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Water management and livelihood choices in Southwestern Bangladesh

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Abstract

Coastal Bangladesh faces an increasing number of challenges including cyclones, tidal surges, floods, drought, saline water intrusion, waterlogging and land subsidence, which pose substantial threats to the livelihoods of the coastal inhabitants. In addition to these threats, profound social and land-use changes are complicating the livelihoods of resource users in the region, including the introduction of aquaculture and increasing competition for ground and surface water sources. The government of Bangladesh has targeted this region for investment with irrigation expansion. This paper uses a sustainable livelihood lens to understand the role of investments in water management and irrigation in driving and shaping livelihood changes and transitions over the past ten years and offers recommendations for investments. We find that while water infrastructure development has greatly enhanced the role of agriculture in coastal livelihoods over the last 10 years, further development of irrigation infrastructure should only be prioritized after issues of water governance and inequity across agricultural and aquacultural livelihoods are addressed.

1 Introduction

Coastal Bangladesh faces an increasing number of challenges including cyclones, tidal surges, floods, drought, saline water intrusion, waterlogging, and land subsidence, which pose substantial threats to the livelihoods of the coastal inhabitants (Lazar et al., 2015). The environment and thus livelihoods of people in the region depends upon the mixing of fresh and saline water. However, declining freshwater availability, partially linked to the construction of the Farraka Dam in 1975, threatens both the crop and fish diversity the region can support (Gain and Guippone, 2014; Gain et al., 2013). As a result of decreased freshwater flows, saline water has been intruding further inland, contributing to expanded use of irrigation for crop production, albeit with more limited supplies (Gain et al., 2007). At the same time, climatic changes, including extremes, such as cyclones and tidal surges are pushing increased development of shrimp farming. Injudicious use of rice land for shrimp farming, in turn, has reduced the economic returns and potential of rice farming (Khan et al., 2014). The introduction of saline varieties is important but these varieties cannot cope with climatic extreme events, such as Cyclone Aila and successive events (Rabbani et al., 2013). A common coping strategy of growing demands on and reduced supplies and increased variability of freshwater resources has been seasonal and permanent rural-to-urban migration (Mallick and Vogt, 2014).

A key component of the government of Bangladesh's strategy to improve livelihoods in the coastal south has been massive investment for improved provision of surface water, including surface water augmentation in Khulna and Barisal divisions (Bangladesh and FAO, 2013). Recent findings suggest that with good governance, storage of surface freshwater flows in polders could increase rice production by 15% every second year, or as high as 40% with increased investments in surface water infrastructure (Sharifullah et al. 2009). The need for improved infrastructure is also highlighted in the Bangladesh Climate Change Strategy and Action Plan *(*Ministry of Environment and Forests, 2009*),* which identifies 44 adaptation programs based on the following six pillars: (1) food security, social security and health, (2) comprehensive disaster management, (3) infrastructure, (4) research and knowledge management, (5) mitigation and low-carbon development, (6) capacity building. To a considerable extent the action plan is based on measures to enable continuation of existing land uses – including, for example, through better maintenance and reconstruction of flood control and coastal embankments to higher standards so that they continue to function in the face of rising sea levels and more frequent severe storms and

cyclones. However, the plan is also directing investment into research, development, and extension for crops (mainly rice) that are tolerant of climate related stresses, and expanding irrigation. In addition, other key projects and investments in the region, including the Blue Gold (2013-2019) and the Bangladesh Delta Plan 2100, are exploring a range of issues related to integrated water management in polders and on addressing the potential impacts of climate change.

Some research has found that farmers consider irrigation as a key climate change adaptation strategy (Uddin et al., 2014). However, Bell et al. (2015) examine farm production data from a nationally-representative survey and find that the case for expanding irrigation in the south is not compelling, and points instead to the importance of understanding and managing the interplay between brackish-water shrimp aquaculture and irrigated freshwater agriculture as competing approaches to cope with the stressors faced by the coastal south. These conflicting findings raise uncertainty regarding the role that irrigation may play in strengthening coastal livelihoods in the coming decades.

This paper employs a sustainable livelihoods approach to contribute thicker descriptions of rural stressors and priorities in Bangladesh to this discussion. First, we aim to understand changing livelihood patterns in the region, to identify if there is a broad switch to agricultural or aquaculture-based livelihoods. Within that, we focus specifically on understanding the role that changes in physical and natural capital—access to water management and irrigation infrastructure and resources—have played in driving these changes, to understand if this supports or challenges planned water resource investments. Finally, we hope to untangle the priorities and perspectives of local farmers as to their key water-related challenges moving forward.

2 Context and History:

In coastal Bangladesh, livelihoods are intertwined with water and fishing, and land-use has evolved through both human and natural actions (Khan et al. 2014). The area of this study, southwestern Bangladesh, is a highly productive environment shaped by the interplay of freshwater from rivers and saline water entering from the Bay of Bengel (Shameem et al., 2014). Farmers in the region have long practiced traditional coastal aquaculture, known locally as *Bheri*; in this practice, cultivators allowed tidal water in paddy fields from January/February to June/July for aquaculture and would then cultivate transplanted aman rice during the monsoon season (Paul, 2012). In the colonial period, *zamindar* (landlords) oversaw the construction of temporary earthen embankments that were replenished through community labor (sometimes compulsory) until the *zamindari* system was disbanded in the 1950s (Dewan et al., 2015).

A large-scale government investment program in coastal embankments (polders) in the 1960s-80s to protect agricultural land from saltwater intrusion and tidal waves expanded the area that could be cultivated with rice and was largely accompanied by an increase in irrigation, particularly groundwater irrigation (BADC, 2012; FAO, 2012). While green-revolution varieties could now be grown in these areas, these investments also effectively ended traditional brackish water shrimp farming (Paprocki and Cons, 2014; Paul, 2012). These polders also encouraged more settlers to move to the coastal area, providing a sense of permanence (Dewan et al., 2015). Land-use and cropping patterns in this area have been largely influenced by the salinity and the availability of irrigation water for dry-season crops. (Kabir et al. 2015).

Strong international demand for shrimp (beginning in the 1970s) and increased waterlogging, which raised the production costs of rice, encouraged the spread of commercial shrimp farming into rice

growing areas (Karim 1986). Shrimp farming received strong support from both the government of Bangladesh and international development agendas (Rivera-Ferre, 2009). The latter started to promote commercial shrimp production in the 1980s (Adnan, 2013). Much of the expansion of shrimp production has centered in the southwest, particularly in the districts of Bagerhat, Khulna, and Satkhira, with Satkhira having the greatest potential for expansion (Ahmed, 2013). The vast majority of these operations (about 70%) practice traditional aquaculture in *ghers*[1] that support sequential rice and shrimp culture, with the exchange of tidal water (Paul and Vogl, 2011). During this time period as well, the government of Bangladesh began to favor investments in smaller-scale water projects rather than larger-scale projects (Dewan et al., 2015).

