ADAPTATION TO SALINITY IN SOUTHWEST COASTAL BANGLADESH: AN ENVIRONMENTAL AND QUALITATIVE STUDY OF WATER AND FOOD SECURITY IN AN ERA OF CLIMATIC CHANGE

by
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Abstract

Problem Statement

Salinity intrusion, a process by which seawater moves inland into freshwater sources and the surrounding land, affects much of the southwest coastal region of Bangladesh. The resulting increase in soil and water salinity impinges on diverse aspects of rural livelihood, including access to freshwater, agriculture, and aquaculture. Our overall objective was to conduct a comprehensive, yet in-depth, analysis of how communities living in salinity-affected areas perceived salinity as a phenomenon, how they were affected and adapting, and how well the assistance provided and prioritized by NGO and government actors met their needs.

Methods

We conducted 86 in-depth interviews and 6 focus group discussions with community members across three sites in the districts of Khulna, Bagerhat, and Satkhira. We also measured salinity of soil and water samples, and administered household questionnaires to 25 households. At the stakeholder level, we conducted 24 and 16 in-depth interviews with representatives of NGOs and government, respectively. All qualitative data collection activities were transcribed and thematically analyzed. Results from salinity testing and questionnaires were mapped and tabulated.

Results

Although community members recognized some salinity as inevitable due to the area's coastal geography, they emphasized saltwater shrimp aquaculture and sluice gate management as major exacerbating factors. NGO and government perspectives aligned to some extent with those of communities. However, they prioritized measures to address the impacts of salinity rather than actions to curtail potentially modifiable causes.

Salinity had a significant effect on households' ability to obtain freshwater, particularly during winter and hot season. It also inhibited households' ability to produce food. Methods to adapt effectively to these impacts were generally resource-intensive, and sometimes inaccessible even with external assistance provided by development actors. In implementing interventions to promote adaptation, NGO and government actors faced numerous challenges. These included designing effective interventions, selecting beneficiaries in a fair and transparent manner, and ensuring that infrastructure remained functional.

Conclusions

The overarching conclusion is that those affected by salinity do not feel they are receiving the assistance they need. Despite a variety of adaptation strategies being proposed, negotiated, and implemented, effective adaptation remains a critical challenge.

Thesis Readers

Pamela Surkan, ScD, PhD (Advisor); Robert Lawrence, MD (Chair); Frank Curriero, MA, PhD; Keeve Nachman, PhD; Peter Winch, MD, MPH

Preface

There is little doubt—though there may be self-interested denial—that we live on a planet undergoing significant, irreversible change. It is hard to feel at ease with the amount of uncertainty that this entails: What will happen as species are lost, soils fail, and waters run dry? As our planet becomes less inhabitable, what toll will be exacted on human life and livelihoods? And most importantly, what will be society's response?

I do not cope well with this type of uncertainty, and I suspect neither do many of my colleagues in the field of public health. By honing in on one of the most ecologically and socially complex regions of the world—the Ganges river floodplain of southwestern coastal Bangladesh—this research seeks to illuminate, as much as a PhD thesis can do, some of the answers to those questions.

I am extremely grateful to the community members and organizations at our study sites, who welcomed me and participated in this research. They shared their experiences, insights, and time with a generosity little deserved by a US-based researcher flying in from 9,000 miles away on a carbon-emitting jet plane. I owe a huge debt to Abdul Matin and Afsana Sharmin, who conducted hundreds of hours of interviews, served as linguistic and cultural interpreters, and provided genuine friendship through weeks of hot and rainy season fieldwork. That the fieldwork was so productive and evokes such fond memories is a testament to their character. Other colleagues at the International Centre for Diarrhoeal Disease Research, Bangladesh (icddr,b) provided much-needed guidance and support: Fosiul Alam Nizame, the local PI on this study, Leanne Unicomb, Dostogir Harun, Donald Bapi Das, Solaiman Doza, Md. Mahbubur Rahman, among others. I must also thank Saleemul Huq and his team at the International Centre for Climate Change and Development for hosting me as a visiting researcher.

Many excellent mentors at Hopkins have shaped both this dissertation research and my doctoral experience more broadly. The indelible imprint of Professor Peter Winch on this work and my general trajectory in public health would likely be recognized by some. I am also incredibly grateful to Professor Pamela Surkan, who has been a supportive and thoughtful advisor from the beginning. Other faculty who generously lent their expertise to this research include: Bob Lawrence, Joanne Katz, Courtland Robinson, Steve Harvey, Meghan Davis, Frank Curriero, Tim Shields, Keeve Nachman, Naveeda Khan, Bill Ball, and Katalin Szlavecz.

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Finally, there are too many friends and family members to name, who have served as a beacon of encouragement during my PhD experience. These include my classmates in the Department of International Health, who have done double-duty as colleagues and friends impeccably, as well as the students, staff, and faculty in the Social and Behavioral Intervention Program and at the Center for a Livable Future, who helped make those two places my intellectual and spiritual homes at Hopkins over the past five years. Beyond these circles, I am profoundly indebted to Jacob Kopas—possibly the only person I know

who can give such confident and convincing advice in a field outside his own—for his insights, enduring patience, and unwavering moral support.

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List of Abbreviations

BARI	Bangladesh Agricultural Research Institute
BRRI	Bangladesh Rice Research Institute
CI	confidence interval
DAE	Department of Agricultural Extension
DAP	diammonium phosphate
DHS	Demographic and Health Survey
EC	electroconductivity
ESF	ecohydrology-based shrimp farming
FAO	Food and Agriculture Organization (of the United Nations)
FGD	focus group discussion
g	gram
GCF	Green Climate Fund
HYV	high-yielding varietal
icddr,b	International Centre for Diarrhoeal Disease Research, Bangladesh
L	liter
LDC	Least Developed Country
MAR	managed aquifer recharge
NDA	National Designated Authority
NGO	non-governmental organization
NIE	National Implementing Entity
μS/cm	microSiemens per centimeter
RWH	rainwater-harvesting
SIDS	Small Island Developing States
SRDI	Soil Resources Development Institute
TDS	total dissolved solids
TSP	triple superphosphate
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
US	United States
USD	US dollars
WARPO	Bangladesh Water Resources Planning Organization
WASH	water, sanitation, and hygiene
WHO	World Health Organization

Prologue

On the outskirts of the village of Motbati in southwestern Bangladesh, the ground was so hard that the newly sharpened soil knife could barely dig up the dirt we needed – two cups' worth for making a soil-water suspension that would be used for gauging salinity. Even without applying our scientific knowledge and equipment, we had a feeling our measurements would confirm what we could visibly observe: that saltwater intruding from the Bay of Bengal had destroyed the fertility of this corner of the Ganges river floodplain, rendering agriculture operose and worth the toil of a peasant farmer only because livelihood options were so few and human labor came so cheaply in this region of the world.

This small desiccated plot of land was located on the east side of the village, within view of a pond where *bagda*, saltwater Asian tiger shrimp, were being farmed, and within a short walk of the shady trees and gardens of the village's greener west side. At the height of dry season, we had come to the village to study one of the region's biggest food security threats: increasing soil and water salinity, and the impact of this environmental change on food and water. The causes of salinity were contested, but included at least saltwater aquaculture, upstream diversion of the Ganges' freshwater, and sea level rise. As we knelt down and pounded the knife into the un-giving, cracked earth, we began to discern multiple layers of inequity in this situation.

Within this single area, one villager had been able to afford creating and stocking a shrimp pond that would allow him to take advantage of the intruding saltwater and that would (according to some) exacerbate the area's salinity; another, on the other hand, had been forced to give up farming and (in much likelihood) might now be working for the shrimp pond owner as a daily laborer, earning two dollars a day. Within this single village, some had the better fortune of living on the western side, where home gardens were still productive and fruit trees provided abundant shade, while others on the eastern side attempted to graze their goats on a few dusty blades of grass scorched by the dry season sun. Within this single floodplain, India, which borders Bangladesh on 95% of its land border, was a far more powerful country in negotiating riparian rights and could divert the flow of the Ganges away for generating hydroelectric power, while downstream hundreds of Bangladeshi farming and fishing communities lacked any domestic or international recourse. And finally, on this single climate-disrupted planet, those in the developed world contributed to rising sea levels through disproportionate carbon emissions, while inhabitants of the environmentally vulnerable Global South sacrificed their food sovereignty and self-sufficiency to produce saltwater shrimp, ironically, for international export and consumption by the Global North.

Chapter 1. Introduction

The coastal region of southwest Bangladesh faces multiple environmental challenges, including cyclones, coastal and inland flooding, water-logging, groundwater contamination, and salinity intrusion [1–9]. These problems, which result from a complex interaction of weather patterns, climate change, land use, river damming, and large-scale coastal engineering, are not new. However, they present a growing obstacle for rural communities' livelihoods and health. Certain events have increased or are projected to increase in severity or frequency, and some impacts will exacerbate others [10].

One challenge of particular salience in the low-lying deltaic region is salinity intrusion—a process by which saltwater from the ocean moves inland into freshwater sources. Increasing water salinity and soil salinization due to saltwater intrusion have been documented, affecting as much as 60% of arable land in the southwest coast during hot season [8, 11, 12]. As many of the region's inhabitants engage in food production – growing rice, cultivating homestead gardens, rearing livestock, and raising fish in ponds and canals– soil and water salinity pose serious threats to their food security and sources of livelihood. In addition, salinity of surface and groundwater renders the water sources used for drinking, cooking, washing, and bathing less secure, setting the stage for water, sanitation, and hygiene (WASH)-related health problems.

It is not possible to attribute salinity intrusion in a given location to a single cause, and in general the attribution of specific environmental phenomena to specific causes is a contested and often political matter. Factors that have been cited in the scientific literature as contributing to salinity intrusion and/or exacerbating salinity in general include sea level rise, cyclone storm surges, diversion of the Ganges River by dams in India, tidal flooding during rainy season, changes in pressure during dry periods, and, not least of all, large-scale saltwater aquaculture, specifically shrimp farming [3, 6, 8, 13–19].

Nevertheless, under the rubric of "sustainable rural development," "climate change adaptation," or "building climate resilience," in recent years governmental and non-governmental organizations (NGOs) have proposed and implemented projects to help residents cope with salinity in soil and water. These include interventions related to freshwater infrastructure, as well as modified agricultural practices and inputs. Many of these projects are funded by international public and private donors.

However, formative research conducted in June and July 2014 revealed concerns about how salinity was being addressed. First, many interventions did not appear to be based on evidence—i.e., scientific knowledge about the gains in well-being that could be expected in practice from a given type of intervention. Such evidence was either missing or not applied. Second, some community members and grassroots NGOs highlighted development actors' limited engagement with intended beneficiaries, implying insufficient attention to their needs and preferences in designing potential adaptation strategies. There was also little information on the successes, failures, and challenges of various NGO and government interventions, especially as seen from the perspective of community members.

With growing concerns over environmental sustainability, climate justice, and the post-2015 sustainable development agenda, funding to promote livelihoods in the face of ecological stresses will likely increase for countries like Bangladesh. Thus, it is evermore essential to ensure that initiatives are based on the best available evidence, attend to local perspectives and actual needs, and make discernible contributions to physical and mental well-being.

The research described in this manuscript contributes to this effort by drawing on a combination of ethnographic methods, participatory systematic data collection, field observations, and salinity testing. Based in the southwest coastal districts of Bagerhat, Satkhira, and Khulna, the research objectives were to:

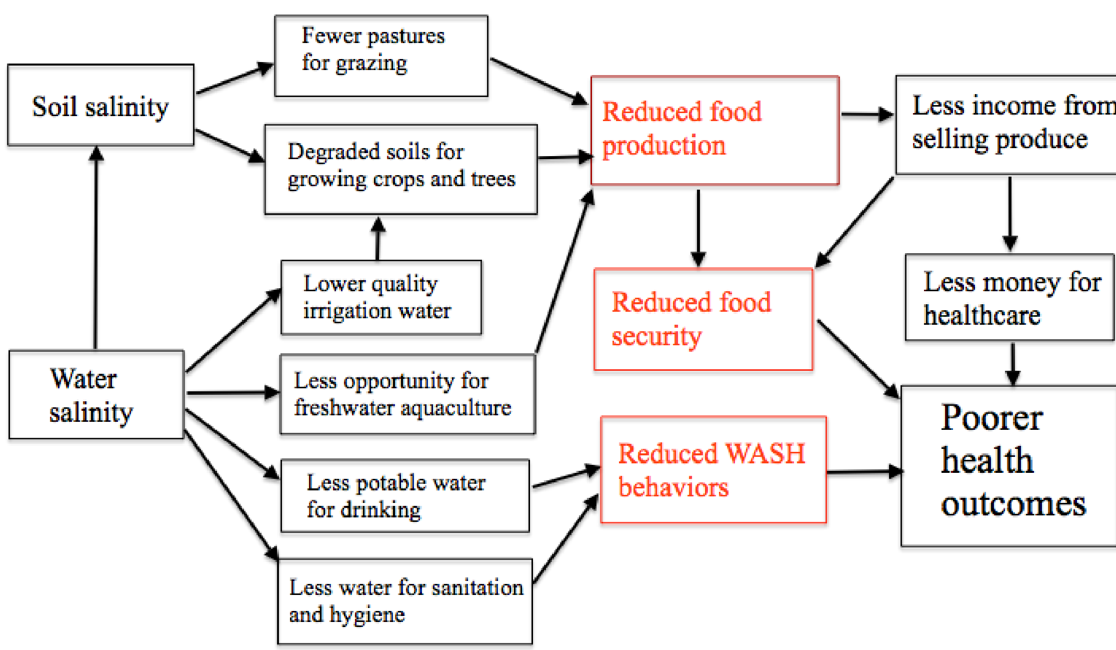
(1) Assess and compare how communities, NGOs, and government actors perceived the phenomenon of salinity and solutions to it, including the extent to which it could be prevented.
(2) Document the impacts of salinity on rural household water use and adaptation strategies and challenges, from the perspectives of affected communities and NGOs working in the region.
(3) Document the impacts of salinity on rural household food production and adaptation strategies and challenges, from the perspectives of communities and NGOs, as well as government actors.

The rest of this manuscript proceeds as follows: additional context for the study is provided in Chapters 2 and 3, which provide information on the public health significance of salinity and describe the study setting. Chapters 4, 5, and 6 address the first, second, and third study objectives, respectively, and are structured as independent research papers. Chapter 7 is a policy chapter that presents challenges observed in the design and implementation of interventions. Based on that information and results presented in earlier chapters, it presents implications and recommendations for future funding. Finally, Chapter 8 provides overall study conclusions.

Chapter 2. The Public Health Significance of Salinity

In the absence of adaptive responses, salinity can be expected to reduce health and well-being through multiple pathways. Both soil salinization and increased water salinity would reduce household capacity to produce food, which would diminish the quantity and diversity of food available for household consumption, as well as the income a household might make from selling extra produce. Moreover, water salinity would have impacts on drinking water quality and the availability of water for WASH and other uses. These specific pathways are illustrated in Figure 1. As the subsequent discussion will illustrate, some links are better documented than others.

Figure 1. Conceptual diagram of negative health impacts of soil and water salinity



Description: Pathways by which soil and water salinity are hypothesized to lead to poorer health outcomes, in the absence of adaptive actions. This research focuses on adaptation that happens at the points shown in red.

Salinity and Food Production

Salinity in soil and irrigation water poses a challenge for the cultivation of crops, trees and pastures, as it reduces water uptake by altering osmotic pressure and causes ion toxicity when salts are present in high concentrations [20]. Salinity, moreover, degrades soil quality, changing soil structure, permeability and aeration, thereby affecting plant growth [21]. Most saline soils also have low organic matter content, nitrogen and phosphorous, as well as fewer micronutrients, like zinc and copper [22]. These factors combined lead to a reduction in yield or, in severe cases, total loss of yield [22].

Soil salinity is measured either as electrical conductivity, EC (in units of deciSiemens/m or microSiemens/cm), or total dissolved salts (TDS, measured in mg/L or parts per million).[1] According to guidelines provided by the Food and Agriculture Organization of the United Nations (FAO), important levels to bear in mind for soil salinity are 4,000 µS/cm, the point at which many crops become affected, and 16,000 µS/cm, the point beyond which only a few highly saline-tolerant crops will have satisfactory yields. (See Table 1.) Water salinity is also measured as EC or TDS.[2] For purposes of irrigation, key thresholds for water are around 700 µS/cm, when there will be some restrictions to use, and around 2,500 or 3,000 µS/cm, when water is so saline that its use for irrigating typical crops is extremely limited. (See Table 2.)

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[1] Soil salinity is tested in the field by measuring apparent electrical conductivity using an electromagnetic induction device, and then calibrating the values in a laboratory setting [23]. In the laboratory, soil salinity can be determined directly by measuring the amount of total dissolved salts after evaporating a soil water extract, by assessing electrical conductivity of a 1:5 soil-to-water suspension, or by assessing electrical conductivity of a saturated paste extract [23].

[2] To study water salinity, samples are taken at different point sources and tested either for electrical conductivity (EC) or total dissolved solids (TDS). EC can be measured simply using a conductivity meter, while TDS usually requires evaporating a sample in the laboratory and calculating the remaining solids.

Table 1. Soil salinity classes and crop growth [20]

Soil salinity class	EC (μS/cm)*	Effect on crops
Non-saline	0 – 2,000	Salinity effects negligible
Slightly saline	2,000 – 4,000	Yields of sensitive crops may be restricted
Moderately saline	4,000 – 8,000	Yields of many crops are restricted
Strongly saline	8,000 – 16,000	Only tolerant crops yield satisfactorily
Very strongly saline	> 16,000	Only a few very tolerant crops yield satisfactorily

* EC values correspond to measuring EC of a saturated soil-paste extract in a laboratory setting.

