

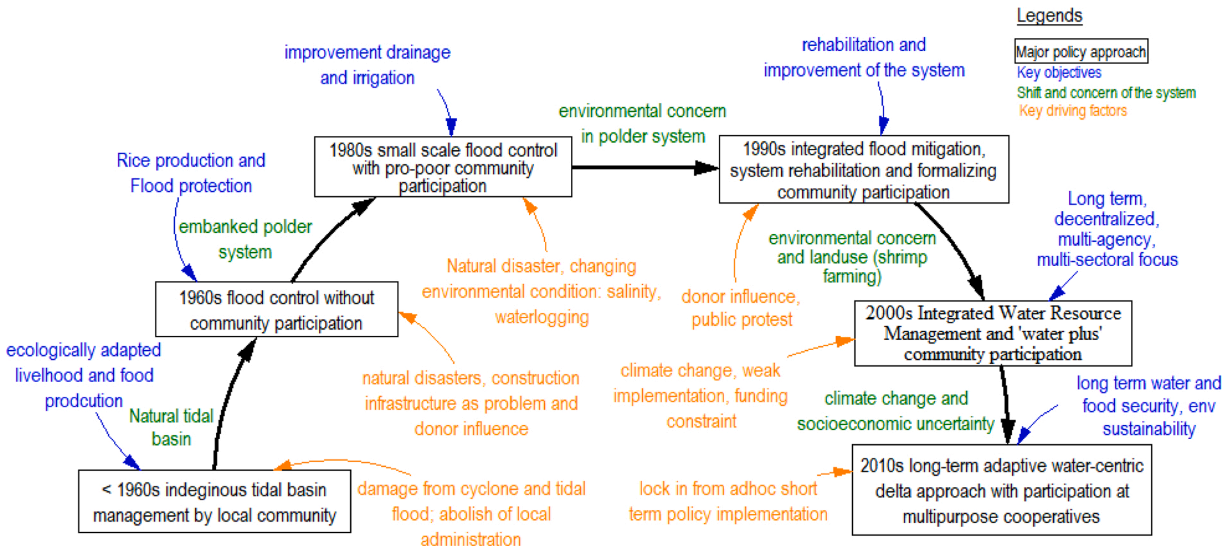

Fig. 2. Historical timeline of transitions and shifts in delta management (based on literature in Table 1). The six major policy approaches are shown in the boxes. The key objectives are in blue color; Major shift and concern of the system are in green color and key driving factors are in orange color.

3.2.1. Environmental conditions: compound context including salinization

The dynamics of the environmental conditions and polder management approaches summarized in Fig. 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.

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 1960–2015, 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).

3.2.3. Community Livelihood Adaptation in Polders 30 and 31

As illustrated in Fig. 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.

3.2.3.1. 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 1967–1972 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