However, the expansion of the sector in Bangladesh has largely been unplanned and without regulation or oversight. An extensive literature details the environmental and social problems associated with the expansion of shrimp farming. Key challenges include conversion of mangroves and agricultural land into shrimp ponds, loss of capture fisheries and biodiversity, water pollution, and growing salinization of agricultural fields (Paul and Vogl, 2011; Islam, 2008). Other impacts have included reduced profit margins, disease, and intermittent export bans. Socially, the introduction of shrimp culture has led to the displacement of small landholders who could not afford costlier and riskier shrimp production, waterlogging for nearby farmers, increases in the prices of land, loss of livestock grazing land, exacerbated power inequalities, and a loss of employment in rice fields (Paul and Vogl, 2011; Ito, 2002; Paprocki and Cons, 2014; Adnan, 2013). There is also some evidence that larger shrimp farms, owned by outsiders and investors, acquired land leases from small farmers through coercion (Islam, 2008).). Many of the large *ghers* were later abandoned, while individual landowners established smaller, owner-operated shrimp farms. In the areas studied, respondents reported that there is now reported to be more land under small shrimp farms than under large ones. Despite the challenges associated with shrimp farming, farmers continue to invest in this practice due to the higher profit margins compared to rice and despite the long-term environmental consequences, as poor infrastructure and lack of governance offer few other livelihood options (Swapan and Gavin 2011). Farmers have made some adaptations to reduce the adverse environmental impacts of aquaculture, including the use of saline-tolerant rice cultivars, the flushing out of accumulated salt, and allowing the soil to dry following the rice harvest (Kabir et al., 2015). Yet, these farmer-level adaptations may not be enough to overcome the challenges of deteriorating community infrastructure. The 2004 National Water Management Plan noted needs for large investment at the community level in maintaining, rehabilitating, and restoring water infrastructure, but the current governance arrangements do not allow for the allocation of these resources (Dewan et al., 2015).

Ultimately, local farmers and land-users face a tradeoff between two distinct paths: continuing with brackish water shrimp cultivation and controlling and reversing salinity intrusion into croplands to allow for irrigation and dry-season cropping (Kabir et al., 2015). While farmers recognize that shrimp farming has negative environmental implications, including a troubling loss of ecosystem functionality that may limit the ability of households to opt out of this system in the future, it does promise shorter-term financial benefits—albeit ones that are not equitably shared and with other social impacts, including on labor and land access (Shameem et al., 2014; Lázár et al., 2015). However, shrimp farming is not the only cause of environmental degradation and salinity, for the region is in is in the "throes of multiple overlapping ecological crises" (Paprocki and Cons, 3 2014).

[1] An area (usually several dry season fields) enclosed by earthen bunds to retain water used for cultivating shrimp or fish.

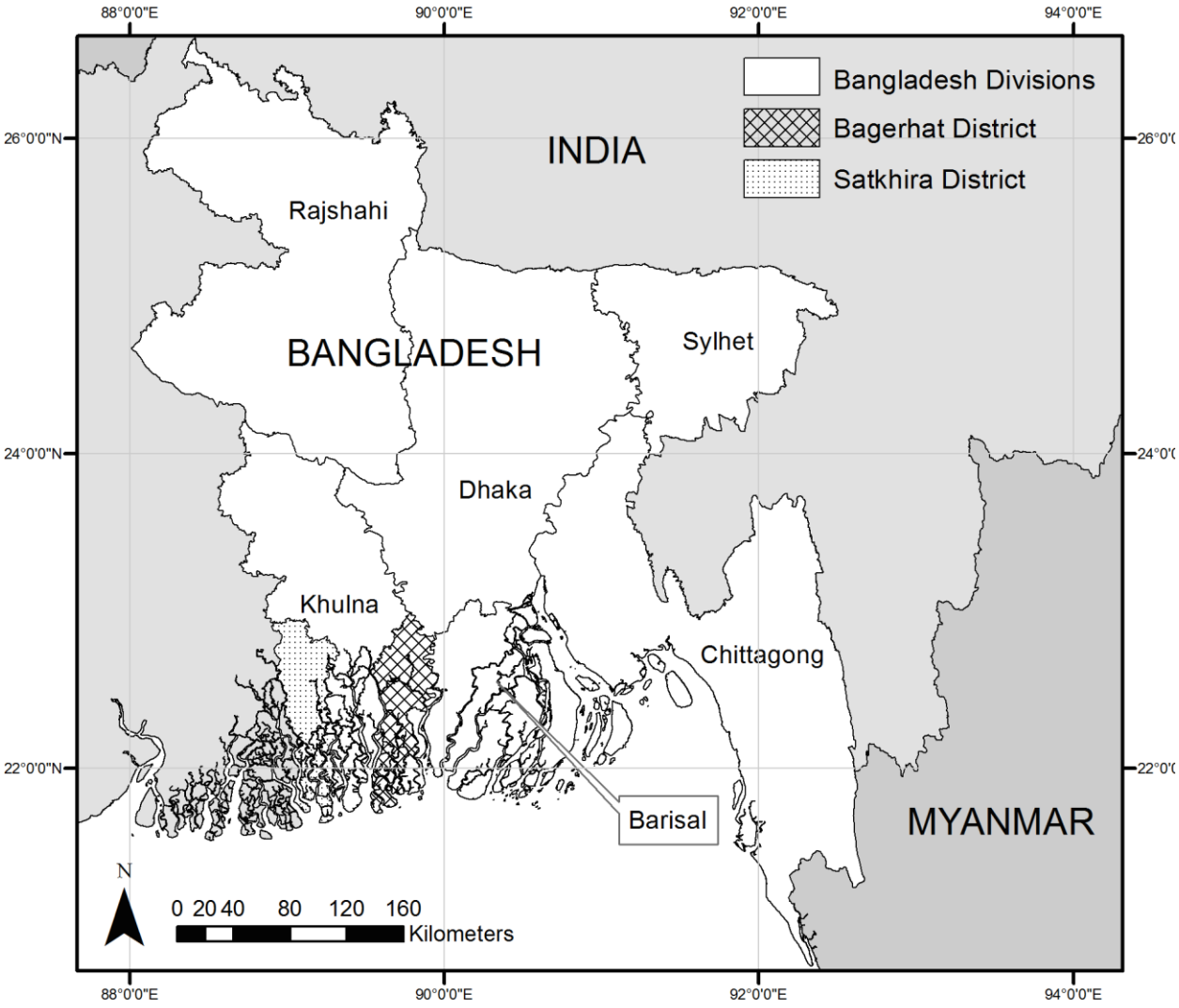
3. Analytical Approach

This study uses the sustainable livelihoods approach, a framework developed to improve the understanding of livelihoods of poor farmers by focusing on ability to access and use four different capitals: human, natural, physical, and socio-cultural (e.g. Bebbington, 1999; DFID, 1999; Scoones, 1999). We find this approach useful, as it allows us to understand 1) the different capabilities, assets, and activities utilized by different households to create livelihoods, 2) the linkages between individual, household or community assets (in our case, irrigation related technologies) and the activities the households engage in)(Ibid), and finally, 3) to understand the broader context of vulnerability in which these livelihood activities take place (Bhandari, 2013; Allison and Ellis, 2001; Carney, 2002; Ahmed et al., 2008). Furthermore, the use of livelihoods analysis allows us to identify different livelihood trajectories and to evaluate the tradeoffs that occur from different livelihood pathways (Scoones, 2009). We supplement the livelihoods analysis by employing a political ecology lens to address issues of politics, power, and governance, as well as the role of state and development institutions acting as drivers of landscape and livelihood change (see for example Zimmer, 2011; Harris, 2006). We finally seek to also integrate literature on the new "rurality", which understands that "in response to the various encroachments of capitalist development, smallholders' agrarian livelihoods have not disappeared so much as diversified and hybridized, albeit with varying degrees of success" (Fairbairn et al., 659, 2014).