Table 2. Irrigation water salinity classification systems applied in Bangladesh

<table>
<tr><th>Source</th><th colspan="5">Level of restriction on use / level of salinity</th><th>Study applied in Bangladesh</th></tr>
<tr><td>FAO (TDS) [24]</td><td colspan="2">No restrictions on use
< 450 mg/L</td><td colspan="2">Slight to moderate use restrictions
450-2,000 mg/L</td><td>Severe use restrictions
>2,000 mg/L</td><td>Shahid, Chen and Hazarika 2006 [9]</td></tr>
<tr><td>FAO (EC) [24]</td><td colspan="2">No restrictions on use
< 700 μS/cm</td><td colspan="2">Slight to moderate use restrictions
700-3,000 μS/cm</td><td>Severe use restrictions
>3,000 μS/cm</td><td>Rahman, Rahman and Majumder 2012 [7]</td></tr>
<tr><td>Rao 2005 [21]</td><td>Low
<250 μS/cm</td><td>Medium
250-750 μS/cm</td><td colspan="2">High
750-2,250 μS/cm</td><td>Very high
>2,250 μS/cm</td><td>Rahman, Rahman and Majumder 2012 [7]</td></tr>
</table>

Rice, a staple crop both in terms of subsistence consumption and local food security in the southwest, is considered tolerant of medium salinity levels. However different varietals vary in their sensitivities, and at the stages of germination and seedling growth rice may be particularly vulnerable [25]. A Khulna University lab study on the varietal BR11, a high-yielding variety (HYV) developed by the Bangladesh Rice Research Institute (BRRI), showed that it was able to withstand salinity levels up to 7,810 μS/cm without significant decreases in biomass and height compared to when cultivated in non-saline water [26]. However, progressively higher levels of salinity in irrigation water were observed to impact growth and yield negatively, with the number of tillers dropping by about 50% and the amount of biomass by 75% as salinity increased to 31,250 μS/cm [26]. As will be discussed below, salinity levels this high have already been observed in rivers throughout the region.

Besides cultivation of crops, salinity has also affected food production and livelihood opportunities by causing shortages in grazing pastures, feed, straw, and freshwater for raising livestock [27]. Additionally, higher salinity of water sources has impacted ability to cultivate freshwater fish and can also reduce fish diversity in streams and rivers. For example, Gain, Uddin and Sanna interviewed local fishermen in two villages with medium (10,000 – 30,000 μS/cm) and high salinity (20,000 to 45,000 μS/cm) rivers in the southwest zone, and found that fish species had been reduced from 24 to 19 species, and from 29 to 12 species, respectively, from 1975 to 2005. Fishermen and key informants attributed the reductions in biodiversity to river salinity over that period [28].

Notably, few studies examine the impact of soil and water salinity on food production in conjunction with food security and/or nutritional status. There is room for research that elucidates the impacts of these environmental changes on more distal outcomes. The results described in Chapter 6 contribute to setting the stage for these studies by detailing the multi-dimensional impact of salinity on food production, as well as factors that may inhibit or facilitate successful adaptation.

Salinity and Drinking Water

Multiple factors impair drinking water availability in Bangladesh's rural coastal areas: some tubewells are not functional, others contain arsenic, surface water may be contaminated, and both surface and groundwater may be affected by salinity. A drinking water survey of 750 households in Khulna and Bagerhat Districts revealed that 91% of households used more than one source to obtain drinking water [29]. Sources varied greatly by time of year, with 91% of households using household-level rainwater harvesting during rainy season, and 69% of households using pondwater during hot season [29]. Those households that did report using tubewell water—about 5% and 1% of respondents in hot and rainy seasons, respectively— complained of iron and salinity. Farmers surveyed by Rahman, Lund and Bryceson also reported a progressively saline taste of river and tubewell water beginning around 1990. To adapt, they traveled increased distances to obtain water or created alternative water sources, such as a communal pond with high walls to prevent river water from entering [25].

Beyond taste, there are now a few studies that examine the health outcomes of sodium intake specifically from drinking water in Bangladesh. A 2008 study in Dacope sub-district in Khulna found that women who drank from shallow tubewells had significantly higher urinary sodium levels than women who drank rainwater [30]. Moreover, researchers indirectly estimated—from environmental data and assuming an average daily consumption of 2L of water[3]—that sodium intake from drinking water ranged from 5 to 16 g/day in the dry season, compared to 0.6 to 1.2 g/day during the monsoon season [30]. Finally, using hospital data, they found that prevalence of

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[3] Salinity measurements of water sources obtained in units of EC can be converted into amount of salt per volume of liquid, or TDS. There are rough conversion factors between TDS and EC, though strictly it is not possible to express one as a function of the other because conductivity depends on the temperature and precise ionic composition of the solution. For practical purposes, conversion factors from EC (in μS/cm) to TDS (in mg/L) range from 0.50 to 0.75, depending on salinity level [31]. For example, 1,500 to 2,000 μS/cm corresponds to 1.0 g/L at 20 to 30 degrees Celsius [32]. Once TDS is known, an estimate of amount of water consumed per day can be applied to approximate the daily intake of salt from drinking.

hypertension in pregnancy was 2.39 times greater (95% CI: 1.43-3.99) in the dry season compared to the monsoon season [30].

Building on this, the researchers subsequently conducted a case-control study in the same sub-district to examine associations between salinity in drinking water sources, on the one hand, and preeclampsia and gestational hypertension, on the other. Accounting for age, parity, mid-arm circumference, and socioeconomic status, they found that adjusted risks for preeclampsia and gestational hypertension were each significantly associated with higher salinity of drinking water. Moreover, considering both outcomes together, there was a statistically significant dose-response relationship for increasing sodium concentrations [33].

These studies complement the body of research on the health impacts of dietary salt intake in the general population, which have been widely studied outside of Bangladesh. One recent meta-analysis of prospective studies showed that higher daily sodium consumption was associated with greater cardiovascular disease mortality in the general population [34], while another meta-analysis based largely on cohort studies found that low daily sodium (< 2.6 g) and high sodium (> 4.9 g) intake were both associated with increased all-cause mortality [35]. A modest reduction of salt intake over longer periods (four or more weeks) was also determined to lower blood pressure in both hypertensive and normotensive adults of both genders [36]. Finally, a recent systematic review has shown some limited evidence to support an association between high daily sodium intake (> 4.6 g) and adverse renal outcomes [37].

While the World Health Organization (WHO) recommends consuming less than 5 g of sodium per day [38], it has yet to establish a maximum acceptable concentration for sodium in drinking water. In its most recent guidelines on drinking water quality, it considered sodium “not of health concern” at the levels normally found in drinking water [p. 177, 39]. It only recognized that at concentrations beyond 0.2 g/L, sodium might affect taste and therefore acceptability of drinking water [39]. For this same “aesthetic” reason, the United States Environmental Protection Agency establishes 0.25 g/L of chloride as a secondary maximum contaminant level [40].

However, elevated salinity in drinking water may lead by itself or in combination with food intake to consumption of sodium in excess of 5 g/day. A 2003 policy paper by the Water Resources Planning Organization (WARPO) of the Bangladesh Ministry of Water Resources in fact recommended setting a “practical” standard of 2,000 μS/cm for groundwater salinity in coastal areas [p. 4, 32], which corresponds roughly to a concentration of 1 g/L [32]. The standard is noticeably higher than salinity of potable water in the United States, which usually ranges from 30 to 1,500 μS/cm [41].

Salinity and Other Water Usage

The implications of salinity for other uses of water, including cooking, sanitation and hygiene, have been less documented, in terms of both behaviors and health outcomes. Vineis, Chan and Khan reference government and NGO documents that report a range of health problems in the coastal population, including skin disease, gestational hypertension, miscarriage, acute respiratory infection, and diarrheal disease, due to increased salinity exposure via drinking, cooking and bathing [42]. However, the cited documents were not accessible online. Anecdotal evidence obtained from some community members during formative research (including women working in saltwater shrimp aquaculture, village doctors, midwives, and family planning health workers) did indicate a possible link between salinity —particularly prolonged exposure to saline water while working in shrimp ponds— and female reproductive tract infections and skin and eye irritations. This was a widely held perception, but there were no supporting health records or other data on the issue, reflecting a pressing need for epidemiological and behavioral science research on the impact of water salinity on hygiene practices and associated outcomes, as well as occupational health.

Chapter 3. Study Context: Southwest Coastal Bangladesh

Physical Characteristics

Bangladesh is a low-lying country with 440 miles of coastline, and a coastal area that is divided into three zones: the southwest, the south central, and the southeast zone. As measured going inland, the coastal zone extends between 20 to 120 miles from the shore, and the most exposed coastal area lies between 23 and 35 miles from the shore [16]. Sixty-two percent of the coastal zone is less than 3 meters (approx. 10 feet) above sea level, while 86% is no more than 5 meters (about 16 feet) above sea level [16]. Extending from the border with India to the Haringhata River Estuary, the southwest coastal zone includes the districts of Satkhira, Khulna, and Bagerhat. (See Figure 2.) Each district is composed of sub-districts, and in rural areas each sub-district is divided into unions, the smallest rural administrative unit with local government. A union comprises several wards, with roughly one village corresponding to one ward.

Salinity levels vary depending on the time of year, the year itself, and the specific location [19]. Currently, saltwater can intrude as far as 110 miles inland, seeping in by way of rivers and channels, especially during the months of January through June, when there is less rainfall and insufficient downstream flow of freshwater from the Ganges river and its distributaries [22, 25, 43]. Generally, areas closer to the shoreline are considered more saline-prone than those further inland [19]. However, it is also important to consider the polder[4] in which a site is located. Many of the ecological features at a given location have resulted from the way water and land have been managed within the corresponding polder. Although there are global and more distant processes that impact salinity levels at a specific site (such as the environmental phenomena alluded to in Chapter 1), one relatively proximate factor that influences salinity is the control of water and extent of saltwater aquaculture in that polder.[5] These and other causes of salinity, as understood by the region's inhabitants and relevant governmental and non-governmental actors, are explored in detail in Chapter 4.

Between 1973 and 2009, the Soil Resource Development Institute observed an expansion of areas affected by soil salinity, along with intensification of degree of salinity, in the three southwest coastal districts of Khulna, Bagerhat, and Satkhira [46]. (See Table 3.)

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[4] A polder is a tract of floodplain enclosed by mud embankments, such that the water inside is separated from the water outside the polder, and flow is controlled by means of a sluice gate. Beginning in the 1960s and continuing through the 1980s, an expansive system of Dutch-style polders was constructed to control tidal flooding so that rice production could be intensified [44]. The initiative, known as the Coastal Embankment Project, dramatically changed the landscape, with a total of 123 polders constructed in that period [45]. However, due to the hydro-dynamically active nature of the altered areas, by the 1990s there was drainage congestion within the polders and heavy siltation in the distributaries and areas outside the polders [45]. Waterlogging resulted, with saline water filling the polders and seeping into surrounding agricultural land [19].

[5] For example, one study, which sought to assess the impact of shrimp farming on soil quality, examined changes in soil salinity by sampling four locations in a village in Satkhira district first in 1985, then again in 2003 [3]. At the location being used for rice and legume cultivation, salinity increased about 6.7%. At the other three locations where rice and shrimp were being cultivated, salinity increased by over 30%, with greater increases corresponding to longer duration of shrimp farming: 32.5%, 36.3%, and 38.5% increases, for 5-, 10-, and 15-year shrimp farming histories, respectively. At each location, 15 samples were taken, and an analysis of variance test was used to determine that the differences among salinity increases for the four types of land use were significant.

Figure 2. Bangladesh Southwest Coastal Region, Study Districts and Sites

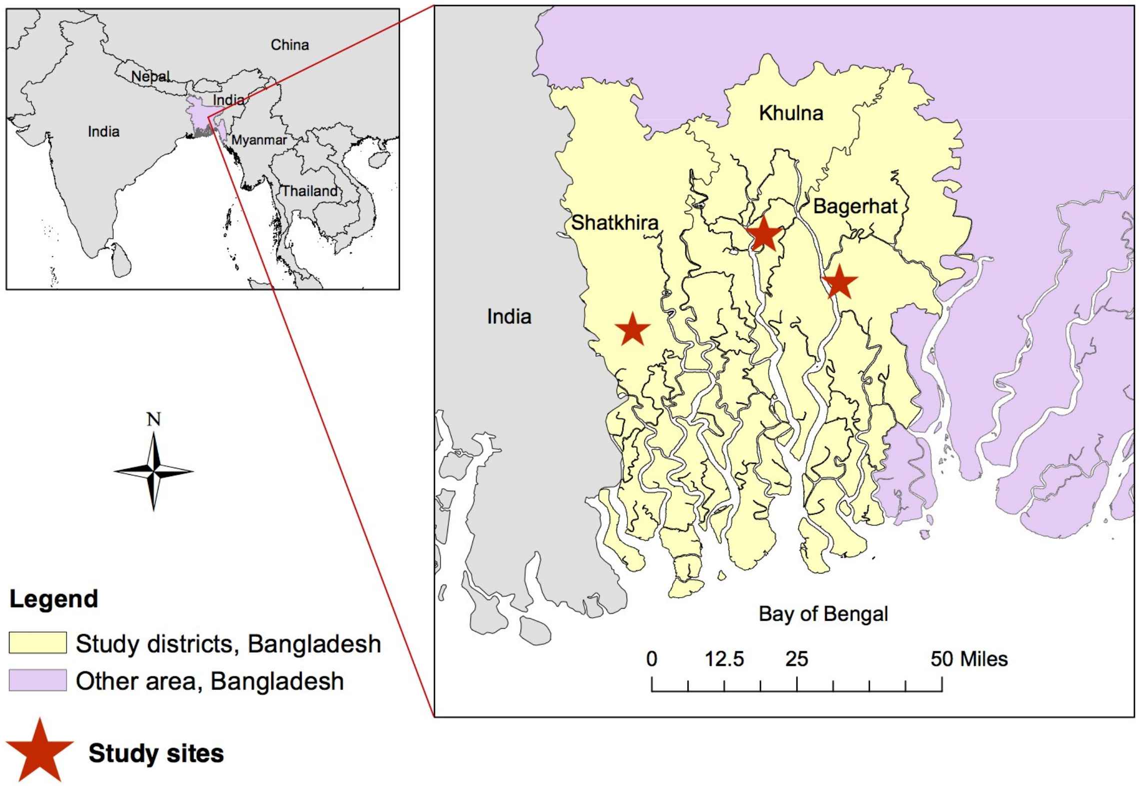


Table 3. Soil salinity (in μS/cm) in Khulna, Bagerhat, and Satkhira Districts: 1973, 2000, 2009

District	Salt affected area (in 1,000 hectares)			Slightly saline 2,000-4,000 μS/cm			Moderately saline 4,100-8,000 μS/cm			Saline 8,000-16,000 μS/cm			Highly saline >16,100 μS/cm			Four-decade increase in total affected area
	'73	'00	'09	'73	'00	'09	'73	'00	'09	'73	'00	'09	'73	'00	'09	
Khulna	120	145	148	14	29	24	93	38	27	14	60	48	9.8	20	31	23.3%
Bagerhat	108	125	131	8.3	36	32	77	43	43	3.6	41	53	0	6.7	9.2	21.4%
Satkhira	146	147	153	27	29	31	86	39	33	35	61	70	11	22	29	4.62%
TOTAL	**374**	**417**	**432**	**49**	**94**	**88**	**255**	**120**	**102**	**52**	**161**	**169**	**21**	**48**	**68**	**15.4%**

As for water salinity, studies sampling from various sources throughout the southwest region reveal high salinity levels, in terms of both the drinking water and irrigation water parameters described in the previous chapter. For example, a study sampling from three deep tubewells in one sub-district in Khulna found salinity levels of

3,500 μS/cm, 2,500 μS/cm, and 1,000 μS/cm, with the first two salinity levels designated "more harmful" and "harmful," respectively [43]. Salinity levels for the first two sources exceed WARPO's groundwater standard, cited earlier. In Satkhira district, Rahman et al. divided one sub-district into three zones and tested deep groundwater samples from each zone. In the northern, central, and southern zones, average EC was found to be 2,082 μS/cm, 1,594 μS/cm, and 614 μS/cm, respectively [7]. Using Rao et al.'s standards for irrigation water, the northern and central zones were classified as high salinity and the southern zone as medium salinity [7]; in other words, irrigation would be notably restricted in the first two areas. Surface water from rivers and canals has also been tested for salinity, revealing the potential for even higher salinity levels [43].

Moreover, the problem may be worsening. As with soil salinization, a few studies have noted increases in average yearly water salinity in specific water sources, such as the Kazibacha river in Khulna, the Rampal river in Bagerhat, and the Kakshiali river in Satkhira [25], as well as increases in the highest recorded salinity levels in Kaliganj sub-district in Satkhira [25], and the Rupsa River in Khulna [8, 43]. Although precise predictions are not possible, the saline water front is projected to move further inland due to sea level rise, among other factors, and salinity is expected to intensify [4, 10, 43].

Socio-Demographic Characteristics

Bangladesh's coastal zone is characterized by a growing population and livelihoods that are deeply dependent on the land. Approximately 40 million people reside in an area of about 47,000 km^2, and the number is projected to grow to 60 million by 2050 [47]. Over half of the coastal zone population lives below the absolute poverty line [47], and 30% percent of inhabitants are completely landless [45]. Among landholders, 80% are small farmers, 18% are medium farmers, and 2% are large farmers [45]. Land use is described as "diverse, competitive and conflicting," spanning agriculture, shrimp farming, salt production, forestry, shipbreaking yards, ports, industry, human habitation, and wetlands [p. 238, 45].