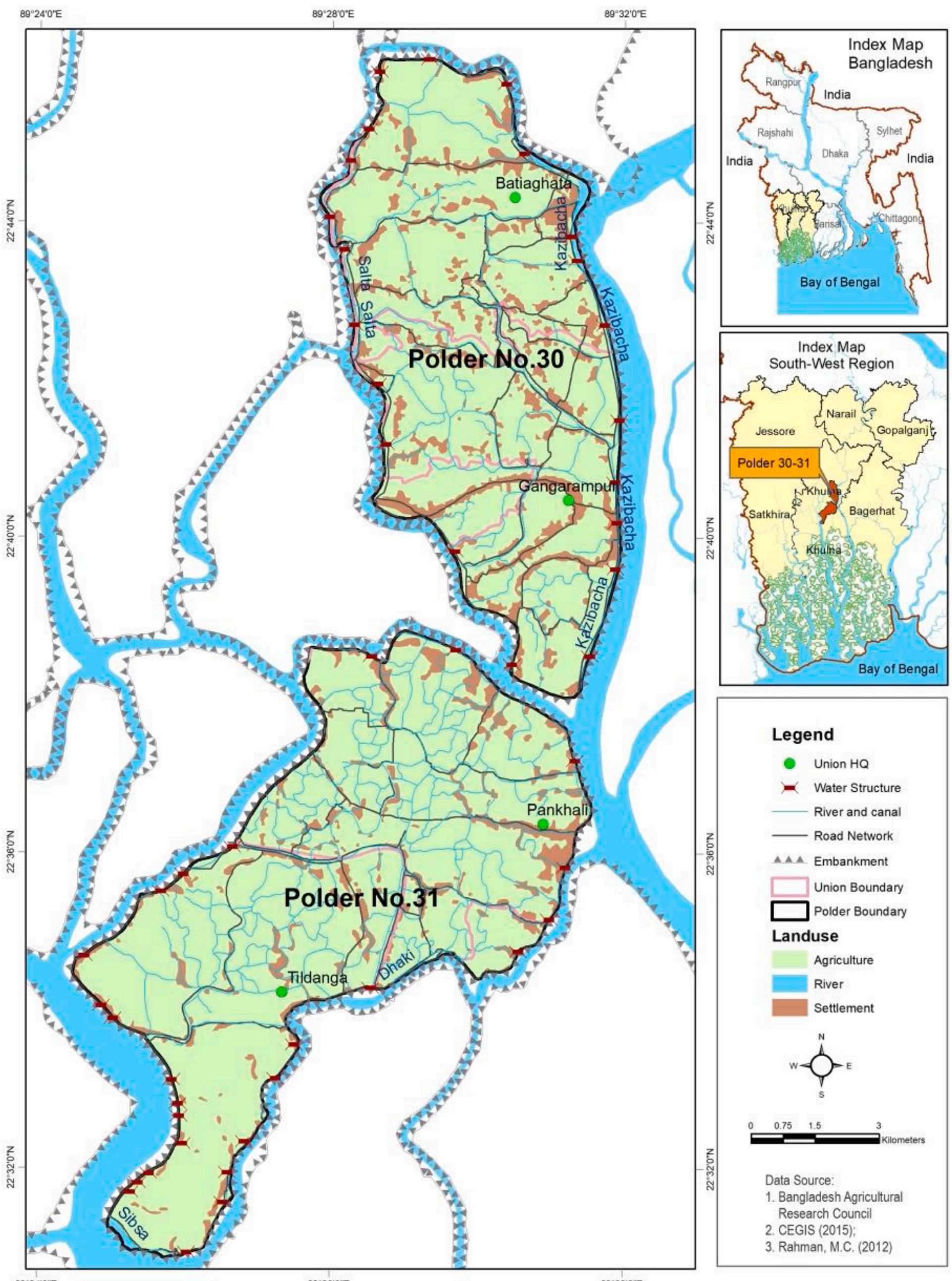

Fig. 3. Major features of the Polder 30 and 31.

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.

3.2.3.2. 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*[4] 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 embankment shifted from protecting saline