4 Methods and Data

The study is based on a series of Focus Group Discussions (FGDs) conducted in Khulna Division in Bagerhat and Satkhira districts. These two districts were selected as they are also part of the CGIAR Climate Change, Agriculture, and Food Security (CCAFS) program and because they represent two different potential types of water management systems: medium saline, without potential for much groundwater access (due to salinity intrusion and percolation into groundwater) (Bagerhat), and highly saline but with higher potential for shallow groundwater use due to less salinity intrusion into groundwater (Satkhira). The authors selected four villages in each district to represent varying levels of access to water infrastructure and levels of access to groundwater; characteristics of each village are included as Appendix 1. The authors contacted a key informant from each village, who provided information on the types of households in the selected villages. The authors then invited a random sample of each type of household to come to the meeting. In each community, the authors conducted three FGDs: a community-wide discussion, to understand community livelihood trends and land use patterns, and one FGD each with male and female respondents, to discuss more specific livelihood changes and water related issues. The number of participants in each focus group varied between 8-12 people. In total, there were 109 people who participated in the interviews and FGDs (60 women and 49 men).

Map of Bangladesh, showing Khulna Division



In the meetings, the FGD facilitators asked about livelihood changes over the last 10 years, in order to understand factors driving these shifts and the changes in the different capitals, outcomes, and contextual factors identified in the livelihoods analysis. The semi-structured questionnaire focused on identifying the importance attributed to the various capitals included in the livelihood framework—human capital, physical capital, natural capital, financial capital, and social and cultural capitals.

The facilitators divided the participants by main sources of household income (e.g. crop farmer, fish/shrimp farmer, fisher, share-cropper, etc) in order to ensure representation of the various livelihood types in the ranking activity. In this activity, facilitators asked participants individually about the current livelihood support activities adopted by him/her and others of the same gender (either men and boys, or women and girls) from his/her household and how those differ between wet and dry seasons. Each participant then ranked the relative importance of these activities from 1 = most important, onwards). If there were any changes in the livelihood activities or any change in ranking the participants explained why they had (or had not) changed over this timeframe.

After completing these individual activities, facilitators used FGDs to address a range of questions. These included topics such as future livelihood activities and aspirations, changes in water management and access, water related risks, and water related conflict and cooperation among community members. Fieldwork was conducted in Bangla, and later transcribed and translated to English for analysis.
The significance of rankings across sets of responses (grouped along dimensions of i) male and female and ii) Satkhira and Bagerhat districts, across individual-level responses for activity rankings and village-level responses for water challenge rankings) was evaluated using the Skillings-Mack test statistic. The Skillings-Mack statistic generates a group rank ordering from individual rank orderings, and extends the Friedman test for cases where data are missing (i.e., all individuals in a group have not necessarily included all items in their rankings) (Chatfied and Mander, 2009). In our context, the Skillings-Mack statistic tests the null hypothesis that there is no significant ordering of livelihood activities (by priority), or of water challenges (by importance).

5 Results

We first present information to characterize the livelihood changes and patterns that we see for male and female farmers and fishers in the two areas and also the water needs and perceptions as identified by study participants. We then move on to an analysis of the reasons behind these changes, focusing on the role of water management, as well as the other livelihood capitals.

5.1 Livelihood Changes in the Past 10 Years

Participants were asked to rank livelihood activities by importance i) 10 years ago and ii) today; separate rankings were taken in male (Figure 1) and female (Figure 2) groups in each of the villages. Figures 1 and 2 separate different livelihoods activities (labeled panels from top to bottom) as well as villages (separated from left to right within each panel). Individual responses are organized from left to right within each village. An “x” is the ranking of the particular activity’s importance 10 years ago while an “o” is the current ranking. If an “x” stands alone, this indicates that the respondent discontinued the activity, while an “o” by itself means it is a new activity. A vertical line from an “x” to an “o” within a panel indicates a change in the ranking of that activity for a particular respondent over the last 10 years. An “x” inside an “o” indicates that the ranking did not change.

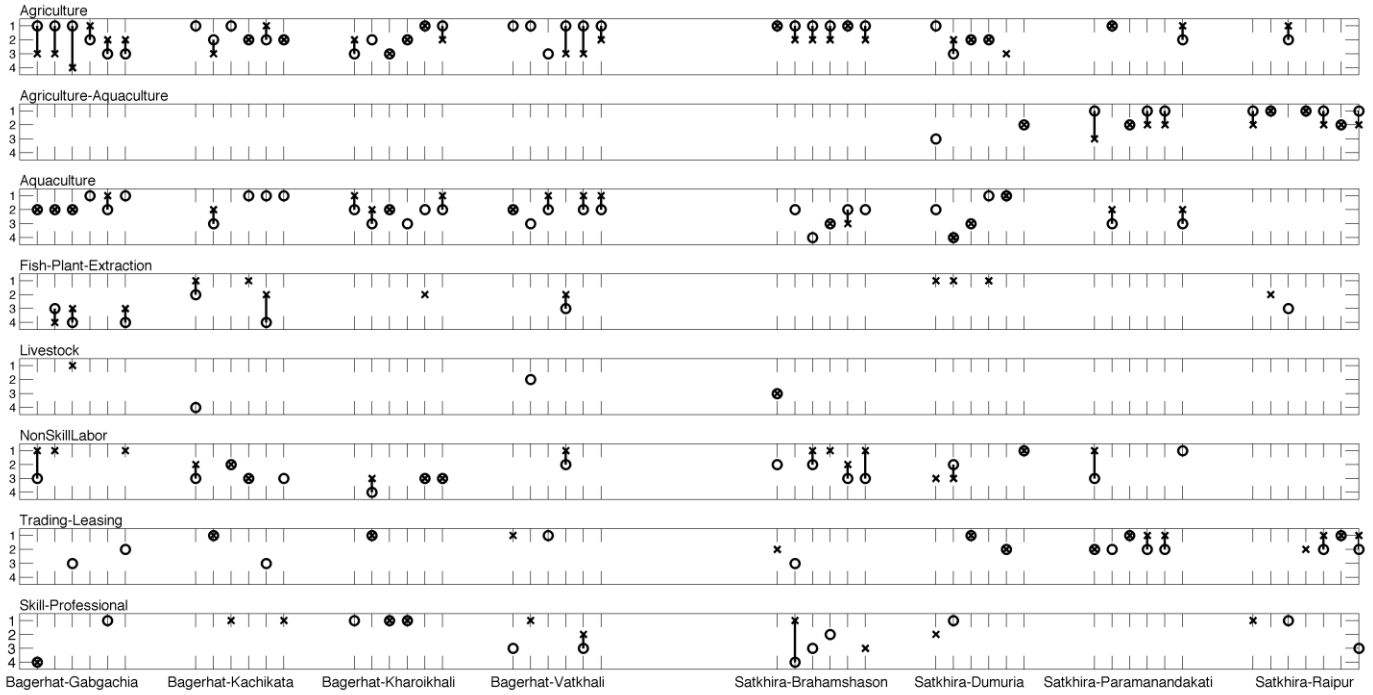


Figure 1: Ranking of Importance of Main Activity for Males in Satkhira and Bagerhat