Persisting nutrition and food security challenges are reflected in country-level health indicators provided by the 2014 Demographic and Health Survey (DHS). In rural areas, 38% of children under five were considered stunted, 15% were considered wasted, and 35% were considered underweight [48]. Focusing specifically on Khulna Division, which includes our three study districts, prevalence of stunting, wasting, and underweight were 28%, 14%, and 26%, respectively. Despite a number of governmental and NGO initiatives that seek to address nutrition and food security [49] and some advances in health indicators over the past decade, nutritional status continues to be one of the country's most pressing challenges. A recent analysis of food, agriculture, and health policies in Bangladesh attributed these poor outcomes to the fact that most policies focus on increasing availability of food, particularly rice, neglecting the accessibility and utilization dimensions of food security [50].

Regarding water-related health challenges, the country still faces a significant deficit of infrastructure for drinking water, sanitation, and hygiene, which is manifested in the high number of diarrheal-disease related deaths occurring in children under five, among other figures [51]. Nearly all households in Bangladesh technically have access to an improved source of drinking water, with 94% of households in rural areas using water from a tubewell [48]. However, issues regarding water quality (e.g., bacteriological and heavy metal contamination) severely limit the availability of potable water. Groundwater in Bangladesh's coastal regions is affected by salinity, arsenic, iron, and manganese [52]. A study analyzing 22,113 water samples collected over a 14-year period (1996-2010) from hand tubewells in the deltaic region found that 55% of those samples had arsenic in excess of 10 ppb (the WHO guideline for arsenic in drinking water), while 33% had arsenic in excess of 50 ppb [53]. In addition, only 3.4% percent of rural households use an appropriate water treatment method, according to the DHS. Regarding sanitation, 36% use non-improved toilet facilities [48]. There are many foreign-funded WASH-related interventions, including ones led by the government, research organizations like the International Centre for Diarrhoeal Disease Research, Bangladesh (icddr,b), and NGOs such as BRAC and WaterAid. Geophysical factors related to climate and environment, however, pose a continuing challenge to achieving and sustaining progress in WASH outcomes.

Study Sites: Selection Process and Characteristics

Site selection was carried out in February 2015. We aimed to select three sites (villages/communities), one in each of the southwest coastal districts of Khulna, Satkhira, and Bagerhat. Consulting local government officials and NGOs in the area, and existing salinity data from the Soil Resource Development Institute [46], we identified two potential research sites per district, for a total of six candidate sites. We visited each candidate site, met with the corresponding village leader and community members, mapped the site borders and landmarks, and tested surface water, groundwater, and soil samples at dispersed locations throughout the sites. Mapping was done with a Garmin Dakota® 20 GPS device and Google Earth software.

The final three sites were purposively chosen with a focus on areas where salinity was a moderate to significant problem, and where some level of adaptation in methods for cultivation and managing household water had been observed. The sites were Moshamari village (Tildanga Union) in the Dacope sub-district of Khulna; Dokin Chandpai village (Chandpai Union) in the Mongla sub-district of Bagerhat, and Khagraghat village (Munshiganj Union) in the Shyamnagar sub-district of Satkhira. (See Table 4.)

Table 4. Site Characteristics [54–56]

Site	Pop.	No. of households	Literacy rate male / female	Percent of pop. Muslim / Hindu	Percent of households with electricity
Moshamari (Khulna)	675	164	74% / 49%	7% / 93%	27%
Khagraghat (Satkhira)	1794	415	57% / 42%	94% / 6%	24%
Dokin Chandpai (Bagerhat)	2,034	384	53% / 50%	92% / 8%	55%

Chapter 4. Soil and Water Salinity in Southwest Coastal Bangladesh: Local Understandings of Causes and Potential Solutions

Introduction

As climatic and other environmental changes occur globally, communities in low-resource settings cope with or adapt to these changes, while external institutions (like government agencies and development organizations working in the affected areas) make resources available to facilitate certain types of responses. Communities' and organizations' preferences for specific strategies may depend on their interpretation of the environmental phenomena underway. Examining what these actors perceive to be the causes of a given phenomenon can not only impart local knowledge about the phenomenon, but also may facilitate an understanding of why certain strategies are prioritized and succeed, while others have limited uptake and fail.

Salinity in the Southwest Coastal Region of Bangladesh is a complex environmental phenomenon. Various factors have been cited in the literature as contributing to salinity intrusion—a process by which saltwater intrudes inland into freshwater sources— and/or as exacerbating salinity levels in general. These include sea level rise, cyclone storm surges, diversion of the Ganges River by dams in India, tidal flooding during rainy season, changes in pressure during dry periods, and large-scale saltwater aquaculture, specifically shrimp farming [3, 6, 8, 13–19, 57, 58]. Salinity in surface water, groundwater, and soil has had enormous repercussions on the population's water and food security, which are discussed in detail elsewhere (see Chapters 5 and 6).

Affected communities have responded by altering water management and food production practices, while in recent years governmental and non-governmental organizations have attempted projects to improve rural livelihoods in the context of soil and water salinity.

By shedding light on the causes of salinity, as understood by local communities, NGOs, and government actors, the present study seeks to elucidate the implicit assumptions underlying the responses to salinity currently being undertaken. The research also elicits explicit prioritization of adaptation strategies from relevant governmental and non-governmental actors, providing insight into the future direction of development efforts and where gaps may remain.

Methods

Our sites consisted of three villages/communities, purposively selected to represent the three southwest coastal districts of Bangladesh and to have moderate or high severity of salinity in soil and water. The sites were located in the Dacope sub-district of Khulna District, the Mongla sub-district of Bagerhat District, and the Shyamnagar sub-district of Satkhira District.

Data Collection

There were two phases of data collection: the first entailed community-level data collection at the three sites, and the second involved government officials and NGOs in the Southwest Coastal Region and Dhaka city. The data collection team consisted of three public health researchers: two were Bangladeshi and the third was a PhD student from the United States. All members had graduate level training and experience in qualitative research methods. Written consent was obtained from all study participants. The study was approved by the Institutional Review Board of Johns Hopkins Bloomberg School of Public Health, and the Research Review Committee and the Ethics Review Committee of the International Centre for Diarrhoeal Disease Research, Bangladesh (icddr,b).

Phase 1 – Community-level data collection

We had two rounds of community-level data collection. The first round took place in May and June 2015. Across the three sites, we conducted 59 in-depth interviews and 6 focus group discussions with community members, selected to achieve a balance between male and female participants, geographic spread across the sites, and coverage of occupations and roles within the community. Interviews and FGDs were semi-structured, guided by open-ended questions on perceived causes of salinity and prospects for reducing salinity, among other topics. The second round of community-level data collection took place in October 2015, during which we conducted follow-up interviews with 25 previously interviewed participants. In follow-up, we administered a rating exercise, whereby participants were shown six pictures of factors cited in the literature or during round 1 as a cause of salinity. If the participant was aware of the factor, then we asked whether he/she thought it was a cause of salinity, and if so, whether it was a significant or minor contributor. Participants were probed on the basis for their choices. We also asked about what ideas participants had, if any, about climate change and the source of that knowledge.

Phase 2 – Stakeholder-level (government and NGO) data collection

The second phase of data collection took place in January and February 2016. We conducted in-depth interviews with 24 NGO and 16 government representatives based in the Southwest Coastal Region and Dhaka. The government entities concerned were the Ministry of Land, Ministry of Water Resources, Ministry of Health and Family Welfare, Ministry of Fisheries and Livestock, Ministry of Agriculture, and Ministry of Environment and Forests. The interviews entailed semi-structured discussion, during which we asked open-ended questions about what they perceived as the causes of salinity, among other topics. A systematic ranking exercise was administered to 47 NGO and government representatives (the 40 who participated in interviews, plus seven others recruited for this purpose). In the ranking exercise, respondents were shown a list of seven adaptation strategies, asked to order them in terms of funding priority, and probed on the reasons behind their rankings. The strategies listed derived from observations and findings obtained during site selection and phase 1 community-level data collection.

Data Analysis

Results from the systematic ranking and rating exercises were tabulated. Interviews and focus group discussions were audio recorded and transcribed. Transcripts in Bangla were translated into English by native Bangla speakers.

Transcript by transcript analysis entailed three components: (1) coding quotes that were particularly notable using MaxQDA software, based on codebooks that followed the major topics of each data collection activity (see appendices for the specific codebooks used); (2) extracting information into a 3 to 5 page summary document based on a standardized template corresponding to the topics of the data collection activity; and (3) updating a separate memo of observations on cross-cutting themes, new analysis ideas, and unexpected or particularly noteworthy information. Findings were synthesized by topic from the summary documents, which contained the bulk of the information, and these findings were supplemented by notable quotes and the memo on coding observations.

Results

The breakdown of community participants by gender and district are provided in Table 5, while the household characteristics of only those who participated in the rating exercise are provided in Table 6. The breakdowns of NGO and government stakeholders by institution are provided in Table 7.

Table 5. Community participants by gender and district

	In-depth interviews			Focus group discussions # of FGDs (# of participants)		
District	**Males**	**Females**	**Total**	**Males**	**Females**	**Total**
Bagerhat	10	9	19	1 (7)	1 (15)	2 (22)
Satkhira	11	10	21	1 (7)	1 (11)	2 (18)
Khulna	10	9	19	1 (8)	1 (9)	2 (17)
Total	**31**	**28**	**59**	**3 (22)**	**3 (35)**	**6 (57)**

Table 6. Profile of participants in "perceived causes of salinity" rating exercise

Characteristic	Number (out of 25)
District	
Bagerhat	8
Satkhira	9
Khulna	8
Gender	
Male	12
Female	13
Age group	
18-24	1
25-44	14
45-59	6
60 and above	4
Highest level of education attained by a household member	
No formal education completed	3
Primary	10
Secondary	8
Post-secondary	4
Household religion	
Muslim	17
Hindu	8
Primary occupation of household head	
Agriculture	6
Aquaculture	5
Fish trading	2
Daily (wage) labor	11
Services	1

Table 7. Stakeholder participants by institution

Institution	Number (out of 47)
Government	
Ministry of Agriculture	5
Ministry of Fisheries and Livestock	3
Ministry of Water Resources	3
Ministry of Environment and Forests	4
Ministry of Land	2
Ministry of Health and Family Welfare	3
Non-governmental	
Local/regional	6
National	6
International	15

Community Member Ratings of Potential Causes of Salinity

Several factors were mentioned during round 1 data collection as causes of salinity in soil and water, including saltwater *ghers* (dyke-surrounded ponds used for aquaculture), upstream dams in general, Farakka dam, local sluice gates deliberately used to bring in saltwater, storms/cyclones causing coastal flooding, decreased precipitation, reduced Himalayan ice melt, proximity to the ocean, and salty winds. Based on how prominent these explanations were in interviews, and accounting for additional explanations noted in development sector and scientific publications, we decided on the following six factors for the rating exercise in round 2: *ghers*, Farakka dam, sluice gates, cyclones, "natural" salinity due to the ocean's proximity, and sea level rise. These factors had overlap as scientific phenomena, but represented sufficiently distinct concepts to our study population.

As the results of the rating exercise show (see Table 8), saltwater *gher* aquaculture was perceived to be the biggest driver of salinity. Every participant perceived it as a cause, with most deeming it a major cause. Proximity to the ocean, cyclones, and sluice gate management were also perceived to be significant contributors to salinity. However, our probing about the ocean and cyclones revealed that not all participants recognized that seawater was salty. Some thought the ocean contained saltwater in some areas and freshwater in other areas, or perceived that salinity intruded via salty ocean breezes, more so than through water. A few stated that cyclones could bring in either freshwater or saltwater.

Community-level awareness about Farakka dam in India and sea level rise as a long-term environmental phenomenon was much lower, and most participants did not recognize these factors as drivers of salinity. Although they were aware of the daily changes in sea level (from high tide and low tide), as well as seasonal changes in water levels from rainy season flooding and tidal surge from cyclones, most community members were unaware that long-term sea level rise was occurring. When probed, the majority of participants revealed that they were unfamiliar with the concept of climate change as it related to sea level rise and salinity, although many noted that they had observed changes in the weather over their lifetime.

Table 8. Community rating results on perceived causes of salinity

Factor	Contribution to salinity (n = 25)			Awareness of the factor
	Major	Minor	None	
Ghers	21	4	0	Everyone had awareness.
Sluice gate management	16	1	8	2 out of the 8 who attributed to role were unaware of the factor.
Ocean	15	5	5	Everyone had awareness.
Cyclones	11	2	12	Everyone had awareness.
Sea level rise	7	2	16	12 out of the 16 who attributed no role were unaware of the factor.
Farakka dam	5	2	18	7 out of the 18 who attributed no role were unaware of the factor.

Community Narratives on Salinity and Prospects for Reducing Salinity

Community members portrayed salinity, at least some amount of it, as always having existed and largely inevitable. Many perceived that cyclone events exacerbated salinity, bringing in "poisonous saltwater" that killed vegetation. However, the salinity associated with cyclones was seen as something that peaked with the extreme weather event and then subsided over the next several years. Saltwater shrimp farming and sluice gate management were also seen as exacerbating salinity, generally getting worse with time. As one woman from Satkhira narrated:

> *Before [Cyclone] Aila, there was salty water, and salinity increased after Aila. But where the saltwater came from before Aila, we don't know. We were young then…. Growing up, we could see there was saltwater. We saw that from doing* ghers*, there was more saltwater. We saw that where* bagda *shrimp were being cultivated, there was more saltwater.*

There was some recognition that saltwater shrimp farming in *ghers*, which started around the 1980s and 1990s in our study districts, began as an adaptation response to natural salinity, especially during the hot season when there was higher salinity. Over time, the proportion of agricultural area dedicated to *ghers* increased and saltwater *gher* aquaculture increasingly became a year-round activity – factors widely perceived to contribute significantly to soil and water salinity in the Southwest Coastal Region.

One common narrative told by our participants was that saltwater *gher* aquaculture was started by wealthy individuals often from other localities, who leased land from villagers to construct *ghers* and cultivate *bagda* shrimp (*penaeus monodon*, also known as Asian tiger shrimp or giant tiger prawn). The activity expanded for two reasons. First, *bagda* farming appeared to be a profitable endeavor, at least initially, because *bagda* was highly valued for international export. As a woman from Bagerhat recounted: "*People became addicted to ghers…. Everybody started one by one.*" Second, even those farmers who wished to cultivate crops could not continue to do so, as salinity intruded from neighboring *ghers* onto their land. They either tried *gher* farming or leased their land to larger-scale *gher* operators, who paid low rents and took advantage of the fact that many landowners were smallholder farmers left with few other options. The extent to which farmers affected by saltwater aquaculture resisted the trend varied by location, ranging from little protest to physical confrontations. Some villagers, whose lands were affected, reported that they filed court cases or complaints with local administrative officers, but lost them because *gher* operators bribed the officials.

The management of sluice gates, another factor widely perceived as a driver of salinity, was closely related to saltwater *gher* aquaculture. Communities noted that sluice gates were originally constructed as part of the polder embankment system to facilitate drainage during rainy season. However, with the growth of the saltwater shrimp farming industry, they were utilized instead to trap saltwater and maintain a high level of salinity in the *ghers* year-round. Community members in our study areas reported that small and large *gher* owners paid a fee to the gatekeepers, and politicians called for an auction every year to auction off control of the gates and the machines that diverted saltwater from the rivers to the *ghers.* It was not clear to what extent the process was legal, but there was consensus that various local politicians and administrative officers were involved and paid through this process.

There was also a common perception that saltwater *gher* aquaculture enriched the wealthy, while the poor became increasingly impoverished, due to less subsistence production, fewer opportunities for land-poor peasants to work as daily laborers in agriculture, and economies of scale that could only be reaped with larger-scale *gher* farming. However, there was also a perspective that saltwater *ghers* were on the decline. Many participants reported that it was no longer profitable, as problems with disease and contamination were affecting the shrimp stocks and making Bangladeshi shrimp lose value in the international market. In this context, many community respondents thought that it might be possible to reduce salinity in the area and completely stop saltwater shrimp farming.

The general view was that eliminating saltwater *ghers* would lead to a gradual reduction in salinity, to the point where the land would once again be suitable for farming. Nearly all of the participants located at our Bagerhat and Satkhira sites—where saltwater shrimp farming was prevalent—perceived salinity to be increasing, while most of those at the Khulna site—where saltwater shrimp farming had been abolished several years earlier through political mobilization—perceived salinity to be decreasing.

While eliminating saltwater *ghers* was mostly viewed as a desirable outcome, villagers living in areas still affected by *ghers* expressed pessimism that it could be achieved without significant government action and cynicism that the government would undertake such action. For example, in Bagerhat many suggested that the government build a large embankment and sluice gate to prevent saltwater from entering and to take in freshwater for the cultivation of rice, other crops, and freshwater fish. Various community members, including the ward-level official (corresponding to an elected village leader), recalled requesting this infrastructure in meetings with higher-level officials, but told us that progress was either slow or non-existent. They hypothesized that their request went unheeded because *gher* owners and local Ministry of Fisheries representatives opposed it, and moreover the infrastructure could impede navigability of waterways and prevent ships from docking at a port nearby. They saw the government as prioritizing economic interests over general community welfare and viewed themselves as helpless. As one farmer put it: *"If you fasten the four legs of a cow and then slaughter it, what could the cow do then? Our situation is the same."*

On the other hand, at our Khulna site political mobilization against saltwater *gher* aquaculture began around mid-2007 and ultimately resulted in the elimination of saltwater *ghers* in 2009. Community members cited several factors driving this outcome. First, local politicians responded to public pressure and ordered the closure of one of the sluice gates that was allowing saltwater to come in, and additionally issued an ordinance prohibiting the leasing of land for purposes of *gher* aquaculture. Second, the profitability of saltwater shrimp farming had declined due to diseases affecting the shrimp, and quality issues had led to devaluation of Bangladeshi shrimp internationally. Third, the *gher* owners, who were said to customarily pay local inhabitants money to "win" their support, for some reason had failed to do so in this area, leading to an upswell of discontent with *ghers*. Participants from our Khulna site reported that since 2009, agricultural activity has been increasing yearly.