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

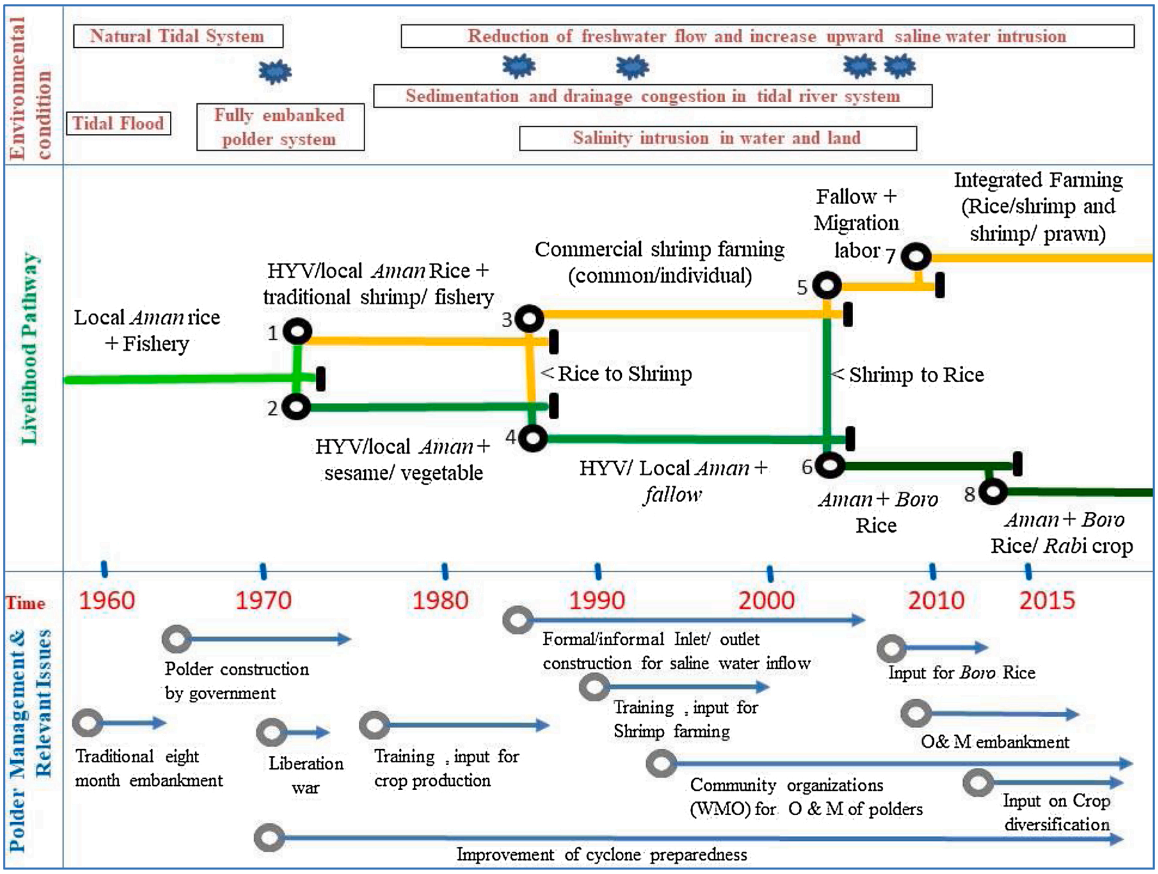

Fig. 4. Livelihood pathways of local farmers' community, with an indication of relevant environmental conditions (on top), and polder management and other relevant issues (bottom). The green line shows the rice cultivation pathway and the yellow line shows the shrimp farming pathway. ⭘ represents the transfer of livelihood ▮, represents the terminal of livelihood ⭘➞, represents the timing of issues. ✸ represents major cyclones.

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 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.

3.2.3.3. 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 Dacope Upazila decreased from 13,395 ha in 2008–2464 ha in 2012 (Kabir et al., 2016).

3.2.3.4. 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).

3.2.3.5. 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[5] 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).

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 Fig. 5. As the drainage capacity of the rivers decreased gradually, waterlogging[6] 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.

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[7] 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.

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 ha that were worst affected by the

[5] Not assumed or expected in the single focused objective of grow more rice at the time of plan.

[6] The saturation of soil with water, impeding plant growth.