Note: An "x" is the ranking of the particular activity's importance 10 years ago while an "o" is the current ranking. If an "x" stands alone, this indicates that the respondent discontinued the activity, while an "o" by itself means it is a new activity. A vertical line from an "x" to an "o" within a panel indicates a change in the ranking of that activity for a particular respondent over the last 10 years. An "x" inside an "o" indicates that the ranking did not change. The scale of 1-4 is the ranking that the respondent gave to that particular activity, with 1 being the most important.

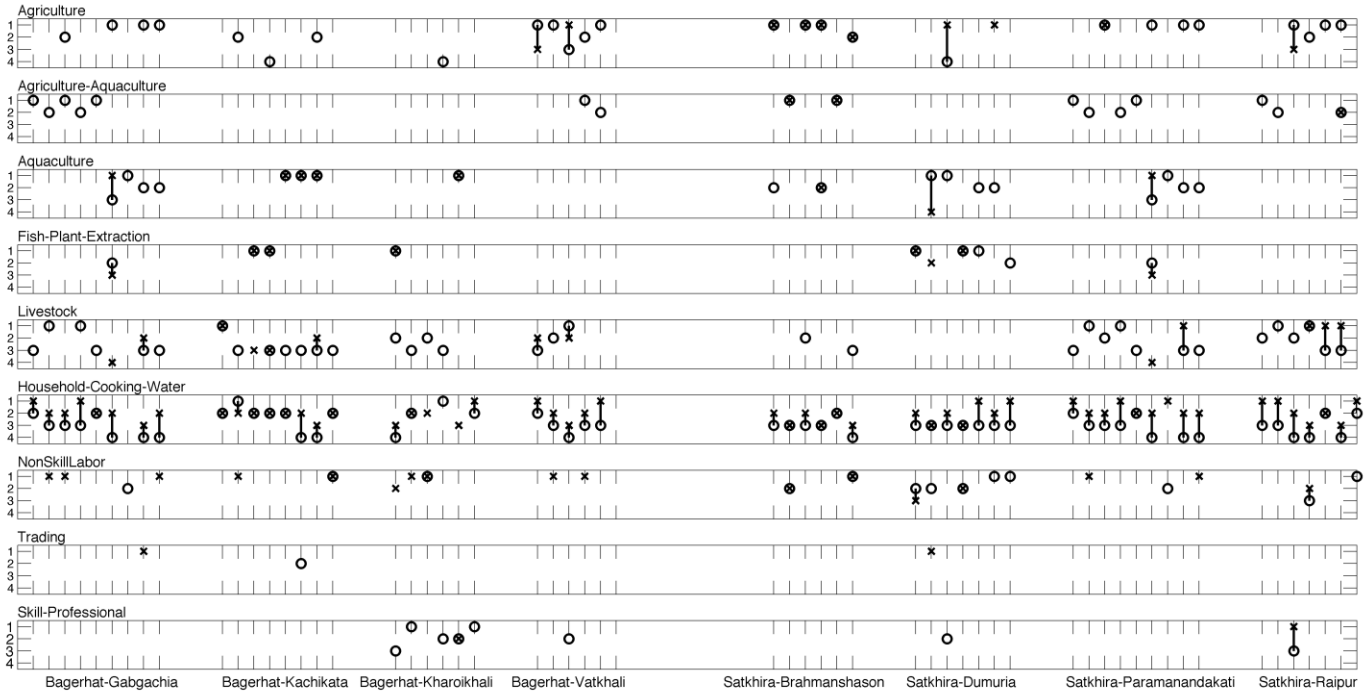


Figure 2: Main Activity Importance Ranking for Females in Satkhira and Bagerhat

An “x” is the ranking of the particular activity’s importance 10 years ago while an “o” is the current ranking. If an “x” stands alone, this indicates that the respondent discontinued the activity, while an “o” by itself means it is a new activity. A vertical line from an “x” to an “o” within a panel indicates a change in the ranking of that activity for a particular respondent over the last 10 years. An “x” inside an “o” indicates that the ranking did not change. The scale of 1-4 is the ranking that the respondent gave to that particular activity, with 1 being the most important.

Table 1: Male Activity Rankings

	Bagerhat				Satkhira				Overall			
	Then** (SM 14.295, p = 0.0265)		Now*** (SM 17.728, p = 0.0069)		Then* (SM 12.925, p = 0.074)		Now (SM 9.058, p = 0.2485)		Then (SM 9.688, p = 0.207)		Now*** (SM 20.551, p = 0.0045)	
Male Activity List	*Rank*	*n*	*Rank*	*n*	*Rank*	*n*	*Rank*	*n*	*Rank*	*n*	*Rank*	*n*
Agriculture	7	17	1	24	4	12	1	13	7	29	1	37
[1]Agriculture_Aquaculture	-	0	-	0	8	11	2	9	8	11	3	9
Aquaculture	2	12	3	21	7	7	8	12	6	19	5	33
Fish_Plant_Extraction	6	8	6	6	2	4	6	1	5	12	8	7
Livestock	3	1	5	2	6	1	7	1	4	2	6	3
NonSkillLabor	5	10	7	9	3	8	4	8	3	18	7	17
Skill_Professional	4	6	4	7	5	4	3	6	2	10	4	13
Trading_Leasing	1	3	2	6	1	11	5	11	1	14	2	17

[1] In several villages, respondents referred to Agriculture and Agriculture jointly.
*** Ranking significant at 1% level; ** Ranking significant at 5% level; * Ranking significant at 10% level
"Then": 10 years ago; "Now": Present day