NGO and Government Perspectives on Salinity Causes and Solutions

Most NGO and government officials recognized that there were various causes of salinity: some that had always existed and were unavoidable, others that were due to distant/global processes, and still others that were due to local practices in land use and natural resource management. These included naturally saline aquifers, the ocean's proximity, anthropogenic climate change (manifesting as hotter temperatures, erratic precipitation, and sea level rise), tidal flooding from cyclones, diversion of water by Farakka dam, lateral seawater intrusion caused by falling groundwater tables, sedimentation and water-logging due to the polder system, saltwater *gher* aquaculture, and sluice gate management.

Among the government ministries, however, there was a notable division of opinions regarding whether salinity should even be considered a problem, and whether saltwater shrimp farming was responsible for it. On one end, the Ministry of Fisheries maintained that most salinity was inevitable. As one official insisted, *"The air is salty, the water is salty, the soil is salty. Everywhere, there is salinity. How could you prevent it?"* Moreover, salinity was not a "curse," but a "gift," because it could be harnessed for saltwater shrimp farming. Ministry officials claimed that inhabitants of the region were coping successfully with salinity; those with difficulties were migrants from other regions or landless. One Ministry official accused NGOs of falsely portraying salinity as a problem and claiming that people were vulnerable in order to secure donor funding, which they pocketed for their own benefit. The Ministry of Health officials we interviewed had a stance similar to that of the Ministry of Fisheries, but it was not clear whether this was an institutional position, or the personal stance of the representatives interviewed.

On the other end of the spectrum, the Ministry of Agriculture maintained that salinity was a significant problem in the Southwest Coastal Region. Their officials argued that saltwater *gher* aquaculture contributed to salinity, while benefitting a few at the expense of the majority. One Ministry of Agriculture official, himself a *gher* owner, pointed out that there were regulations—currently being disregarded—against bringing in saltwater from the rivers to make *ghers* saline.

In general, NGO perspectives on the drivers of salinity were more unified and aligned fairly closely with community-level perspectives. Virtually all of the NGO representatives thought that saltwater *gher* aquaculture contributed to salinity. One NGO representative pointed out, and numerous others reiterated, that those who owned the *ghers* were "politically well-connected" and therefore able to bypass regulations against bringing saltwater into the area. However, a couple respondents noted that the situation had improved. For example, a representative from a grassroots NGO operating in the region recounted that saltwater shrimp farming used to be completely unregulated ten to fifteen years ago, but now some regulations were being enforced that helped control its environmental impacts.

Another contentious factor cited as a cause of salinity was the management of sluice gates. While there was general recognition that sluice gates were being used to bring in saltwater for *gher* aquaculture, it was more ambiguous which entity was accountable. Most participants noted that sluice gate control fell under the jurisdiction of the Ministry of Water's Water Development Board, but the Ministry of Water officials we interviewed in Khulna told us that they perceived the operation of sluice gates to be beyond their control. These officials stated that as of 2000, the central government had decided that control of the sluice gates should be delegated to the local communities in the gates' catchment areas, specifically to their elected union-level representatives. One Ministry representative criticized this shift to "participatory water management," calling it an imposed "mistake."

NGO and Government Ranking Results on Salinity Response Priorities

NGO and government officials ranked seven different strategies for addressing salinity, based on how much they would prioritize that type of response. The strategies were: implementing more rainwater-harvesting infrastructure, training community members on special methods to adapt homestead cultivation to a saline environment, researching and disseminating more saline-tolerant varietals, creating more non-agricultural livelihood options, increasing saltwater shrimp farming, decreasing saltwater shrimp farming, and assisting out-migration away from salinity-affected areas. (See Table 9.) (Chapters 5 and 6, on water and food production, respectively, describe these strategies extensively.)

The government respondents' most prioritized responses to salinity were rainwater-harvesting infrastructure, which was ranked as the top choice by most, and saline-tolerant plants, which came in second. NGO respondents' top choice was special methods to adapt homestead cultivation to saline conditions, followed by saline-tolerant plants. Both groups of respondents generally viewed rainwater-harvesting infrastructure, special cultivation methods, and saline-tolerant plants favorably. The fact that these were the first three strategies listed may partially account for this preference, but not entirely, as confirmed by in-depth probing for respondents' explanations. For example, various respondents insisted that saline-tolerant plants—the top choice overall—were the region's pathway to "*achieving self-sufficiency in food*," despite shortcomings in technology and implementation (see Chapter 6).

Table 9. Stakeholder ranking results on responses to salinity, showing average rank

Strategy	Government (n=20)	NGO (n=27)	Combined (n=47)
Saline-tolerant plants	2.25	2.33	2.30
Special cultivation methods	2.85	2.07	2.40
Rainwater-harvesting	2.10	3.00	2.62
Non-agricultural livelihoods	5.10	3.93	4.43
Decrease shrimp farming	5.00	4.22	4.55
Increase shrimp farming	4.50	6.48	5.64
Assisted out-migration	6.20	6.00	6.09

NGO actors more strongly opposed increasing saltwater shrimp farming, compared to government actors. Expanding shrimp farming was generally viewed unfavorably. Even though saltwater shrimp farming generated income for the country, it delivered, as one NGO representative called it, “instantaneous gain” to the detriment of long-term sustainability. However, with the exception of a few individuals (who were mostly from the NGO sector), respondents also argued against actively reducing shrimp farming, citing several reasons. First, many claimed that the area was naturally saline and salinity would increase due to sea level rise. Inhabitants of the region had to “*learn to use salinity as a resource*,” and saltwater aquaculture was one of the few options available to them. Second, if saltwater aquaculture were eliminated, it would take several years for salinity to decrease enough for crop cultivation, and in the meantime there would be no other livelihood options. A third line of reasoning offered by the Ministry of Environment, among others, was that shrimp farming was too important economically. They maintained that saltwater shrimp farming could be environmentally sustainable, or at least restricted through zoning. Yet at the same time, many respondents, especially from the government sector, claimed that regulations against saltwater shrimp farming would be ineffectual. They said that large *gher* owners had more power than the government, and “*it would cause problems if the government tried to interfere*,” as one Ministry of Agriculture remarked.

Regarding the strategy of investing in non-farm and off-farm livelihoods, NGO representatives generally recognized this as a priority more so than government officials did. Respondents from both sectors, however, were consistently opposed to assisting migration away from the area. A few NGO respondents clarified that they would not help people leave the rural Southwest Coastal Region, but *would* help migrants who had arrived in cities like Dhaka and Khulna, who needed assistance.

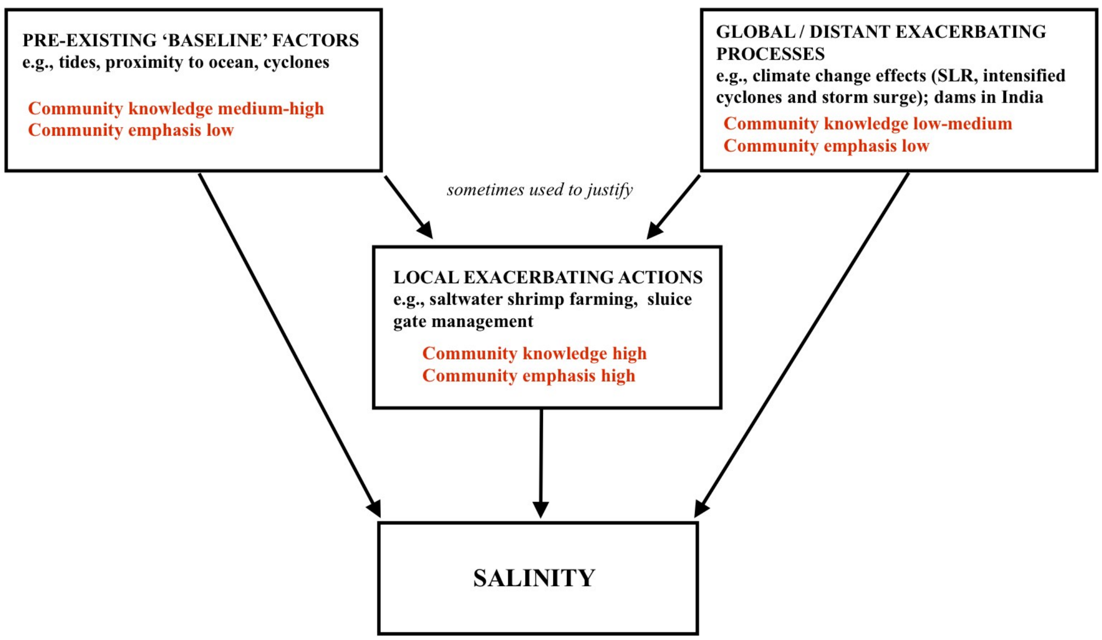
Discussion

As a review of the scientific literature suggests, salinity is a complex, multifaceted phenomenon. Participants in our study attributed salinity to diverse factors, ranging from pre-existing conditions that created some 'baseline' amount of salinity, to local drivers and global/regional processes that exacerbated those pre-existing levels. The three respondent groups—community members, NGO representatives, and government actors—varied in the types of factors they emphasized. Moreover, they offered different perspectives on the extent to which salinity was a problem and, if so, whether it *could* or *should* be controlled.

In conceptualizing salinity as a challenge, community members thought that salinity had always existed due to conditions like proximity to the oceans and normal tidal flow, but they emphasized that salinity *had become a problem* due to exacerbating factors. Further, in describing these exacerbating factors, community members generally focused on the local actions—specifically, saltwater shrimp farming and sluice gate management—rather than global or more distant processes—for example, sea level rise from anthropogenic climate change and diversion of water by dams in India. (See Figure 3.) This would seem to suggest that those directly affected by salinity might support measures to tackle the local perceived causes of rising salinity, as much as measures that respond only to its symptoms.

Regarding the perception of causes behind salinity, the results revealed some alignment between community and NGO perspectives, especially on local land use and water management practices as exacerbating factors. It was more difficult to generalize about the government sector, given the contrasting views held by different ministries about the causes of salinity and whether salinity should even be portrayed as a problem. Certain institutions—the Ministry of Agriculture being the clearest example—appeared to align more closely with communities in their perspectives, while others—particularly the Ministry of Fisheries—appeared to diverge most significantly from them.

Figure 3. Factors contributing to salinity, rated and described by community members



However, in prioritizing strategies for addressing salinity, representatives from both the government and NGO sectors generally emphasized actions that sought to mitigate the effects of salinity, such as developing saline-tolerant plants, special cultivation methods, and rainwater-harvesting infrastructure. Neither sector strongly advocated a proactive reduction or regulation of saltwater shrimp aquaculture, which community participants universally identified as an exacerbating factor. Further, while some justification for not taking active measures to restrict saltwater aquaculture related to the perceived inevitability of salinity intrusion—due to pre-existing biophysical factors and global/distant processes—, much of the argument also derived from the political and economic status of the commercial shrimp farming industry locally. The weakness (or reticence) of state institutions to regulate this activity was highlighted across all three respondent groups—community, NGO, and government—alike.

Our study contributes to the growing body of scientific literature that analyzes perceptions of and adaptation to environmental changes in Bangladesh [59–62] and elsewhere [63–70]. However, it can be distinguished from existing research in three ways: (i) most studies analyzing perceptions of environmental change tend to rely on more closed-ended survey questions; (ii) they often explore perceptions of changes but not the *causes* behind those changes; and (iii) they rarely discuss the implications of these perceptions for prioritizing adaptation responses, and usually focus only on affected populations (i.e., they do not additionally examine the views of stakeholders—government and development actors—who have a role to play in shaping adaptive responses).

Nonetheless, there are two lines of research worth highlighting. First, several recent studies in our locations of interest have also deconstructed the salinity phenomenon, as understood by local affected populations. For example, Abedin et al. studied community perceptions of the reasons behind drinking water scarcity in the same two sub-districts of Satkhira and Khulna in a sample of 240 mostly male, literate inhabitants [59]. They found that respondents perceived salinity to be the main threat to potable water, followed by arsenic contamination, then drought. Asking respondents about the perceived causes of salinity, they found that around 70% attributed salinity to saltwater shrimp farming and about half implicated Farakka dam, while over 90% attributed salinity to “salinity intrusion” and a fifth attributed it to sea level rise. These results roughly match ours, and differences may be attributed to variation in sample characteristics and wording of responses. The 90% figure is difficult to interpret because of the ambiguity and broad scope of the term, “salinity intrusion,” which itself may be attributed to various factors.

In a different sub-district of Khulna, Jodder et al. interviewed 100 farmers on perceived causes of salinity [71]. They found “extensive shrimp cultivation” and “faulty management of coastal polders” to be the two top “human induced” causes, recognized by a third of the respondents; however, more respondents (about 70%) recognized natural tidal flooding to be responsible for salinity, while comparable proportions (about a third) recognized sea level rise and “increase of saline intrusion” as factors. The latter factor is hard to interpret, given the broad scope of the term, while the relatively high percentage of respondents (compared to our study) who identified sea level rise as a cause warrants further investigation. (For example, it is unclear from the methods described what format the question followed and whether researchers first verified respondents’ understanding of sea level rise, as a concept.)

Shameem et al. [61, 62] conducted a study in the same sub-district of Bagerhart District as our site, on perceptions of climate variability among 30 shrimp farmers, and approximately half of their sample reported that salinization of soil and water was “fully or mostly caused” by prolonged saltwater shrimp cultivation. Other causes of salinity included coastal flooding during cyclones, upstream dams, and lower seasonal rainfall [61]. While attribution of salinity to saltwater shrimp farming appears more universal in our study, the difference could be due to sample characteristics, as Shameem and colleagues purposively selected respondents, based on local leaders' recommendations, to represent a cross-section of the shrimp farming community [62]. In any case, Shameem et al.'s case study of Bagerhat concluded with the interpretation, aligning with our study, that salinity due to external factors originally motivated saltwater shrimp farming, which has in turn exacerbated salinity to the point of creating more vulnerability and stress.

Our study, which used in-depth qualitative methods among a sample of 116 community-level participants and 47 government and NGO representatives, expands on this line of prior research by demonstrating, more so than previous studies, the extent to which salinity is perceived as a local problem by local stakeholders. This holds true particularly among community respondents and even substantially among stakeholder groups. Exacerbating factors at the most proximate level are the most readily observable and tangible, and therefore awareness about them and perception of their importance tends to be high—a tendency also documented in the environmental psychology literature on environmental perceptions and attitudes. Meanwhile, factors at the regional and global levels become increasingly difficult to observe and appreciate.

Conversely, international organizations that support responses to the challenges of salinity intrusion and salinization of river deltas may tend to focus on regional and global factors. If these organizations insufficiently consider local factors and how problems appear to local stakeholders and communities, there is a risk that policies and programs they establish respond poorly to the local perceptions of problems. The foregoing is a particular concern in Bangladesh, where much of the funding for supporting adaptation and other responses to environmental challenges will be channeled from multilateral sources, such as the Green Climate Fund, associated with the United Nations Framework Convention on Climate Change (UNFCCC) (see Chapter 7).

A second line of research related to our results, conducted in settings outside rural coastal Bangladesh, uses both sociopolitical and ecological lenses to analyze a given environmental challenge, and finds that facilitating adaptation of those affected requires more than strictly providing what is needed for their survival. These case studies have theoretical underpinnings that draw from the field of political ecology—one of its central tenets being that the costs and benefits of environmental changes are not distributed equally, but rather reflect structural factors, such as social and economic inequalities [72]. For example, a study conducted by Haque and colleagues examined climate change adaptation by poor households in Khulna city, and found *"a need to address urban vulnerability and responses to climate change through more politically informed approaches that explicitly examine the role of power relations in shaping these issues*" [73]. Citizen participation of low-income urban residents in urban governance, for example, could form part of this "*more transformative pathway for adaptation*" [73].

Similarly, in a study set in Eastern Saloum in Central East Senegal drawing on local farmers' perceptions and historical data, researchers concluded that agricultural policies, market conditions, and land use (especially ground nut monocropping) were the main drivers of environmental change in the area, more so than climate variability (e.g., erratic rainfall) [74]. They labeled the environmental changes observed in the region, such as reduced soil fertility, soil erosion, and water scarcity, as "land degradation," and argued that degradation was "*a complex issue linked to much more than climate change and variability.*" As such, national policies on water, agriculture, livestock, and decentralization should not only be viewed as responses to environmental change, but also analyzed as drivers and adjusted accordingly.

With these perspectives in mind, there appear to be two paths going forward for policymakers, funders, and development organizations working in salinity-affected regions. Either they can focus on where there is common ground among stakeholders—i.e., measures that seek to alleviate the impacts of salinity—or on more transformative actions that alter the political economy of the area—i.e., governance-building measures that lead to effective regulation of local actions perceived to increase salinity. At present, it appears that most activity is situated within the former domain [13, 16, 75]. (See also Chapters 5 and 6.) The latter, however, would align with communities' emphasis on proximate exacerbating factors, and facilitate empirical studies testing the extent to which salinity could in fact be reduced through alternative natural resource management.

Such alternatives, as some academics and civil society actors have already urged, could take the form of bans and moratoria on saltwater shrimp farming [19], which our Khulna site and other case studies suggest might lead to lower soil and water salinity [44]. Other proposals consist of regulations that impose strict temporal and/or geographic limits on the land used for commercial shrimp farming [18]—an amount that has increased by 1125% between 1980 and 2010 in Bangladesh [61]. In this regard, Sohel and Ullah have advocated for "ecohydrology-based shrimp farming" (ESF), which involves the creation of buffer areas around saltwater shrimp *ghers*, to protect surrounding agricultural land from salinity. In the buffer area, salt-accumulating halophytes—plant species that naturally grow in saline areas—would be planted and harvested regularly to progressively lower the salt content of the soil [58]. As the researchers recognized, however, most semi-intensive and intensive shrimp farms are operated by national and multinational investors. These actors would need to be given clear incentives for dedicating part of their operations to creating ESF systems (or penalties for failing to do so), and it is in this regard that state and non-state stakeholders could assume some responsibility.