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

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

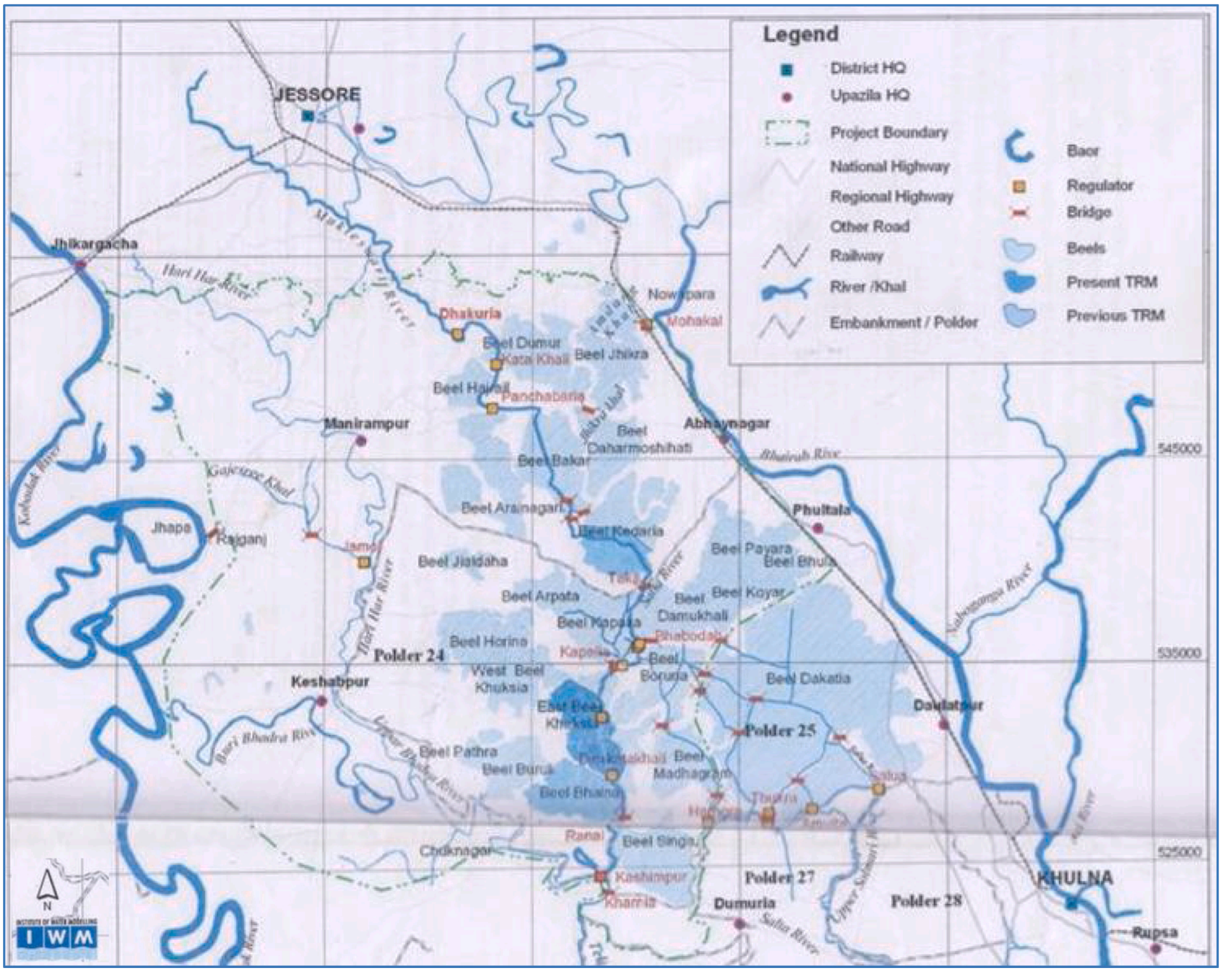

Fig. 5. TRM areas around polder 24 and 25 under KJDRP project (de Die, 2013).

drainage congestion in the southwest 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*. Fig. 5 shows TRM areas around polder 24 and 25 under KJDRP Project.

3.3.2.1. 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.

3.3.2.2. Community responses and adaptation in Beel Vaina. The violent social protest continued, and a new public cut was made at *Beel Vaina* in 1997. The cut turned the 1000 ha *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).

3.3.2.3. 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).

3.3.2.4. 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).

3.3.2.5. 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.

3.3.2.6. 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 Fig. 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.

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.

4. Discussion and conclusions

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

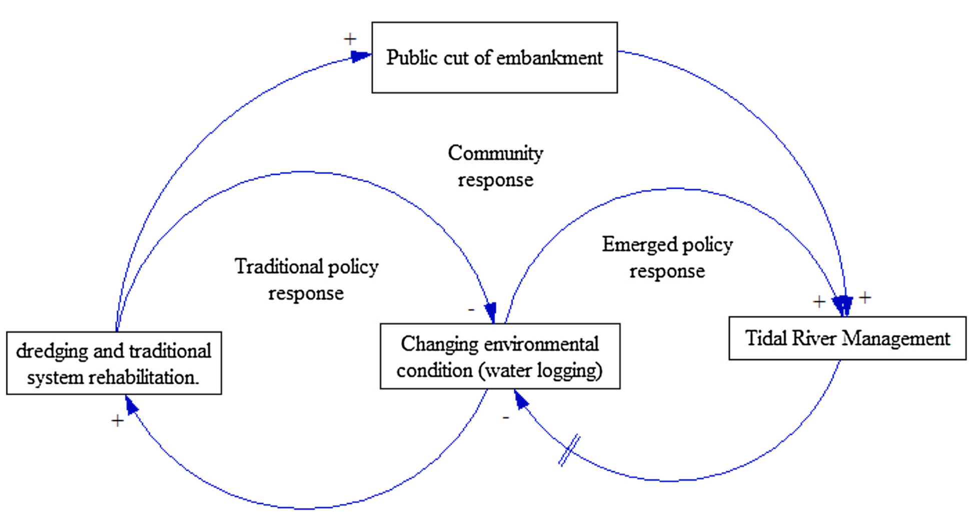

Fig. 6. Co-evolution of TRM in policy and community response to waterlogging[8]. The traditional policy response loop has triggered a community response loop with 'the public cut of embankment' which contributes in the emergence of a new 'Tidal River Management' policy response loop to waterlogging.

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.

Author statement

We are thankful for insightful suggestions for improving the paper. The Authors statements in response to reviewer comments are incorporated at the reviewers comment file.

Looking forward for your concern (if any) for publication.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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