Table 2: Female Activity Rankings

	Bagerhat				Satkhira				Overall			
	Then*** (SM 20.312, p = 0.0049)		Now*** (SM 22.099, p = 0.0047)		Then* (SM 15.42, p = 0.0515)		Now*** (SM 38.607, p = 0)		Then*** (SM 29.522, p = 0.0003)		Now*** (SM 56.526, p = 0)	
Female Activity List	*Rank*	*n*	*Rank*	*n*	*Rank*	*n*	*Rank*	*n*	*Rank*	*n*	*Rank*	*n*
Agriculture	5	2	4	13	1	8	1	13	5	10	1	26
[1]Agriculture_Aquaculture	-	0	3	7	3	3	2	9	6	3	2	16
Aquaculture	2	5	1	8	8	3	4	10	2	8	4	18
Fish_Plant_Extraction	3	4	2	4	5	4	3	5	3	8	3	9
Household_Cooking_Water	8	21	9	25	9	20	9	28	9	41	9	53
Livestock	7	8	8	20	6	5	6	15	8	13	8	35
NonSkillLabor	1	10	5	3	7	7	5	10	1	17	5	13
Skill_Professional	6	1	6	6	4	1	7	2	7	2	6	8
Trading	4	1	7	1	2	1	-	0	4	2	7	1

[1] In several villages, respondents referred to Agriculture and Agriculture jointly.
*** Ranking significant at 1% level; ** Ranking significant at 5% level; * Ranking significant at 10% level
"Then": 10 years ago; "Now": Present day

Skillings-Mack tests on the rankings of the activities identify any statistically significant orderings of the activities across the sites and genders (Tables 1, 2). A lack of statistically significant ranking indicates that there is no consistency across the individuals in that set of rankings.

Among men, agriculture generally gained in importance as a livelihood activity over the last 10 years (Figure 1; Table 1). In Vatkhali (Bagerhat) there were also several new entrants into agriculture. In Satkhira, there were less dramatic changes regarding the importance of agriculture; most male respondents reported the same ranking or a one-step improvement for agricultural activities. In addition, men in Paramandakati (Satkhira) and Raipur (Satkhira) described their activities as mixed agriculture and aquaculture (the only groups of men to describe it as such); these all gained in importance or stayed the same for men. The ranking of aquaculture activities for men in Bagerhat generally declined, although we do see new entrants to aquaculture and those in which the ranking remained the same. Declines in aquaculture ranking often parallel an increase in the importance of agricultural activities. The Skillings-Mack rankings for Bagerhat men showed agriculture to have risen to the top rank from having been the bottom rank 10 years ago. For Satkhira, aquaculture roughly stayed the same in terms of importance in the rankings, although we do see many new entrants to aquaculture activities; Skillings-Mack results for present Satkhira results are inconclusive. In terms of non-skilled labor, individuals were most likely to report lower importance of working as a laboring or cessation of working as a laborer; for males in Bagerhat, non-skilled labor is now the lowest ranked activity (Table 1). In Bagerhat, respondents also reported new opportunities in trading fish/fry and leasing land or equipment, but these activities seem to be less important overall than they were 10 years ago, when they were the highest ranked livelihood activity. Respondents in Satkhira were more likely to ascribe lower importance to trading or leasing of land than compared to 10 years ago, as well as less importance for non-skilled labor.

For women, many more reported engaging in agriculture and aquaculture-related activities now than in the past. These new activities were often ranked among their top two livelihood activities. In the Skillings-Mack results for Bagerhat, Satkhira, and across both sites, these activities were consistently ranked in the top 3 activities. We recognize that for some of these data, the changes that we are seeing are a result of changes in the lifecycle of individuals (representing a shift from living with a parent to moving into their own household or from being married to being widowed/divorced/abandoned). However, the data do seem to suggest (and were supported in comments made in Kharoikhali, Bagerhat) that women were assuming greater responsibilities outside of the home, which is also reflected in the doubling of female employment in the agriculture sector between 1999/2000 and 2005/06 from almost 4% to 8% of the total workforce (BBS 1999/2000 and 2005/06). Previous findings have also suggested that the expansion of prawn aquaculture is accompanied by an increase in women's involvement (Ahmed et al. 2009). We also see a large entry of women into livestock rearing, both poultry and cattle (which were infrequently mentioned by men as important livelihood activities), but this does not seem to change the ranking of importance of livelihood activities. Similar to the results from men, we see changes in female rankings of non-skilled labor. Overall, the importance seemed to decline, but looking specifically at Satkhira, it increased in importance for women.

We also see changes in the role that extraction of natural resources plays among livelihood options. These activities particularly appeal to women, for example shrimp fry collection, as they do not require financial resources and otherwise have few barriers to entry. We see in the Skillings-Mack rankings, that they are ranked second and third most important in Bagerhat and Satkhira, respectively. Extraction related activities declined in importance for most men, particularly in Satkhira, but women are more likely to still be engaged and rank it equally or even higher than before. However, there is a conflict over

the extraction grounds, and recent government bans/restrictions on extraction of natural resources (such as shrimp fry, crabs and palm fronds) from the Sundarbans make such extraction increasingly uncertain in the future. For women, such as this respondent for Satkhira, extraction related activities are the only option, aside from working for shrimp farmer to repair the *ghers*, an activity for which women get paid less than men.

> "Mostly I am catching shrimp fry in the Kholpetua river. Shrimp fry collection starts from the month of Boishak [mid April] and peaks in Jaishtho [mid May]. We can continue through to Bhadro [mid September] when the numbers of fry start falling. I spend early dawn hours or the late evening catching shrimp fry. During the full moon there are more fry and I work all hours. There are quarrels with other women over where we can catch shrimp fry. But wild shrimp fry collection is banned by government during March to July. I know it is banned and I am doing it illegally, but I have to survive with my three children. I am tired and want to do something easier. But how?"

A number of men (and at least one woman) reported fishing for wild fish as a livelihood activity. However, the introduction of water control mechanisms seemed to be directly at odds with this livelihood activity and most participants who reported relying on fishing noted that the introduction of sluice gates reduced fish populations and the opportunity to fish.

In general, survey respondents highlight a trend towards increasing diversity of livelihoods and respondents report being involved in more activities than before, taking advantage of new markets and new opportunities that have been created. While this may represent an imperfect measure of increased diversity, it does recognize that respondents think of their livelihoods as being more diverse and composed of more activities. However, this trend does not apply to men in Satkhira, who generally did not change the number of activities over time. Women in Satkhira, however, reported more diverse portfolios of livelihood activities.

5.2 Looking Forward: Water Challenges in the Future and Climate Change Adaptation

In each village, men and women ranked water related challenges that they believed they would face in the future. We conducted similar Skillings-Mack analysis to identify statistically significant rankings between men and women in Bagerhat and Satkhira (Table 3).