A third path, open to those working beyond Bangladesh, would entail addressing the global/distant processes perceived to contribute to salinity, such as anthropogenic climate change and diversion of the Ganges river in India. In this regard, the issues of climate change mitigation and negotiation of riparian rights are recognized as priorities but fall beyond our study's scope.

Limitations

At the community level, our study design incorporated ethnographic methods employed over two rounds of data collection. This level of engagement enhanced rapport with participants and confidence in the credibility of our results, which was important given that some of the topics of discussion were politically sensitive. However, it also limited the number of sites that we could select. For this reason, other localities in the region warrant study, especially before the design and implementation of programs that should, in any case, account for site-specific social and environmental characteristics.

Moreover, our intention was to cover a range of government institutions in order to understand their respective roles and positions, and thus we were only able to engage a limited number of representatives per ministry. We would recommend that future research target specifically the Ministry of Environment, the Ministry of Water, and the

Ministry of Fisheries, including representatives at different levels of government, in order to delve deeper into the feasibility and acceptability of the salinity responses discussed above, especially more robust regulation of saltwater shrimp farming.

In addition, although we were able to access a range of non-governmental stakeholders, the majority would be considered implementing organizations, rather than donor organizations. Given that the former often respond to the demands of the latter, research with stakeholders representing the funding community would greatly improve our understanding of the viability of the options proposed in this study.

Conclusion

Local understandings of the reasons for increasing salinity can affect communities' uptake of methods to cope with or adapt to it, as well as the potential for them to mobilize around this challenge through self-devised or NGO/government-facilitated solutions. Our results demonstrate that salinity is not understood as a purely environmental or climatic problem; rarely did communities and stakeholders perceive it as a biophysical phenomenon beyond human control. Given this local understanding, we strongly recommend expanding the range of possible salinity responses under consideration to include initiatives that might effectively alter the scope of the problem, beyond those that only remedy its symptoms. On-going difficulties in finding sustainable remedies (e.g., maintenance of community rainwater-harvesting infrastructure [see Chapter 5] and lag in research and implementation of salinity-tolerant varietals [see Chapter 6]) provide further impetus for this recommendation.

Chapter 5. Adaptation to Salinity Impacts on Water for Drinking, Cooking, and Hygiene: A Qualitative and Environmental Study in Southwest Coastal Bangladesh

Introduction

In the latest nationwide survey data from Bangladesh, nearly universal access to "improved sources of drinking water," such as a piped water supply, borehole, tubewell, rainwater, or bottled water, was reported across both urban and rural areas [48]. Notwithstanding this indicator, water quality and treatment remain as challenges, and recent studies have documented persisting public health concerns associated with using surface and groundwater sources contaminated by pathogens or heavy metals [52, 76–81]. Moreover, the access indicator does not capture key aspects of domestic water usage, including non-drinking uses of water, water collection time, reliability of the source, and cost, among others characteristics, which are fundamentally linked to overall water security [82].

Salinity intrusion—a process by which saltwater intrudes inland into freshwater sources—poses a threat to water security in the Southwest Coastal Region, and salinity may increase due to various environmental and manmade drivers (see Chapter 4) [3, 6, 8, 13–19, 57, 58]. Studies throughout the region have reported surface and groundwater sources as being significantly more saline than what would be considered safe or acceptable for consumption [7, 30, 33, 43, 83, 84]. Recognizing the particular salinity situation faced by the coastal region, Bangladesh's Water Resources Planning

Organization established a relatively high groundwater salinity standard of 2,000 μS/cm for that region [32]. By comparison, salinity of potable water in the United States ranges from approximately 30 to 1,500 μS/cm [41], and the US Environmental Protection Agency establishes a drinking water guideline of 500 mg/L for total dissolved solids (roughly 1,000 μS/cm, if all TDS took the form of sodium chloride) [40].

Moreover, while salinity varies greatly based on season, year, and location, there appears to be an overall upward trend in salinity in the Southwest Coastal Region. A few studies have noted increases in average yearly salinity in specific water sources, such as the Kazibacha river in Khulna, the Rampal river in Bagerhat, and the Kakshiali river in Satkhira [25], as well as increases in the highest recorded salinity levels in Kaliganj sub-district in Satkhira [25] and the Rupsa River in Khulna [8, 43]. The saline water front is projected to move further inland due to sea level rise, among other factors, and salinity is expected to intensify [4, 10, 43, 85].

This context motivated the present study, in which we sought to understand the impacts of salinity on the availability of water for a range of purposes, including drinking, cooking, and hygiene. In particular, we sought to combine ethnographic methods and environmental testing to obtain a more nuanced view of the challenges affecting rural communities in the region. We also sought information about how communities were adapting their water management practices to respond to salinity, and how external development actors were assisting or not assisting with adaptation.

Methods

Our sites consisted of three villages/communities, purposively selected to represent the three southwest coastal districts of Bangladesh and to have moderate or high severity of salinity, as measured during site selection in February 2015. The sites were located in the Dacope sub-district of Khulna District, the Mongla sub-district of Bagerhat District, and the Shyamnagar sub-district of Satkhira District.

Data Collection

There were two phases of data collection: community-level data collection at the three sites, and NGO-level data collection in the Southwest Coastal Region and Dhaka city. Prior written consent was obtained from all subject participants. The study was approved by the Institutional Review Board of Johns Hopkins Bloomberg School of Public Health, and the Research Review Committee and the Ethics Review Committee of the International Centre for Diarrhoeal Disease Research, Bangladesh.

Phase 1 – Community-level data collection

We had two rounds of community-level data collection. The first round took place in May and June 2015, coinciding with hot season and the beginning of rainy season. Across the three sites, we recruited 25 households with whom we conducted a structured visit. The visit consisted of: two separate in-depth interviews with a male and female member of the household[6], a household questionnaire, and salinity testing of the

[6] If two members of the opposite gender in the same family (*khana*) were not available, then someone of the opposite gender within the same compound (*bari*) was interviewed. The household questionnaires were applied at the family (*khana*) level with either one of those individuals. *Khana* refers to a group sharing the

household's sources of water. Household interviews were semi-structured with an interview guide that covered the impacts of salinity on water for drinking, cooking, and hygiene, and strategies for adapting, among other topics. Questionnaires covered demographic characteristics and water resources (ponds, tubewells, etc.).

During the first round of data collection, across the three sites we also conducted six focus group discussions (three with males and three with females), interviewed 10 community key informants (e.g., village leaders, schoolteachers, NGO fieldworkers), and tested the salinity of community-level sources of water (e.g., community tubewells and ponds). Among other activities, focus group participants discussed the impacts of salinity on water, made seasonal calendars to depict trends in salinity and water management, and ranked and discussed strategies for adapting. Key informant interviews focused on site history and salinity trends and impacts.

The second round of community-level data collection took place in October 2015, in mid-to-late rainy season. We revisited all households recruited during the first round, and conducted a follow-up interview with one member of each household. The interview elicited updated information about how the household fared during rainy season and any recent developments to adapt to salinity. We also re-tested the salinity of the water sources tested during round 1.

Phase 2 – Stakeholder-level data collection

The second phase of data collection involved in-depth interviews with 24 NGO representatives in January and February 2016. The interviews entailed semi-structured

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same cooking hearth, whereas *bari* are made up of one or more (often familial-related) *khana*, whose dwellings are clustered in the same area.

questions about perceived impacts of salinity on access to water for drinking, cooking, hygiene, and other purposes, and strategies for adapting, among other topics.

Data Analysis

Results from the household questionnaires were tabulated. Interviews and focus group discussions were audio recorded and transcribed. Initial interviews and follow-up interviews with household members lasted an average of 121 minutes and 62 minutes, respectively. Focus group discussions lasted an average of 162 minutes, while community key informant interviews lasted 132 minutes on average. In the second phase of research, interviews with NGO representatives lasted on average 94 minutes. Transcripts in Bangla were translated into English.

Transcript by transcript analysis entailed three components: (1) coding quotes that were particularly notable using MaxQDA software, based on codebooks that followed the major topics of each data collection activity (see appendices for the specific codebooks used); (2) extracting information into a summary document based on a standardized template corresponding to the topics of the data collection activity; and (3) updating a separate memo of observations on cross-cutting themes, new analysis ideas, and noteworthy information. Findings were synthesized by topic from the summary documents, and supplemented by notable quotes and ideas from the memo on coding observations.

Salinity Testing of Water Samples

We measured electroconductivity (EC), as an indicator of salinity, in water samples drawn from tubewells, surface water sources such as ponds and canals, and taps that came from a pond filter system or piped water supply. We photographed and took the GPS coordinates of all sources of water sampled. We also recorded information about weather conditions and the last time it had rained. During site selection, we measured electroconductivity using the Extech EC500 pH/conductivity meter, calibrated to standards of 84 microSiemens/cm (μS/cm), 1,413 μS/cm, and 12,880 μS/cm. In the first round of data collection, the same meter was re-calibrated and used to measure water samples. However, due to a technical problem with the meter thereafter, for the second round of data collection, we used Hanna Instruments' HI 86304N electroconductivity meter, calibrated to 5,000 μS/cm.

All water testing happened on site. For tubewells, EC of water pumped from the tubewell at specific intervals was measured. We tested privately owned tubewells and ponds, as well as those considered as belonging to the community. Information was recorded about the reported depth of the tubewell, the uses of the tubewell, the salinity of the tubewell's water as perceived by its users, and the tubewell's history. For ponds and other surface water sources, the EC of water taken from two different depths was measured. Information about the pond's uses and user perception of the pond's salinity was noted. For water taps, the tap was allowed to run for a minute and then EC was measured. The history of the tap system and the perceived quality of water was recorded. A more detailed salinity testing protocol is provided in the appendix.

Results

Salinity Testing

Salinity testing of surface water (ponds, streams, canals) and groundwater (tubewell) samples in the three sites revealed a wide range of salinity levels, even within a site, as well as seasonal variation in salinity.

We tested the salinity of fourteen, fifteen, and eight surface water sources in Bagerhat, Satkhira, and Khulna, respectively. Salinity values measured in June, corresponding to hot season and the beginning of rainy season, ranged from 3,613 to over 19,999 µS/cm Bagerhat, 1,347 to over 19,999 µS/cm in Satkhira, and 1,049 to over 19,999 µS/cm in Khulna.[7] Salinity values measured in October 2015 were much lower: from 825 to 3,998 µS/cm in Bagerhat, 715 to 7,595 µS/cm in Satkhira, and 650 to 4,890 µS/cm in Khulna. (See Figure 4. Note that the change is depicted as linear for simplicity; we do not have sufficient information to model the form of the decrease.)

By way of example, the map of surface water samples from Bagerhat shows the hyper-localized nature of salinity, reflecting disparate values for locations that are relatively proximate. (See Figure 5. Additional maps showing the salinity of surface water samples during both seasons at the three sites are provided in the appendix.)

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[7] The upper limit of the meter used was 19,999 µS/cm.

Figure 4. Salinity of surface water sampled in Bagerhat, Satkhira, and Khulna

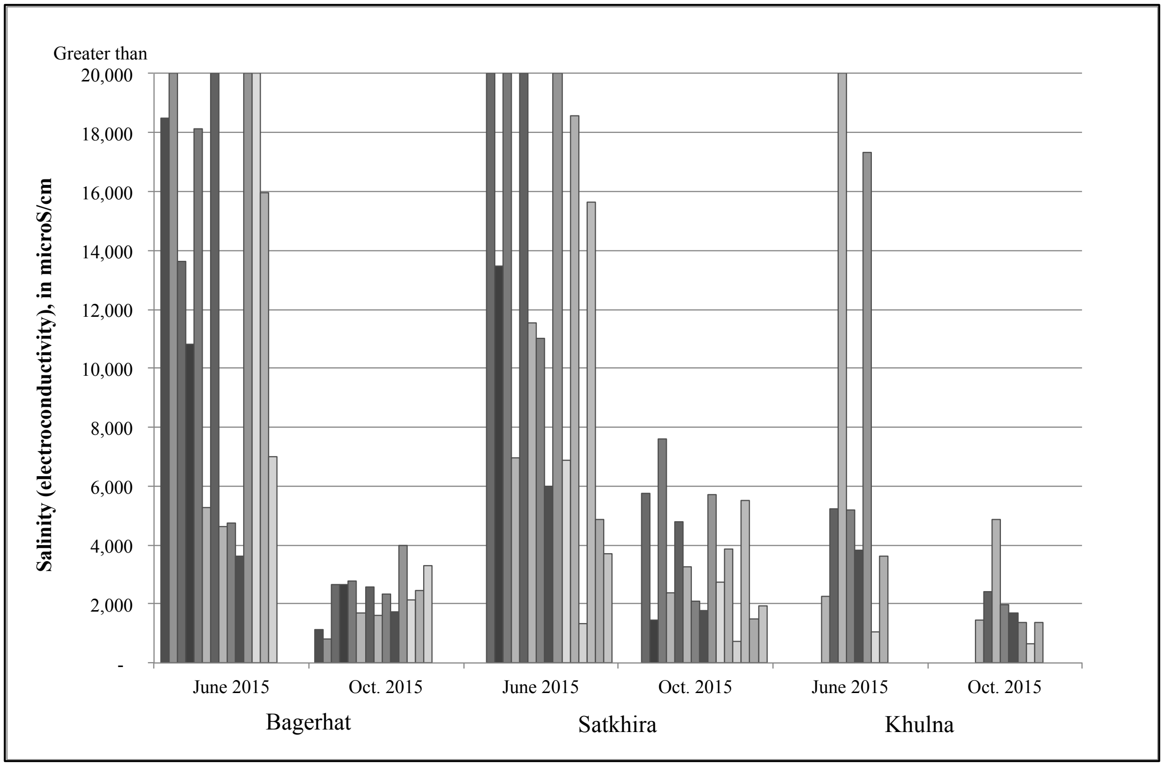
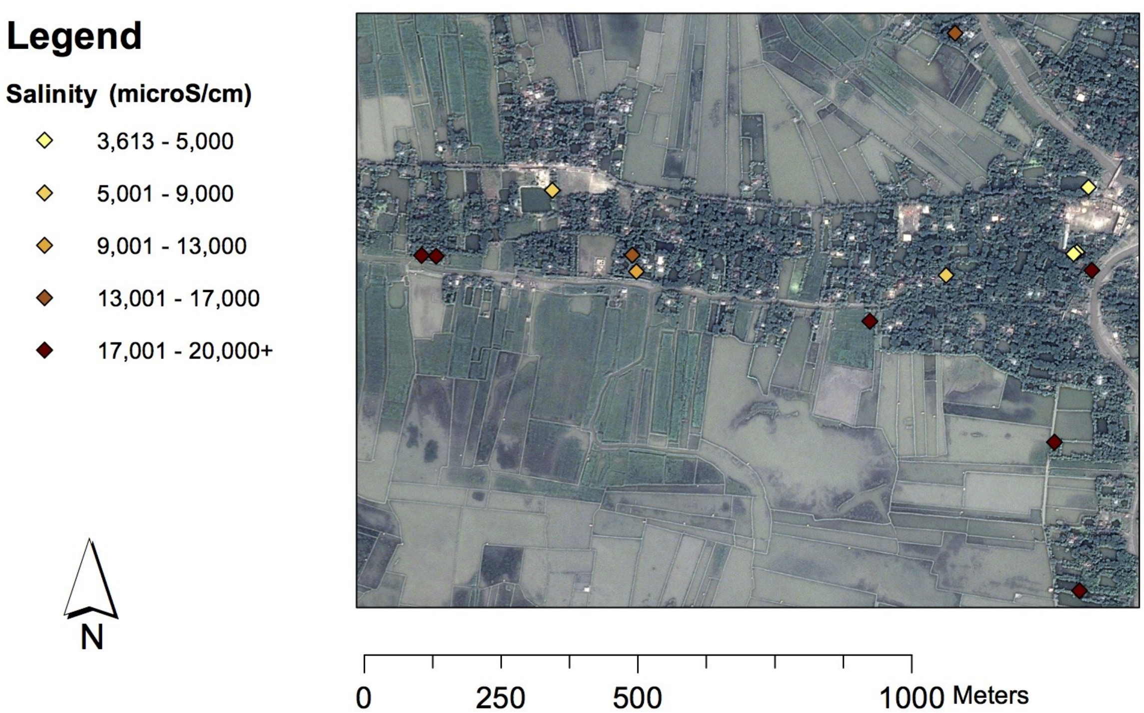
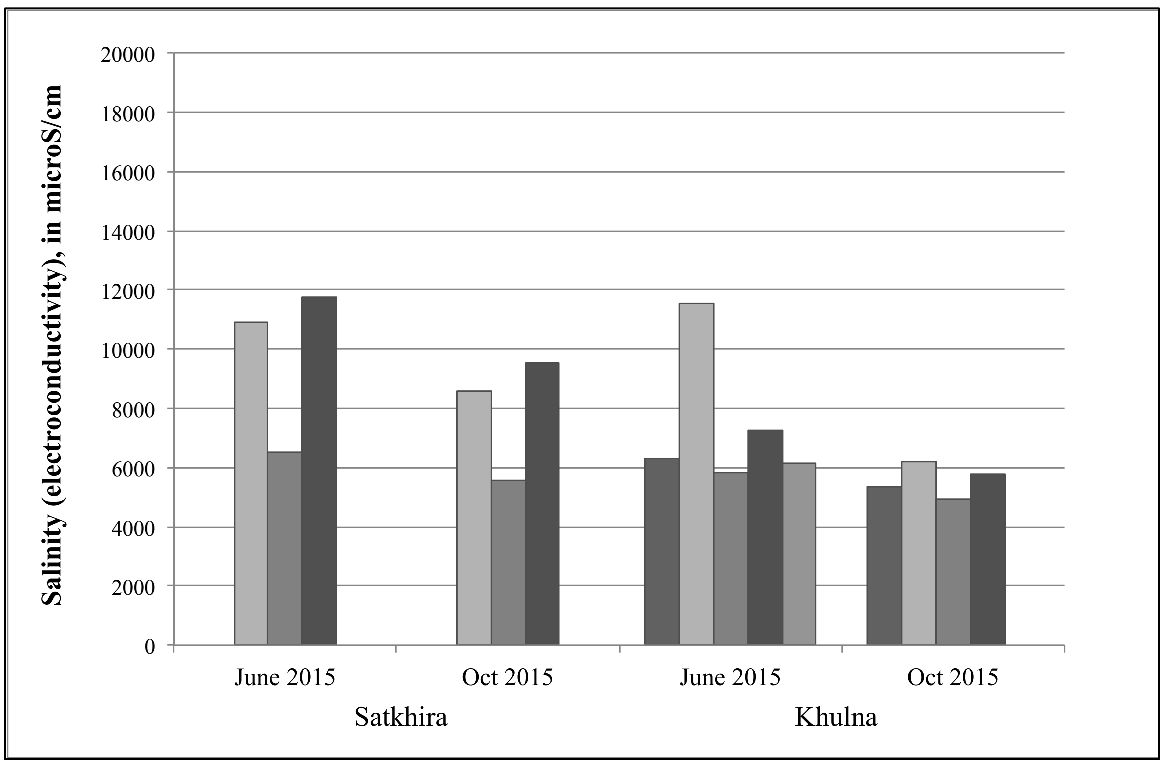


Figure 5. Google Earth image of Bagerhat site - surface water in June 2015



For groundwater, we tested the salinity of three tubewells in Satkhira and five tubewells in Khulna. The tubewells in Satkhira were reported to be approximately 200 feet deep, while those in Khulna were reportedly around 100 feet deep or less. Salinity values of tubewells in June ranged from 6,520 to 11,747 µS/cm in Satkhira, and 5,822 to 11,527 µS/cm in Khulna. Values were slightly lower in October, with ranges of 5,560 to 9,527 µS/cm and 4,905 to 6,197 µS/cm, in Satkhira and Khulna, respectively. (See Figure 6.)

Figure 6. Salinity of groundwater sampled in Satkhira and Khulna



Community Perspectives on the Impacts of Salinity on Access to Water

Salinity in both groundwater and surface water sources contributed to water scarcity across our three sites. Many participants reported that existing tubewells yielded water that was too salty to consume, and typically could only be used for hygiene (e.g., cleaning their hands and faces before prayer), domestic chores (e.g., washing utensils and clothes), and occasionally feeding to animals or irrigating certain crops. Due to groundwater salinity, tubewells were scarce. In fact, there were no functional tubewells found or reported in the Bagerhat site. Surface water sources were also unable to alleviate freshwater scarcity. Participants mentioned that in the past, ponds in their community contained freshwater, but infiltration of saltwater from neighboring saltwater shrimp ponds (known as *ghers*, see also Chapter 4) over the past couple of decades had rendered most ponds too saline to use for drinking and even cooking.

Consumption of saline water was reported to cause various gastrointestinal symptoms, including diarrhea, vomiting, upset stomach, loss of appetite, and irritation/bleeding in the throat. Participants remained thirsty after drinking saline water or did not drink enough water. Several also reported that cooking with excessively saline water rendered food inedible.

Use of saltwater for bathing and other personal hygiene was frequently associated with itchy, irritated skin and eyes, as well as darkening of the complexion. One woman said that the burning sensation caused by bathing in saltwater would keep a person awake at night, and another described how washing one's face with saltwater would irritate the eyes as though they had been rubbed with pepper. Various participants additionally noted that it was not possible to lather soap properly with saltwater, which made it difficult to clean themselves and wash their clothes. Several linked the inability to maintain proper hygiene to developing skin rashes and scabies. There were also reports of refraining from using the latrine or washroom due to lack of freshwater for cleaning afterwards.

However, a minority of respondents reported that they had adapted to bathing in saltwater and preferred it to bathing in rainwater, which would cause them to cough, sneeze, or develop a fever.

In interviews and focus groups, community members confirmed the seasonal nature of salinity. Hot season, roughly March to June, was known as the most saline time of year. Salinity was perceived to decrease starting with rainy season in June, hitting a low at the end of rainy season in October. It then rose with the coming of winter, through winter (roughly October/November to February) and into hot season.

Household questionnaires assessed sources of water throughout the year. (See Table 10.) In general, the shift from rainy season to other times of year obligated households to resort to more distant sources of water for all purposes. In rainy season, nearly all households collected rainwater in smaller earthen pots and plastic containers to use for consumption, and bathed in ponds on their homesteads or nearby. During the months with less rain (winter and hot season), 13 out of 25 households relied on a pond outside their home but within the same village for drinking water. Fifteen of 25 households resorted to a source outside the village (usually another pond, but sometimes a tubewell), and 9 of these households reported that it was their *only* source of drinking water during those seasons. Ponds within the homestead or same village were commonly used for cooking water and bathing in winter and hot season, while usage of tubewells and rainwater-harvesting (RWH) tanks was relatively infrequent, as such infrastructure was often unavailable.

Table 10. Household Sources of Water[8]

	Used in hot season and/or winter			Used in rainy season		
	Drinking	Cooking	Bathing	Drinking	Cooking	Bathing
Household pond	8%	48%	64%	4%	20%	84%
Pond in village[9]	52%	52%	32%	8%	12%	8%
RWH tank (own or in village)[10]	20%	8%	4%	20%	8%	4%
Tubewell (own or in village)	0%	4%	20%	0%	4%	4%
Any source outside village	60%	28%	12%	16%	0%	0%

Although our study did not entail systematically measuring the salinity of every source of water used for drinking, cooking, and bathing, we triangulated information from the household questionnaires and salinity testing to document salinity of some of these sources. During our first visit in hot season, we found multiple sources of water being used for drinking that ranged from 3,000 to 7,000 µS/cm, and for cooking that ranged from 4,000 to 11,000 µS/cm. Many sources of water used for bathing in hot season measured over 10,000 µS/cm, with a few approaching or exceeding the limit of our instrument (19,999 µS/cm).

Options and Challenges in Adapting to Salinity's Impact on Water

Community members and NGO representatives discussed several strategies for acquiring and/or storing freshwater in the context of salinity: rainwater-harvesting

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[8] Note that many households reported using more than one source of water for a given purpose, thus percentages may add up to more than 100%.
[9] We do not distinguish between "improved" ponds, which have a filter installed, or unimproved ponds. This is because firstly, we heard reports that many "improved" systems were dysfunctional and verifying whether the systems were operational was not possible; secondly, participants do not always use the filter and may take water from the pond.
[10] We refer specifically to a large plastic or concrete tank of 500-liter capacity or more.

(RWH), ponds, paying for water delivery, tubewells, managed aquifer recharge (MAR) systems, and desalination technologies.

Rainwater-harvesting

Community members generally viewed rainwater as the best option for drinking water, considering it the purest and best-tasting source of freshwater available. Every household we observed collected rainwater using small, plastic containers, as well as slightly larger earthen jugs, known as *maith*. However, *maith* were only large enough to supply one family with a couple days' worth of drinking water, failed to isolate the water from insect, debris, and other contaminants, and could not prevent evaporation. Given these shortcomings, households universally expressed a preference for large (1,000-liter or more) RWH tanks, suitable for storing water collected off of tin roofs of dwellings.

In our study area, both plastic and concrete RWH tanks were present. Concrete tanks tended to be larger, supplying water for clusters of households. However, many villagers noted that the concrete was low quality and cracked after exposure to sunlight and salt. Some also pointed out that more evaporation occurred in concrete versus plastic tanks. Plastic tanks were generally viewed favorably, although some noted that the water became very heated in hot season. Plastic tanks could also crack, and insects could enter.

The most frequently cited barrier with respect to RWH tanks was their cost, which ranged across our sites around \$100 to \$200 USD. While relatively wealthy rural households could own one or more of these tanks, fewer middle-class and poorer households had access to them. As a woman from Bagerhat remarked, "*We work as daily* *laborers… Are people like us capable of buying a 2,000-liter water tank? No, we don't have that capacity. We are barely eating three times a day."*

Across our sites, various NGOs provided assistance in procuring RWH tanks. However, access was still described as extremely limited. The predominant perspective among NGOs was that giving something for free would mean that the beneficiary would undervalue it and not properly care for it. Most community members expressed willingness to share the cost of a tank for their family. However, according to a community key informant at our Khulna site who had worked on many NGO projects, it was more common for an NGO to give a loan for the cost of the tank rather than to share the cost. When NGO assistance took the form of a loan, it was usually only offered to members of the NGO's *samity* (a cooperative group where members made regular savings deposits and applied for loans). Moreover, not even all *samity* members could afford a loan. For example, one household we interviewed in Khulna participated in Ad-din's *samity,* and had the option of obtaining a plastic RWH tank for 6,000 taka (approximately $76 USD). However, the 3,000 taka down payment required was still too much for the family to pay at one time, even if the balance were provided as an interest-free loan.

When NGOs provided RWH tanks on a cost-sharing basis (which still kept it inaccessible to the very poor) or completely free of cost to the beneficiary (which was extremely rare), the widespread perception at the community level was that tanks were not being distributed fairly according to need. Numerous community members we interviewed pointed to nepotism on the part of local politicians, who played a role in selecting the beneficiaries of an NGO tank distribution intervention. They echoed the sentiment, as expressed by one villager:

> *Aid is provided to their [local politicians'] relatives mostly. If you go speak to the NGOs, you will see that we are not lying. Everything I am saying is true. You are here in person now, and you can tell the NGOs directly about the houses that need water tanks. Then they may understand… But if the tanks are given through the [union] chairman and [ward] member…the house that already has one will get three, and the house without any will not get a single one.*

Tank capacity was another challenge associated with RWH tanks. Given the seasonal nature of salinity, an ideal tank would be large enough so that water—if prioritized only for drinking—would last from the end of one rainy season until the beginning of the next. The exact capacity required would depend largely on family size. For example, one woman from Bagerhat estimated that a 1,000-liter tank would last her family the whole year, as her family was small. Her relative reported that a 1,000-liter tank lasted his five-member household three months, corresponding to the end of winter, after which his family had to drink from a community pond during all of hot season. Yet several villagers suggested that NGOs and others in charge of tank distribution programs did not consider household size as a factor. One community member, who had worked with an NGO on such a program, reinforced this view and indicated that tank size mostly depended on the tanks in stock.

Joint ownership/sharing was another contentious issue related to RWH tanks. NGO representatives and those with previous NGO experience generally thought it unfeasible to supply one RWH tank per family. In some cases, NGOs constructed a slightly larger concrete tank at the site of one household, to be shared between that household and its neighbors. However, when we interviewed community members about this kind of sharing arrangement or probed them on the possibility of pooling resources with their relatives to buy a collective RWH tank, many expressed doubt that sharing would be successful in the long-term. The root of their concern was that there would be insufficient water to last the entire year. Larger households would use more water, which was perceived as unfair by some smaller households. Various participants were worried that other users would take water for purposes besides drinking; they preferred single-family ownership, which could better ensure that water was not misused.

Others pointed to cases where they had seen or heard that a household, which had agreed to share an NGO-provided tank with its neighbors, ceased to share after the NGO left the area. A community key informant from Bagerhat, who previously worked on an NGO's tank distribution project, recounted that the NGO would verify that the beneficiary had a good relationship with his/her neighbors. However, the NGO would only monitor the tank for one to three years, and the focus would be on the hardware, not on whether the beneficiary was sharing with neighbors. A similar problem was reported by a community key informant in Satkhira who had also worked on many NGO projects: contrary to prior agreement, owners would stop sharing after the NGO stopped monitoring. One villager suggested that a guardian could be appointed to each multi-household concrete tank to ensure that each household only took one or two pitchers of water per day, but most respondents said ultimately the solution lay in individual household ownership.

Household and community ponds

In the absence of fresh groundwater options and enough stored rainwater to last through winter and hot season, many households resorted to using pondwater for drinking, cooking, and other purposes. All ponds encountered in our study area were affected by salinity to some extent, but some much less than others. (See, for example, Figure 1.) Aside from salinity, participants noted several other major problems with ponds: travel time, bad odors, dirtiness (from algae, animal waste, dead vegetation, and other contaminants), diarrhea from consuming pondwater, and low water levels in the ponds in hot season.

In order to access a pond that was less affected by salinity, that had a filter installed, or that was deep enough to still have water through hot season, many community members walked farther to retrieve pondwater or, in some cases, paid someone with a bicycle-driven cart to deliver that pondwater. Fetching water caused muscle and joint pain, increased risk, and also took time away from income-generating activities. For example, one woman from Satkhira recounted how she had to go to a neighboring village to fetch water from a fresher filtered pond for drinking, cooking, and some hygiene purposes. It took her approximately half an hour to bring one large urn of water, and her family required four or five of these per day. As she explained, *"There is no other work for women here: cooking and bringing water. That is it. There is no other work in saline areas… It's so tough to bring water. My waist hurts."* Multiple families mentioned that their female members, who would normally fetch water, were in poor health, requiring the males to forego work opportunities and assume that responsibility. Several women reported that fetching water from a distant, less saline pond was so burdensome that they would make the water last longer by mixing it with saline water from a closer source.

Pondwater quality was another major issue highlighted by many participants. Some households filtered pondwater using a strainer or alum (potassium aluminum sulfate, known locally as *fitkari*), mostly with the intent to filter out dirt. Using chlorine and boiling water did not appear to be common practices. The rationale given for boiling water was to avoid drinking cold water, which was perceived to cause illness. Some households reported that pondwater was especially contaminated in the hot season, and perceived greater incidence of diarrhea, dysentery, and other waterborne diseases then. Given salinity and contamination, pondwater was often used only for washing and cleaning, not consumption.

Across our sites, we observed one intervention—a pond sand filter (PSF) system—meant to improve pond infrastructure at the community level. The typical intervention consisted of an NGO (or in some cases the government) finding or excavating a large rain-fed pond that was relatively less saline, reinforcing or building an earthen embankment around the pond to protect it, and installing a system that would allow water to be pumped from the pond through a sand filter and into a storage tank, which had faucet taps for dispensing water. Among NGOs, community PSFs were a relatively popular adaptation intervention, given that they could service, in theory, a larger section of a community more economically than providing each household with an individual RWH tank. There were several challenges associated with PSF systems, however.

In the first place, finding an appropriate pond or site for a pond was difficult. The hydrology of the area had to be such that the pond would be insulated from saltwater, not only at present but also in the medium- and long-term. Additionally, publicly owned land was not always available or suitable, and privately owned lands were often smaller parcels. Moreover, the NGO needed to persuade a private landowner to give up his land or pond for communal use. One community key informant from Satkhira was in fact the owner of a large pond, who had agreed to let an NGO install a filter on the pond and open it to community use. In doing so, he assumed various responsibilities: raising a third of the construction cost from neighboring households, collecting small monthly contributions from those households, maintaining the pond (trimming vegetation, preventing his animals from using it, not using it for washing clothes or bathing), ensuring the filter was in order, and paying for regular filter cleaning. The owner served as the head of a five-member committee that oversaw the filter, and received no compensation. Other community members indicated that this particular individual's altruism was an exception.

Secondly, once operational, PSF systems drew users from surrounding villages, leading to lines or crowds. To avoid waiting for a free tap, some households took unfiltered water from the pond. As one woman told us: "*People come from everywhere, and they have to wait in line…. While I wait for my turn, dusk may come, so to save time and be able to come home quickly, I'll take water directly from the pond...and use* fitkari."

Keeping the PSF systems operational was another significant challenge, as noted by community members and NGO representatives with experience implementing them.

Both groups reported that in many cases, nobody took responsibility for regular cleaning and repairing the filter, and many PSFs in the region were in a state of disrepair. As a schoolteacher from Satkhira noted, "*Many filters are behind in being cleaned. That water is not suitable for drinking…. There are infectious agents, and sometimes people get dysentery and diarrhea… The water smells, and you can't even put it near your mouth.*"

From interviews and focus groups, the maintenance issue appeared related to collective action and responsibility, rather than lack of money. (The problem of users not contributing a small fee for the filter's upkeep was mentioned infrequently.) Some NGOs reported that they had left the community with the tools needed to perform simple filter maintenance and repair, but these tasks nonetheless went uncompleted. One NGO representative recounted, and others similarly echoed, attempts to engage communities:

> *It's not expensive to clean the filter media…. You just need to do it. But in our culture,* who *will do it is the big challenge. NGOs like us, we have been trying for a number of years to make communities understand – we are trying, but it is still challenging. Because the communities' mindset is like this: 'someone came and built this here, so it's* their *responsibility for cleaning it.'*

Storms, flooding, and other natural hazards could also damage PSFs, further compromising their sustainability. Given the challenges with travel and wait time, maintenance, and repair, community members across all three sites viewed and ranked PSF systems unfavorably as an adaptation strategy. Even NGOs that had previously installed many of these systems doubted their long-term viability. As one NGO representative told us, "*If there are ten PSFs developed by the government and ten developed by NGOs, I'm telling you that nine of those government ones are not working, and probably five of the NGO ones are working."*

Paying for water delivery

Paying for water delivery was another option used to obtain drinking and cooking water. The informal method consisted of paying a person who had access to a bicycle-drawn cart to retrieve water from a community water source, typically a community PSF system, considered better than any of the closer options. An alternative method, which participants mentioned having seen in neighboring villages, consisted of piped water delivered to one's household directly or to a distribution point within the village from some outside water source. In some cases, water would be supplied only at certain times in the day (perhaps only once per day).