Table 3: Water Challenge Rankings

	Bagerhat						Satkhira					
	Female** (SM 15.95, p = 0.014)		Male** (SM 12.95, p = 0.0438)		Overall*** (SM 27.251, p = 0.0001)		Female** (SM 12.762 , p = 0.047)		Male (SM 3.83, p = 0.5741)		Overall** (SM 15.698, p = 0.0155)	
Challenge	*Rank*	*n*	*Rank*	*n*	*Rank*	*n*	*Rank*	*n*	*Rank*	*n*	*Rank*	*n*
Cyclone	1	4	2	4	1	8	3	3	4	2	3	5
Drinking water	4	4	4	4	4	8	2	4	2	4	2	8
Drought	2	4	3	4	2	8	5	4	6	4	5	8
Flood	3	4	1	4	3	8	1	3	1	4	1	7
Irrigation	6	4	5	4	6	8	6	4	5	4	6	8
Pollution	7	3	7	3	7	6	7	2	-	0	7	2
Salinity	5	4	6	4	5	8	4	4	3	3	4	7

*** Ranking significant at 1% level; ** Ranking significant at 5% level; * Ranking significant at 10% level

In general, there was broad agreement by women and men in Satkhira regarding the key water concerns, which were flooding/waterlogging and drinking water. Respondents assigned a low importance to irrigation, as well as to droughts. Men highlighted the issue of the costs of irrigation, suggesting that even with irrigation agriculture was not profitable. Both women and men recognized, that while irrigation water is more plentiful now and available for agriculture that this did not necessarily mean that this would hold for the future. Women highlighted the need to focus on water use efficiency in irrigation, and not just in terms of increasing access to water. Both men and women pointed to a need to expand tubewell irrigation; canal water was not the preferred choice for irrigation. Moreover, both men and women suggested remaining difficulties in balancing saline shrimp aquaculture and freshwater fish cultivation in the same *ghers* or where there are shared bunds and an exchange of water between the two types of cultivation systems.

Thus, while current water management activities have enabled a greater expansion and diversification of farming activities, respondents express concerns and reservation about the future, recognizing that waterlogging and the sluice gate infrastructure are key to their ability to continue to use land. Furthermore, FGDs with both men and women suggest that salinity could be better controlled through more effective use and operation of the sluice gates. This highlights the importance of joint planning of saline and fresh water resources.

In Bagerhat, men and women also did not rank irrigation as the top concern. Instead, the threats of cyclones, droughts and flooding loomed large. Similar to Satkhira, men and women largely shared a similar perception of the threats of different water related constraints to livelihoods. Men were more likely to rank floods as the largest hazard, while women ranked cyclones as the largest hazard. These results highlight the heterogeneous impact of drought and the paradoxical 'drought within flood' condition of the south. Similarly, FGD discussions suggest that infrastructure maintenance is a key concern that contributes to reduced availability of water and the threat of waterlogging. There should be greater attention paid to the management and maintenance of such water infrastructure, and not just to the development of these technologies.

Men in Bagerhat were particularly concerned about the limits of their agricultural knowledge and expressed a need for greater access to improved technologies and practices, including the use of more water efficient crops. The men in one village noted a problem with irrigation water availability. At the same time, several men emphasized the need for increased production, value chains and greater investments in agriculture (while also noting the costs of the activities).
Women noted that there is a divide between richer women and poorer women; richer women, who are more engaged in shrimp production, do not view increasing salinity as a problem, while poorer women are more likely engaged in agricultural labor, and view progressive salinization as a larger threat.

6 Discussion

6.1 The resurgence of agriculture

Activity rankings show a clear jump in the importance of agriculture in coastal livelihoods in our study sites. In particular, we also see individuals shifting from hired labor to focusing on their own agricultural activities. Many men, in particular, reported being able to subsist on their own land, as agriculture has become more profitable (and more feasible). Details from our FGDs reveal key mechanisms in this shift.

6.1.1 Farming is Less Risky when Salinity is Controlled

Across both sites, male and female FGD participants largely attributed the trend toward increased agricultural and aquaculture activities to water infrastructure development and management that reduces the risks associated with agriculture—specifically, the risks of flooding and salinity. In Bagerhat, investment since 2000 in sluice gates, embankments, and other infrastructure prevented the intrusion of saline water, stopped tidal flooding, and enabled the use of canal water for irrigation (as it was no longer saline). In both areas in our FGDs, several participants, both men and women, reported that they had been encouraged to return to their agricultural lifestyles as water resources were now better, abandoning lives in cities and urban centers to return to their villages and take up agriculture. One male respondent, who had not been involved in agriculture previously, sold an interest in a construction company to invest in farming, purchasing land because "the sluice gate and embankment meant my home area was protected and people were growing crops and farming fish. Saline water does not damage our crops" (Morrelganj, Bagerhat).

In addition to controlling salinity, FGD participants linked the sluice gates to reduced water logging and flooding, which otherwise caused much damage to crops. However, fears of future drainage and waterlogging in particular seemed to be an issue of concern to participants, as they felt that they would not be able to manage and remove salinity from the soil. Participants, both men and women, highlighted the need for greater investment in the maintenance and re-excavation of canals. Moreover, FGD participants linked incorrect sluice gate operation to waterlogging and drainage issues, as well as lingering salinity issues (particularly in Gabchia).
In Bagerhat, most respondents expressed a preference for expanded agricultural activities, especially in Kachikata and Gabchia (for both men and women). In Satkhira, men said ideally they would like to see more agricultural activities in the future, but said that is not possible as increasing salinity limits possible agricultural expansion.

As a result, there are many changes in the dynamics governing access to land and leasing. As farming is becoming more profitable, the costs of leasing land are increasing. Similarly, land preparation is increasingly expensive, and some male respondents have started to rely on renting out equipment as an important source of income. Participants have also linked the control of salinity to the ability to replace non-skilled labor with agricultural work. As one male respondent from Satkhira explained:

> "I was laboring in different works (for farmers, other people, sometimes van-pulling or fishing). All of these were physically demanding. I have only 17 decimals (.07 hectares) of land where I could grow a little rice in the rainy season, but most of the time water was saline, costs were high and yield was very low. Sometimes the entire crop failed. I could not dare to take any risk like renting a pond to grow prawn or fish. Now that saline water is not entering in my land I can grow two rice crops which meets my household demand and I can sell some. I leased in a pond for prawn and fish culture. Now my family can eat fish and I can sell prawns. Although sometimes due to excessive rain prawns escape. I also cultivate vegetables on the pond dike. I don't have to go for laboring now as I have sufficient income from agriculture and aquaculture for my family."

6.1.2 Role of Irrigation

Irrigation plays a key role in expanding both agriculture and aquaculture, enabling individuals to benefit from an additional agricultural season. However, in Bagerhat, where groundwater development

remains low, nearly all FGDs suggested that there is insufficient irrigation water to meet their current needs, let alone predicted future needs under conditions of greater scarcity. In Satkhira, with access to both surface and groundwater, FGD participants for the most part believed that with improved use and efficiencies, there could be sufficient water to meet farmers' needs, although several participants noted that surface and groundwater supplies did become saline from overexploitation in the dry season. Irrigation is not only beneficial for expanded agricultural activities. In Raipur (Satkhira), for example, villagers estimated that 97% of the total agricultural area was used for combined rice and aquaculture (shrimp, prawn, and fin fish) production in the monsoon, and 50% of farmers continue to cultivate fish (including prawns and a few shrimp) in the dry season, when saline surface water can be freshened through irrigation. Previously, only 10% of the land was cultivated in the second season. In Paramanandakati (Satkhira), FGD participants suggested that, overall, more landowners were now practicing prawn and finfish culture, thanks to the introduction of shallow tubewells and resulting lower risks, whereas they sharecropped out their land in the past.