Most community participants who referenced such a system portrayed it positively, but several NGO informants provided examples of families in other villages who refused to pay even a few taka for piped water. The families reportedly did not understand the advantages of an improved water source or felt that water was something that should be provided free of charge.

Tubewells

Tubewells in our study area were shallow tubewells, with reported depths of 200 feet or less. In general, water from these tubewells was considered too saline to consume. Most community participants perceived that tubewell water had little seasonal variation, and our salinity testing revealed that decreases in salinity between hot season and rainy season were relatively minor, compared to reductions observed in surface water sources (see Figures 1 and 3). The main advantage was that the water was perceived to be unlimited, and by the end of hot season other sources of water—such as RWH tanks and ponds—were depleted.

A few households at our sites reported walking to retrieve water from a more distant tubewell that was less saline. These tubewells were typically privately owned, but the owners allowed others to use them and in some cases collected a small fee to contribute to maintenance. The tubewells were reported to attract so many people that there would almost always be a wait. However, tubewell owners were more willing to share their tubewells because the water was perceived to be unlimited.

Nevertheless, most participants doubted that constructing more tubewells would increase availability of water fresh enough to consume. They recounted that households, NGOs, and government actors had attempted to install tubewells in the past, but largely failed to find freshwater. One participant described how an NGO had set up 100 to 150 tubewells in one union of Satkhira during the prior month, but all produced saltwater and could only be used for bathing. Based on prior experiences and speculation, many believed freshwater would not be found until reaching a depth of 1,200 feet, and the cost for this was considered prohibitive. Others thought that groundwater would be saline regardless of depth due to the coastal geography. Community members suggested that were it possible to identify a freshwater aquifer, a deep tubewell would be the ideal adaptation—superior even to large RWH tanks because of its 'unlimited' nature.

Managed aquifer recharge (MAR) and desalination technologies

According to several NGO representatives, two other options drawing on more advanced technology had potential to alleviate water scarcity in the country's salinity-affected areas. The first, known as a managed aquifer recharge (MAR) system, consisted of collecting rainwater during rainy season and using it to artificially recharge a shallow aquifer. The water, stored underground, would create a freshwater buffer from the aquifer's typically brackish groundwater. The freshwater could then be extracted during other times of the year. Universities and other organizations were piloting MAR systems in the Southwest Coastal Region. However, several NGO informants, including a couple who were working on the MAR pilot projects, noted maintenance challenges, similar to the difficulties in upkeep of community PSFs. As MAR systems were even more sophisticated than PSFs, this was a particular concern.

Reverse osmosis technology, a form of desalination, was also mentioned by a few organizations, but was perceived as impractical for widespread implementation in Bangladesh. The technology consisted of treating and pressurizing saltwater, then passing it through a water-permeable membrane to separate out the salts. However, according to several NGO representatives, its resource-intensive nature—especially the need for a large, stable energy supply—was an obstacle to implementing it in the coastal region. A WaterAid representative described his organization's efforts to use solar power to fuel a reverse osmosis plant, but said that the process was still too costly. The Christian Commission for Development in Bangladesh was also operating a solar-driven plant in a village with unstable electricity, and its staff noted that the solar power was insufficient. A Shushilan representative told us that his organization had installed reverse osmosis plants in two unions, and its international partners were working to reduce the cost of the technology. However, he viewed the technology as still unfeasible for rural Bangladesh, stating: "*This process is not suitable for community people.*" One stakeholder suggested that the private sector could play a part in rolling out this technology, but expressed skepticism that businesses would be regulated and operate with "proper transparency."

Discussion

Examining the impact of salinity on rural household water in Bagerhat, Satkhira, and Khulna, our combination of participant accounts with environmental and structured questionnaire data suggests a situation of high vulnerability, not only in terms of drinking saline water (which has been studied to some extent in the public health literature [30, 33]), but also with respect to cooking with saline water and bathing in water so salty that its salinity exceeded the level that could be measured by our instrument. Even households that manage to procure relatively fresh water for drinking appear vulnerable to the impacts of using saline water for hygiene purposes, which participants described in detail. These include severe skin and eye irritation, poor personal hygiene, and refraining from relieving oneself.

Our research complements prior studies that use larger samples and helps to contextualize some of their findings. For example, Benneyworth and colleagues surveyed 200 households in the Dacope sub-district of Khulna, and observed that an overwhelming majority of respondents did not perceive their water as having a bad or salty taste [83]. However, respondents did associate pondwater with poor water quality and salinity, and our findings suggest that these characteristics would affect their hygiene practices and outcomes. Moreover, while 81% of the respondents manifested that a water collection trip took under twenty minutes round-trip (meeting the Millennium Development Goal standard), the researchers acknowledged that the indicator did not consider seasonality or number of trips per day. Our study suggests a much greater burden during hot season, and at least four or five trips using the typical sized-urn observed in the study areas, in order to supply a four-member household.

Recently, Rahman et al. examined drinking water scarcity among 200 households across four villages of Satkhira District, and documented diarrhea as the most common health problem, with recent episodes of diarrhea reported by 93% and 85% of respondents from “extreme” and “high” scarcity areas, respectively [84]. However, Mallick and Roldan Rojas surveyed 274 households in two villages of Bagerhat and observed that although there was a widely recognized drinking water crisis, most respondents emphasized afflictions unrelated to water-borne illnesses, such as arsenicosis, liver disease, respiratory ailments, and skin disease [86]. Moreover, many participants were hesitant to discuss such health problems with relatives or doctors.

Our study results emphasize the point implied empirically by this body of work and argued conceptually by Goff and Crow [82], among others, that indicators narrowly focused on access to improved sources of drinking water will neglect other dimensions of the water scarcity burden. Inclusion of other metrics common in public health, such as diarrheal disease incidence, may still be insufficient. Further, the spatial and seasonal variation in water salinity observed in our study suggests that future impact assessments be designed with a range of scales and time periods in mind.

Our study is also one of the first to examine adaptation of household water access holistically and to compare community preferences for adaptation with assistance that has been provided by NGOs and government actors. In this regard, we detailed a range of challenges, spanning the environmental, technical, economic, and social. Several studies based in our districts have focused on the technical—examining microbiological and physicochemical parameters to assess quality of water from RWH systems, unfiltered ponds, and PSFs [87–91]. The general conclusion from this body of research is that across all of these options, water is considered unsafe for drinking due to the presence of coliform bacteria and *E. coli*, among other contaminants. PSF systems are not reliable in removing bacteria from pondwater, and in fact one study found an increase in certain contaminants after filtration [89]. Some results support the hypothesis that RWH results in less contamination than ponds or PSFs, which become polluted due to runoff and human contact; nonetheless, RWH—at both the community and household levels—has yielded water unsafe for drinking [87, 89, 91].

Comparing this concerning technical characterization of available water options to practices and perspectives among our study participants, we note several issues: first, although participants were dissatisfied with the quality of pondwater, they were generally confident about the quality of harvested rainwater, describing it as the purest form of water; second, they mostly associated polluted rainwater with rainwater stored in *maith*, not in plastic or concrete tanks; third, physicochemical properties (e.g., iron, salinity) and visible pollutants (debris, insects, etc.) were much more of a concern than microbiological contaminants; and fourth, home water treatment was far from universal, and the most commonly referenced method—alum, which has potential as an (imperfect) disinfectant [92, 93]—was only applied to pondwater, if at all, for the purpose of addressing turbidity.

Prior research has also indicated a disconnect between drinking water assessments and community perspectives/practices. For example, for home-based water treatment, Benneyworth et al. noted that only 24% of the 200 households surveyed used alum and only one person boiled water [83]. Ghosh et al. surveyed 80 households in Mongla and Dacope, finding that 70% were "satisfied" with their current source of drinking water, 21% were "quite satisfied"; only 9% were "not satisfied at all" [87]. Those who drank rainwater were more satisfied than those who drank from ponds or tubewells, but satisfaction overall appeared high. In a survey of 602 households in Dacope, Harun and Kabir found that although 75% of the PSF samples were contaminated, only 10% of households reported water quality as their chief complaint (most cited issues of accessibility instead) [88].

Rather, beyond the domain of the technical, it appears that social and economic aspects of the adaptation strategies are the predominate concerns of community members and NGO stakeholders. As our results above illustrated in some detail, community participants heavily emphasized barriers related to financial accessibility of RWH infrastructure, failure of NGO interventions to redress inaccessibility, skepticism about community-level and even cluster-level sharing arrangements, and physical accessibility of sources. NGO representatives' primary issues of concern included economic feasibility of the various options, and community dynamics that would facilitate or inhibit maintenance of infrastructure.

Our research helps contextualize prior studies, particularly those that survey community adaptation preferences but provide limited insight into the obstacles faced in realizing them [59, 84, 94].[11] Our findings also help put into perspective investigations

[11] It is difficult to deduce a general preference from these studies, as depending on the area and study in question, individual-level RWH, a piped water system, or a PSF may be preferred. For example, Rahman et. al found that individual RWH was the most preferred option in two villages in Satkhira, but if forced to

that examine the cost and feasibility of designing a given intervention, namely RWH infrastructure, without incorporating community perspectives. For example, Islam et al. mentioned that an NGO recently set up a deep tubewell in one area of Satkhira District and charged $0.80 USD per 25-liter container, which would amount to $24 monthly for the drinking needs of a five-member household [95]. Deeming this unaffordable for the poor, the researchers designed a 2,000-liter RWH tank using local materials and arrived at a cost of $171 for building and operating the system, which they "*assumed to be affordable in the region.*" Given that our participants across all three sites quoted very similar estimates and still emphasized unaffordability of the measure, we suggest that this assumption may not hold.

One study that did examine the process of adaptation to water scarcity from the point of view of affected households was conducted by Samaddar et al. in Bagerhat [96]. Researchers undertook a social network analysis among adopters of RWH tanks, and focused on how those who shared a strong, intimate, and direct relationship discussed RWH tank adoption and thus influenced each other to adopt tanks. Adopters also observed tank-owning households that were located nearby. In fact, our results suggest that most households—non-adopters and adopters alike—are acutely aware of RWH as an adaptation strategy. Samaddar et al.'s analysis understates a key issue, which the socioeconomic characterization of their participants reveals: tank adopters are far wealthier and more educated than the typical inhabitant of the area. While most residents

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choose a community-level intervention, respondents preferred a community PSF system over a community RWH system [84]. Piped water systems were not a popular option because of unwillingness to pay. On the other hand, Abedin et al. found that 98% of respondents in an area of moderate drinking water scarcity desired a piped water system, while 68% of those in a severe scarcity area preferred RWH infrastructure [59].

engage in agricultural livelihoods, tank adopters tend to work in non-agricultural occupations, such as teaching, medicine, and business. Their average monthly income is $180 USD, while 40% of the municipality's population lives below the national poverty line of $2 USD per day. (As a point of reference, the authors estimate that a RWH of 4,500 liters, suitable for a family of 6 to 7 members, costs around $190 to $260 USD.) Another observation that can be gleaned from their study, which the majority of community participants in our study highlighted, is the inability of NGO efforts to target the vulnerable. In fact, in their study area an NGO had worked on providing tanks in the municipality, and a total of 68 tanks had been installed in the municipality since 2004. Their study population was 56 of those 68 tank adopters. Perhaps inadvertently, the study provides an example of how an NGO tank distribution effort failed to reach the most vulnerable.

Among NGO stakeholders we interviewed, the general argument was that it was not feasible or cost-effective for organizations to provide everyone with individual RWH infrastructure, and moreover many insisted that requiring households to contribute would ensure that they acquired a sense of ownership and responsibility for the infrastructure. From the perspective of the communities, the issues with the latter argument were that the required contributions or terms of assistance (e.g., loans, participation in the organization's *samity*) were still excessively burdensome, and that even when they were not prohibitive only a few privileged, politically well-connected households were selected as beneficiaries. With respect to the first line of reasoning, there are grounds to question the assumption that community-level infrastructure is truly more cost-effective, given that it often falls into disrepair. Many of our study households noted they would take greater care of something individually owned.

The challenges with implementing sustainable community-level interventions acknowledged by many NGO stakeholders in our study have also been confirmed by prior studies. For example, Islam et al. found that most PSF taps were defective [89], while the large size of community-level RWH tanks prevented them from being washed even annually. Sultana et al. analyzed maintenance of a community-based MAR-type system, which would cost about $5,000 to $7,000 USD to construct [97]. They reported that one part of its filtration system required weekly washing to remove fine materials, while another part required washing and replacement every four to six weeks. Further, the sand and gravel needed to be either power backwashed every six months with the help of contractors charging $100 each time, or manually backwashed by community members at a cost of $10 each time, but at intervals of every one to two months. Additionally, frequent maintenance helped reduce short-term clogging, but long-term clogging still occurred. Even aside from the environmental and technical challenges (e.g., scarce freshwater ponds, power outages), there was a significant burden on the community to manage clogging, the cost of the system still had to be balanced with the community's willingness to pay, and institutional arrangements had to be made for assessing water quality.

On the topic of institutional arrangements, we observed that while NGO representatives readily spoke of obligations that fell to community members, they rarely addressed the accountability of state actors unless we specifically asked about it. The potential for coordinating with local government was viewed with some skepticism, given the centralization of power in Bangladesh and perceived unwillingness of local government to assume additional responsibilities.[12] In this regard, Rahman and colleagues' recent work points out that there are many relevant actors undertaking separate actions related to water scarcity in salinity-affected areas, and "*for an effective, efficient and environmentally friendly coping strategy, the communities, government, NGOs and international organizations need to function as a single body*" [84].

Limitations

Our water testing was constrained to two time points and a relatively small number of samples. Moreover, given the expertise of the research team, we only tested salinity, and did not test for arsenic and other water quality parameters, which would have allowed a fuller characterization of the water available.

Furthermore, scholars have argued for the multi-scalar study of equitable water governance, which envisions analysis across multiple scales—including, social, ecological, and spatial [99]. Here, we have focused on a fairly small socio-geographic scale, and have left treatment of the issue of water governance across larger scales (the Ganges basin, watershed, and beyond) for future research. Moreover, we have addressed only one of four "hydrosocial cycles," namely rural household water. A multi-scalar study incorporating the other three cycles—irrigation, mining and industry, and urban water supply—is pending.

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[12] These results are discussed in greater detail elsewhere. (See Chapter 7.) The need for critically reexamining the relationship between local and central government is supported by the work of Pahl-Wostl and Knieper, who find that polycentric regimes—as opposed to centralized or fragmented regimes—have higher capacity to establish water governance that is adaptive to climate change [98].

Finally, we have not included data from interviews with government officials, which would be useful to understand the panorama of stakeholder perspectives more comprehensively. This is not because we did not interview government officials, but because those respondents had less available time and spent it mostly discussing issues related to food production, the central topic of the next chapter.

Conclusions

Contributing to the literature on salinity in Southwest Coastal Bangladesh, our research provides an in-depth examination of the multi-faceted impacts that salinity exerts on household water use. It moreover documents continued challenges in adapting to these impacts, notwithstanding recent interventions undertaken by development actors in the region. The concerns of community members and NGOs largely pertain to social and economic issues associated with water adaptation options, and likewise many of the gaps between what is desired by communities and what is offered by NGOs fall within those domains. As noted by Perrault, it has "*become something of a truism to speak of water in terms of the* 'hydrosocial'. *Water is neither purely* 'natural' *nor purely* 'social' *but simultaneously and separately both*" [100]. Our research brings this perspective into the public health literature on water and environmental change. Our conclusions point toward the need, not only for increased technical, environmental health, and biomedical research to improve issues such as drinking water quality, but also for social science research to illuminate solutions for challenges related to accessibility, community dynamics, and accountability.

Chapter 6. Salinity and Rural Household Food Production in Southwest Coastal Bangladesh: Perspectives on Impacts and Adaptation from Communities, Non-Governmental Organizations, and Governmental Actors

Introduction

In rural Bangladesh, where some of the world's highest rates of malnutrition can be found, food security and overall welfare are highly dependent on the ability to use land productively [48]. The coastal population engages in agricultural livelihoods—including crops, horticulture, and fisheries—that contribute to making agriculture the second largest sector of the national economy, while also undertaking homestead food production activities that provide a substantial part of their sustenance. The incursion of saltwater into the Southwest Coastal Region, a process attributed to multiple environmental and manmade factors (see Chapter 4), increases salinity of soil and water, compromising the land's productive potential.

Salinity reportedly affects as much as 60% of arable land in the southwest coast during hot season [8, 11, 12]. Between 1973 and 2009, the Soil Resource Development Institute observed an expansion of area affected by soil salinity in the southwest coastal districts of Khulna, Bagerhat, and Satkhira. During that period, there was also a 225% increase in the amount of area classified as "saline" or "highly saline," reflecting greater severity of the problem [46]. (See Table 3.)

According to guidelines provided by the Food and Agriculture Organization of the United Nations (FAO), soil salinity (EC_e[13]) of 4,000 μS/cm or higher affects the production of many crops, and beyond 16,000 μS/cm, only a few highly saline-tolerant crops will have satisfactory yields [20]. (See Table 1.) With respect to food production, water in excess of 700 μS/cm will have some restrictions in use for irrigation, and at levels of 2,500 to 3,000 μS/cm, water is so saline that it has extremely limited utility for irrigating typical crops [21, 24]. Studies sampling from various surface water and groundwater sources throughout the region have revealed higher salinity levels than ideal for irrigation [8, 25, 43, 101].