However, barriers exist to realizing or expanding the benefits of irrigation. Several FGDs mentioned pumping as a constraint to accessing irrigation water, limited both by the number of pumps available (which made renting difficult and did not necessarily ensure access to water resources during critical growth periods), but also predicted that the trend would increase the differences between those able to afford to own/rent low lift pumps (LLP) and those not able to (usually smaller landowners or sharecroppers).

Moreover, irrigation itself remains an expensive enterprise. The costs of renting a LLP—and of diesel fuel—can be larger than the associated increase in productivity. Respondents report that owners of shallow tubewells also charge for access. In addition, women in Paramanandakati village suggested that new technologies, such as LLP, actually increase the wasting of water, as opposed to more traditional water extraction and irrigation methods. Furthermore, there are intra-village differences in the returns from irrigation activities.

Limits to availability of groundwater also constrain irrigation potential. In Paramanandakati, participants noted that shallow tubewell extraction was more profitable in the south of the village than in the north, due to the depth of groundwater. Participants observed that in Satkhira, the development of groundwater has increased the area that can be dedicated to agriculture, particularly in the villages of Raipur, Paramanandakati, and Brahmanshason. Male FGD participants in Dumuria identified extending groundwater access from a nearby village as a potential way of expanding their agricultural activities but noted that water becomes saline at the end of the season.

Irrigation has clearly had positive impacts on the livelihood strategies of many of the respondents included in this survey. As one participant in the Khoroikhali VGD observed, however, there are tradeoffs:

> "We were not aware of groundwater use and depended mostly on pond water and rain water 10 years back, then under a project shallow tubewells were introduced here. Before that we were mostly cultivating crops once in a year and farmed shrimp and prawn in two seasons. Now we can grow two crops and fish with groundwater throughout the year. Since 2007 fish farmers started to stock finfish with rice, but shrimp and prawn farming decreased. The water we get from underground beyond 50 ft is saline. The shallow underground water (50-70 feet deep) is less saline because it gets renewed. But we heard from some "biggani" (scientist) that beyond 300 ft there is no aquifer and only layer of clay and silt clay. If we abstract more ground water

we can grow more crops and shrimp/prawn/fish. But after a few years we will not be able to get drinking water".

While respondents clearly link irrigation with increased agricultural activities, respondents do not identify the expansion of irrigation as a key priority, recognizing the barriers that exist to realizing or expanding the benefits of irrigation, as well as the limits in terms of the availability of groundwater.

6.2 Aquaculture: Explaining differences across sites

The evidence for an increased importance of aquaculture in livelihoods was more ambiguous. Many respondents reported aquaculture as an important livelihood activity, but its overall importance in the livelihood portfolio was possibly lower than it was 10 years ago. Shrimp farming grew in some villages, such as Raipur (Satkhira) and Paramandandakati (Satkhira), encouraging the expansion of linked businesses and services, from supplying fry to farmers, to collecting and trading in harvested shrimp. At the other end of the spectrum, in Vatkhali (Bagerhat) which saw shrimp businesses and cultivation decline, there was a net move away from these types of business activities. Explanations given in FGDs highlight the conflicts and issues that limit the prominence of aquaculture in community livelihoods. In Bagerhat, the introduction of technologies allowing for the control of water—and salinity—encouraged a switch from culturing shrimp to finfish and freshwater prawns, which tolerate less saline waters. However, FGD participants reported that this switch came with an income reduction, which, as men in Vatkhali observed, is difficult to offset, given the increase in land prices and competition following the renewed interested in both agriculture and aquaculture.

In Raipur village, in Satkhira, the introduction of water control structures also encouraged a shift, as sluice gates now control flooding (which would previously cause a loss of shrimp). Furthermore, the canals provide water for keeping fish alive during the dry season. While those in Bagerhat mainly viewed a future of mixed rice and fish culture, those in Satkhira largely thought that increasing salinity would drive them all towards shrimp farming—even if they wanted to expand agriculture with increased access to groundwater. Women especially noted that this path would make it difficult to do any other activity, as the salinity associated with shrimp culture would contaminate the soil. In Satkhira, there is a strong desire to expand agriculture, but growing recognition that increasing salinity may make that impossible.

Fish culture expansion was limited in Paramanadakati (Satkhira) due to the risk of overtopping the bunds; building higher bunds to protect the ghers is very expensive. While most of the households have ponds, they require pumping of water from surface or groundwater sources for continual fish farming. Paramandakati focuses almost entirely on rice and fish production in the monsoon season, with 50% of the land continuing to be used for aquaculture in the dry season. But in Kachikata (Bagerhat) male and female respondents also expressed the view that aquaculture would not be sustainable in the future, due to the decreased water flow in the village.

Moreover, conflicts between fresh and salt water uses were reported in Dumuria, where larger shrimp farmers would cut the embankment, allowing saline water in. Lack of barriers between the shrimp ghers and nearby fields contaminated the entire site with saline water. Women in Gabchia FGDs reported similar issues, of shrimp farmers cutting the embankment to allow in needed saline water for their activities.

Small and marginal shrimp farmers also face barriers in terms of access to sufficient water resources. As participants in the Paramandadakati FGD explained:

> "We are involved in shrimp farming which provides high profit in a short period. Shrimp farming is more profitable than rice cultivation. However, not all areas are suitable for shrimp cultivation. Due to the high short-term profit of shrimp farming and increased saline water intrusion in the fields, many small and marginal farmers have been encouraged to switch from agriculture to aquaculture. There are conflicts between subsistence agriculture and shrimp cultivation and conflicts over land rights and access to resources. Pocket ghers [mini shrimp farms] are in trouble because the bigger gher owners do not allow them to bring water from the sources through their territory. Next is the upstream-downstream conflict for water for shrimp cultivation. Another bigger conflict is over pumping water from the canal. We have to choose the easier way - if we get sweet water we cultivate rice or prawn and finfish, but if the water becomes saline we go for shrimp. Usually the small and marginal farmers can make better return from any of these."

As aquaculture activities have become more important and profitable, issues of access to land and land rights have risen in importance. Women in Dumuria reported that previously larger landholders had forcibly acquired land leases for shrimp farming. More recently, however, cyclones and associated damage to the shrimp farm bunds forced large shrimp farms out of business, allowing the smallholders to regain control of their land and take up activities on their farms. However, shrimp aquaculture activities require larger amounts of capital to invest and may be out of reach of many of the farmers in the surveyed areas. It is also increasingly difficult to find land for lease, so smallholders must make do with small ghers that they are able to construct on their own land.

6.3 Water Resource Management at the Local Level

All FGDs voiced concerns about the management of their irrigation and water infrastructure. These concerns included allegations that the improper management of the sluice gates meant that salinity did not decline as much as it could have. Other comments included that the canals were insufficiently excavated, limiting water supplies, with continued declines ahead absent further investment due to siltation. Many respondents noted that the volume of water supplied decreased after the introduction of sluice gate and other control mechanisms.

Moreover, conflict and allocation issues seemed increasingly pressing. Several FGDs raised complaints about canal grabbing and the allocation/abstraction of canal water closer to the sluices without proper regard for more distant water users. There were numerous allegations of elite capture of water infrastructure—from needing to pay to access sluice gates, to the purposeful cutting of the embankment and diverting of water to serve the needs of the larger and better connected shrimp farmers. Recent work by Dewan and colleagues (2014) offers support for the conclusion that Water Management Committees set up to manage this infrastructure are often captured by elite interests, supporting only the most "visible" productive uses of water (paddy and shrimp), ignoring other household and productive uses of water—and often excluding women from participation in management decisions. Respondents in FGDs for this study reported similar experiences. For example, the Dumuria canal was open to all for fishing and water use activities until influential people, including one Union Parisad representative, took "possession" of the canal and started culturing fish by putting a dam across the canal. Consequently, part of the canal dried up and ultimately, waterlogging in adjacent areas resulted. The villagers made an official complaint about the occupying users, who claimed they had an official lease but ultimately stepped back. An NGO intervened and re-excavated the canal, restoring more

regular water flow to the canal. In general, re-excavation demands more resources than communities have themselves, and as the channels are public (state) property, re-excavation is most often accomplished with support from projects, government agencies or NGOs following requests from communities and local councils (Union Parisad) and after approval from the local administration. Others have noted that the Union Parisad's remain weak and are marred by political centralization and corruption (Vivekananda et al. 2014).

In Vatkhali, both male and female participants noted that there is little management of water releases. Thus, the timing of the water release is uncertain and often not appropriate for either fish culture or farming. They would specially like to see a committee to manage the sluice gates that services the needs of all villagers and not just have those who live closest be in charge of management.
Only one village (Kachikata in Bagerhat) noted that a government staff controlled the sluice gates. In other cases, influential people or those living nearby the gates controlled their opening. In Kachikata, the Bangladesh Water Development Board (BWDB) was employing a *khalasi* (gate keeper) to operate the sluice gate. That person opened and closed the gate according to the instruction of BWDB officials or local government representatives or both. These positions have now been abolished, and according to the government guidelines for participatory water management, local water management institutions (Water Management Committees, and in larger systems Water Management Associations, of the WMCs) have been established to operate and maintain the structures and to represent the views of all stakeholders and users (for irrigation, fishery, etc). In some projects where there are larger, more complex sluices, a person may be employed to take care of the gates, but this is rare.

These committees may also have their own political divisions. In Kachikata, following the abolition of the *khalasi* post, influential community members, including larger farmers, took over the control of the gate. They catch fish, keeping the gate closed when others need it open for water for irrigation or for fish recruitment or for draining water. Moreover, influential community members in some of the other sites also charge other people from the same or downstream villages for opening/closing the gate and some larger land owners open and close the gate when they need water but keep the gate closed when others need water. This creates conflicts, which can sometimes end up in court. This again supports the conclusions of Dewan et al. (2014) who argue that the governance structures established under participatory water management prove "ultimately unsuccessful in ensuring water management," unable to raise sufficient funds to maintain the infrastructure, to address the underlying conflicts related to inequalities, and leading to limited participation of key stakeholders.

7 Conclusions

This paper has focused on understanding the livelihood changes that men and women have made in the last 10 years, exploring the drivers of those changes, including water access and management, and identifying key water related challenges going forward. We find a trend toward diversification of livelihood activities, with a focus, where possible, on both shrimp and crops. Our findings highlight the role that water management and infrastructure, including the ability to control flooding and waterlogging, have played in encouraging those shifts.

Several important conclusions emerge in our study. First, increased infrastructure and water management are clearly linked to the growing importance of agriculture and aquaculture in livelihood strategies. However, as much as groundwater has enabled irrigation, especially in Satkhira, waterlogging, drainage, and the control of salinity remain unaddressed. Respondents are more concerned about future waterlogging and flooding than expanding irrigation. The expansion of

irrigation may increase rice production in Satkhira, but from the FGD discussions, it is unlikely that water would be widely accessible. In Bagerhat, where there is potential to store surface water, irrigation faces a variety of constraints, including limited access to LLPs, the need to re-excavate canals to hold more water, and proper release of water from the sluice gates. In Satkhira, where there is fresh groundwater available, tubewell expansion would require investments by farmers and may only benefit those able to pay to access groundwater (Crow and Sultana, 2002). FGD participants also specifically feared that if water shortages increase, smaller farmers would be first excluded. Thus, if new, large investments will be made into canal systems, then aspects of equity would require particular emphasis.

Second, governance issues and conflicts over existing irrigation water and related infrastructure must be addressed in order for the infrastructure investment to deliver appropriate returns. The concept of Water Management Committees is not (yet) working as intended. Issues of water timing and release, which now often depend on local elites (and may require payments) reduce the amount of water available locally in the dry season and likely contribute to lower crop and fish outcomes especially if water is unavailable at more critical times. Moreover, FGDs pointed to power dynamics in controlling access not only to water but also to land resources. Water extraction in many of the water stressed areas becomes a zero-sum game; those with access to pumps and newer technologies are able to extract more water at critical periods, while others lose out. Management is particularly crucial as progressive salinization and progressive waterlogging of scarce agricultural areas is very costly or sometimes impossible to reserve. Rather than embarking on large additional investments for providing surface water at this time, it would be important to establish more equitable management structures for the existing systems and then link those to future investments.

While shrimp farming may offer higher profits, FGDs seem to suggest a reticence to rely solely on shrimp farming. Respondents in Kachita FGD noted "Although embankments and sluices were constructed, breaching and seepage are common and then led to total loss of income. People here are more cautious about investing in monoculture; rather we prefer polyculture of fish." These sentiments were expressed in several of the FGDs in both Bagerhat and Satkhira, with most respondents suggesting that they preferred to also being able to cultivate crops, as opposed to relying solely on shrimp, and to also stock a mixture of shrimp and fish. In addition, FGD participants in Satkhira expressed serious concerns about future agricultural cropping in their areas. However, especially for the more saline systems, these two activities (food crops and shrimp farming) seem to be incompatible in the same polders, as it is difficult to prevent saline water from entering in freshwater fields, and it is difficult to reclaim fields once they have become saline. Conflicts can arise over issues of inflow of brackish water, the deliberate destruction of bunds, or the drainage problems resulting from the unplanned construction of *ghers* (Ito, 2002).

Additional investment in surface canal systems are still needed for coastal Bangladesh but only once the other constraints to productive crop production are addressed, most of which relate to governance issues. Ensuring greater access to irrigation (either surface or groundwater) may enable the expansion of agricultural and freshwater aquaculture activities; however, there seems to be a clear need for understanding how to use this water more efficiently. This study highlights that priorities for investment under the Bangladesh's Ministry of Agriculture
plan and Bangladesh Climate Change Strategy and Action Plan should include investment in multi-purpose water management (water control for both the wet and the dry season and for both fresh and saline waters), along with increased emphasis on governance and management.

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All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

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