Some survey data, qualitative studies, and review articles discuss how households have experienced the impact of salinity on their food production practices and altered them to respond to salinity in the Southwest Coastal Region [25, 27, 102–104]. However, in general previous research has provided limited information about the nature of adaptive changes made, why they were perceived as necessary, what made them possible, and how they fulfilled or did not fulfill intended goals. Also lacking is a critical exploration of how well inhabitants' needs resonate with the priorities of external governmental and non-governmental actors, who are working to promote sustainable development and environmental (climate change) adaptation in the area. These information gaps motivate the present study, in which we used qualitative research methods and salinity testing to examine how household food production is affected by salinity, how households respond, and how external actors shape those responses.

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[13] EC_e values correspond to measuring electroconductivity (EC) of a saturated soil-paste extract in a laboratory setting.

Methods

The sites consisted of three villages, selected to represent the three southwest coastal districts of Khulna, Bagerhat, and Satkhira, and to have moderate or high salinity in soil and water.

Data Collection

There were two phases of data collection: the first entailed community-level data collection and the second involved government officials and NGOs. Written consent was obtained from all participants. The study was approved by the Institutional Review Board of Johns Hopkins Bloomberg School of Public Health, and the Research and Ethics Review Committees of the International Centre for Diarrhoeal Disease Research, Bangladesh (icddr,b).

Phase 1 – Community-level data collection

There were two rounds of community-level data collection. The first round took place in May and June 2015, coinciding with hot season and the beginning of rainy season. Across the three sites, researchers recruited 25 households and conducted a structured visit consisting of: two interviews with a male and female member of the household,[14] a household tour with questionnaire, and salinity testing of the household's garden soil and sources of water. Household interviews were semi-structured with an

[14] If two members of the opposite gender in the same family (*khana*) were not available, then someone of the opposite gender within the same compound (*bari*) was interviewed. The household questionnaires were applied at the family (*khana*) level with either one of those individuals. *Khana* refers to a group sharing the same cooking hearth, whereas *bari* are made up of one or more (typically related) *khana* whose dwellings are clustered in the same area.

interview guide that covered the impacts of salinity on household food production and strategies for adapting, among other topics. Questionnaires assessed demographic characteristics and food production resources (land, gardens, ponds, livestock, etc.).

During the first round of data collection, the research team also conducted six focus group discussions (three with males and three with females) and interviewed 10 community key informants (e.g., village leaders, schoolteachers, NGO fieldworkers). Among other activities, focus group participants discussed the impacts of salinity on food production, made seasonal calendars to depict trends in salinity and food production, and ranked and discussed adaptation strategies. Key informant interviews focused on site history, salinity trends, and salinity impacts.

The second round of community-level data collection took place in October 2015, in mid-to-late rainy season. The research team revisited all households recruited during the first round, and conducted a follow-up interview with one household member. The interview elicited updated information about how the household fared during rainy season and recent changes.

Phase 2 – Stakeholder-level (government and NGO) data collection

The second phase of data collection took place in January and February 2016. The research team conducted in-depth interviews with 24 NGO and 16 government representatives based in the Southwest Coastal Region and Dhaka. The government entities concerned were the Ministry of Water Resources, Ministry of Health and Family Welfare, Ministry of Fisheries and Livestock, Ministry of Agriculture, and Ministry of Environment and Forests. The interviews entailed semi-structured discussion about perceived impacts of salinity on agriculture and aquaculture and strategies for adapting, among other topics.

Data Analysis

Household questionnaire results were tabulated. Interviews and focus groups were audio recorded, transcribed, and translated from Bangla to English. Initial interviews and follow-up interviews with household members lasted an average of 121 and 62 minutes, respectively. Focus groups, community key informant interviews, and stakeholder (NGO and government) interviews lasted an average of 162, 132, and 80 minutes, respectively.

Transcript analysis entailed three components: (1) coding noteworthy quotes using MaxQDA software (see appendices for codebooks used); (2) extracting information into a summary document based on a standardized template; and (3) updating a separate memo of observations on cross-cutting themes and unexpected topics. Findings were synthesized by topic from the summary documents, then supplemented with quotes and ideas from the memo.

Salinity Testing of Soil and Water Samples

The research team measured electroconductivity (EC, in microSiemens/cm), as an indicator of salinity, in soil and water samples. The team photographed and took GPS coordinates of all sources sampled and recorded weather conditions. During site selection at six candidate sites, the team measured EC of both types of samples using the Extech EC500 pH/conductivity meter. In the first round of data collection, the same meter was re-calibrated and used to measure water samples. However, a problem with the meter arose when trying to recalibrate it before testing the soil samples. Thus, for soil samples and the second round of data collection during which the same water sources were tested again, the team used a different meter –Hanna Instruments' HI 86304N electroconductivity meter. The process undertaken for testing water and soil samples is described briefly below; the detailed protocol is in the appendix.

All of the soil samples tested came from homestead gardens. When sampling soil, researchers recorded information about the types of fruits and vegetables grown, fertilizer use, irrigation practices, whether yields were enough to sell in addition to being consumed by the family, the perceived level of salinity, and whether NGOs or government officers had provided any assistance in cultivating that garden. Soil was collected at a depth of five to seven inches from ten dispersed locations within the garden, and then brought back to Dhaka. Researchers dried the soil overnight, made a soil suspension with one part soil to five parts deionized water, and then measured the electroconductivity of the suspension ($EC_{1:5}$). A soil texture test was performed to classify soil type. Based on the soil type, a specific conversion factor was used to approximate soil salinity (EC_e) from $EC_{1:5}$ [105].

For water, three types of sources were sampled: tubewells, surface water such as ponds and canals, and water from a tap from a pond filter system or piped supply. For tubewells, the EC of water pumped at specific intervals was measured on site. Information was recorded about the reported depth of the tubewell, the uses of the tubewell, the salinity as perceived by its users, and the tubewell's history. For surface water sources, the EC of water taken from two different depths was measured on site. Information about the uses, types of fish in the source, and user perception of salinity was noted. For taps, the water was allowed to run for a minute and then EC was measured. The history of the tap system and the perceived quality of water were recorded.

Results

The three sites selected were located in the Dacope sub-district of Khulna District, the Mongla sub-district of Bagerhat District, and the Shyamnagar sub-district of Satkhira District. Profiles of our community participants, stakeholder interviewees, and study households are provided in Tables 5, 11, and 12, respectively.

Table 11. Stakeholder interview informants by institution

Institution	No. (out of 40)
Government	
Ministry of Agriculture	4
Ministry of Fisheries and Livestock	2
Ministry of Water Resources	3
Ministry of Environment and Forests	4
Ministry of Health and Family Welfare	3
Non-governmental	
Local/regional	5
National	6
International	13

Table 12. Profile of recruited households

Characteristic	No. of households (out of 25)
District	
Bagerhat	8
Satkhira	9
Khulna	8
Female-headed household	2
Household size	
1-2	3
3-4	15
5-6	5
7+	2
Highest level of education attained by a household member	
No formal education completed	3
Primary	10
Secondary	8
Post-secondary	4
Household religion	
Muslim	17
Hindu	8
Primary occupation of household head	
Agriculture	5
Aquaculture	5
Fish trading	2
Daily (wage) labor	12
Retired	1
Housing improvements reported	
Electricity	4
Improved roofing (tiles, tin roof, etc.)	18
Improved sanitation facility (any kind of latrine)	25
Land owned (other than land upon which dwelling is built)	
< 0.10 acre	8
0.10 to 0.49 acre	4
0.50 to 0.99 acre	4
1.0 to 1.9 acres	5
2.0 to 4.9 acres	3
5.0+ acres	1

Salinity Testing

Salinity testing of soil from 27 sampled gardens reflected variation both within sites and across sites. (See Figure 7.) Soil samples were classified as loam, clay loam, or light clay. Adjusted EC values (EC_e) ranged from 7,030 to 30,923 µS/cm at the Bagerhat site, 6,460 to 47,690 µS/cm at the Satkhira site, and 998 to 7,998 µS/cm at the Khluna site. The noticeably lower salinity values at Khulna could be due partially to the timing of testing, as rainy season began just before the research team arrived at that site, and to specific changes in land use there (discussed in the Results sub-section on adaptation).

As shown in the maps depicting the sampled locations at the three sites (see Figure 8 and additional maps in the appendix), locations that were relatively proximate (e.g., within one kilometer) could have substantially disparate salinity readings.

Figure 7. Soil salinity testing results by site in May - June 2015

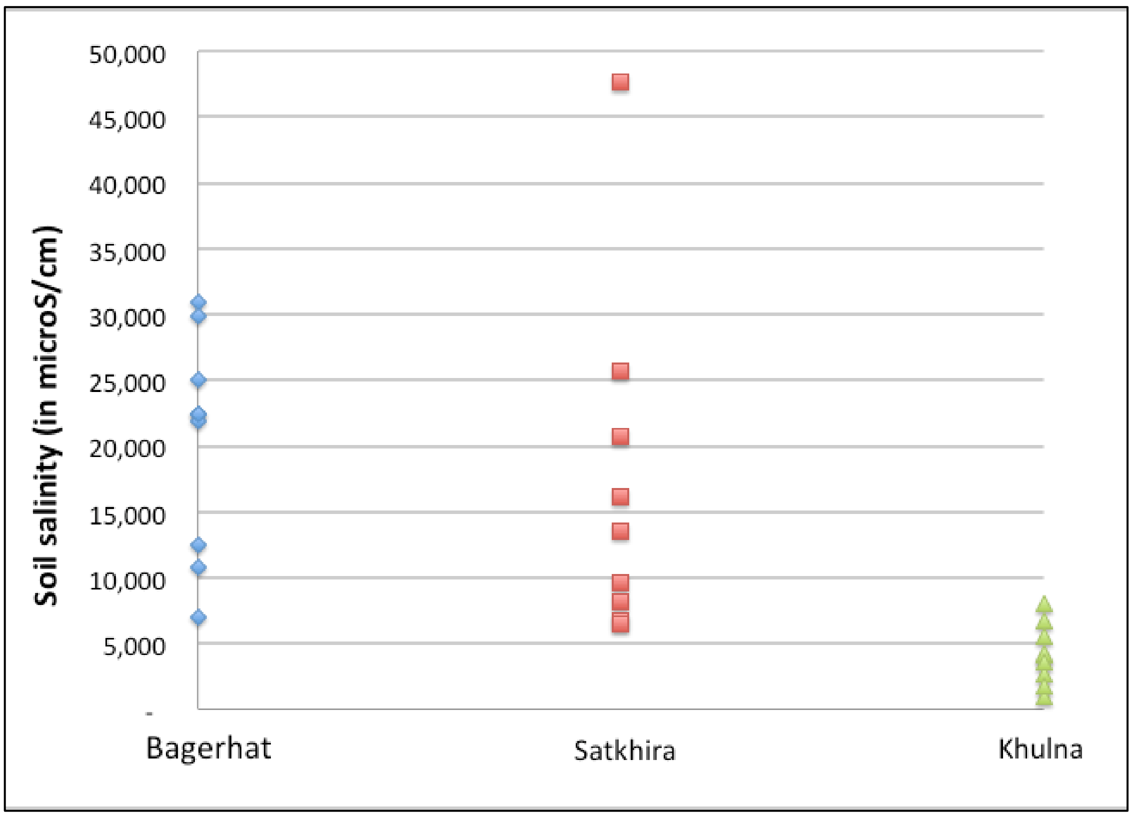
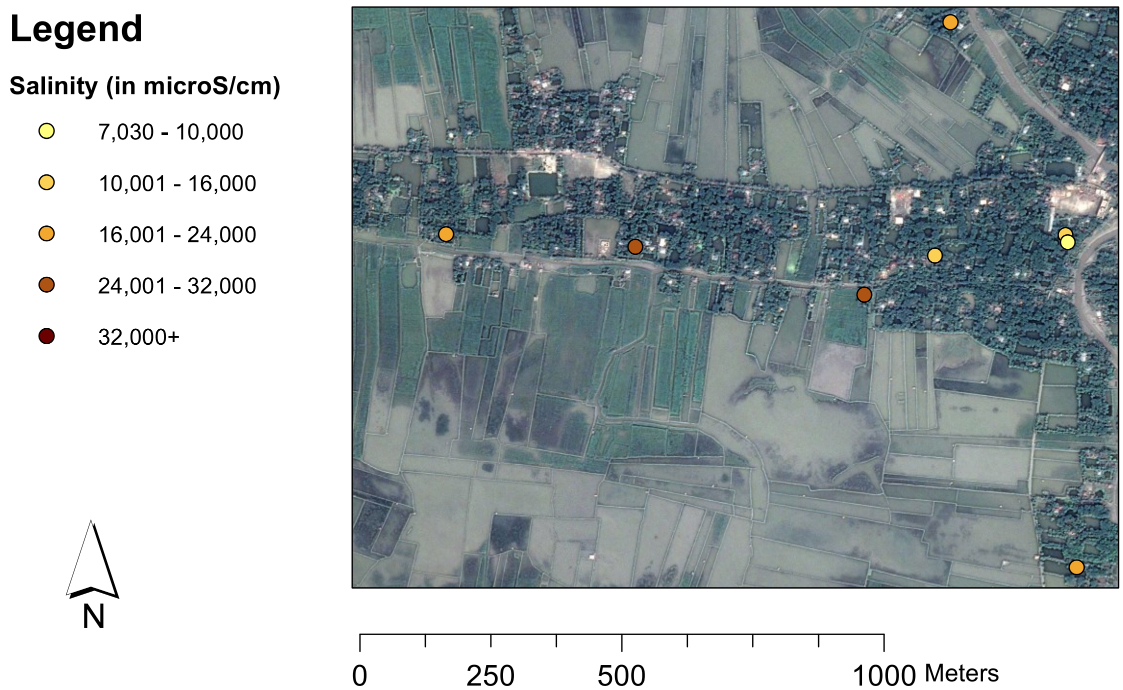


Figure 8. Google Earth image of Bagerhat site - soil in May - June 2015

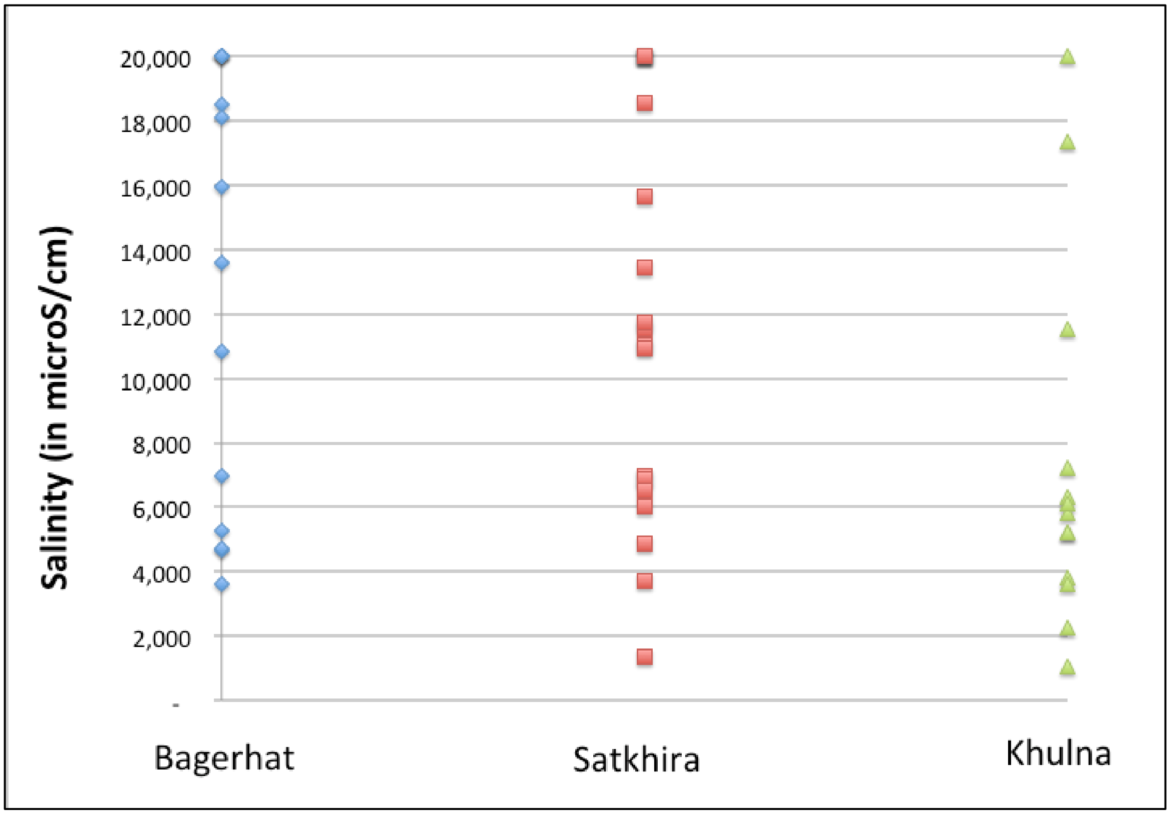


Results from testing the salinity of groundwater and surface water across the three sites presented elsewhere (see Chapter 5), revealed that the majority of those sources would be of limited utility for irrigating typical crops, based on the irrigation water guidelines cited earlier. While there is no specific threshold that separates suitable and unsuitable irrigation water (and factors beyond salt content influence the quality of irrigation water), for illustrative purposes we note that all eight tubewells tested in Satkhira and Khulna[15] exceeded 3,000 µS/cm in both seasons, ranging from 5,822 to 11,747 µS/cm in June 2015 and 4,905 to 9,527 µS/cm in October 2015. Of the 37 surface water sources tested, 34 sources exceeded 3,000 µS/cm in June 2015. (See Figure 9. Note that rainy season began mid-June, and this may have contributed to lowering salinity at

[15] No functional tubewells were found at the Bagerhat site.

the third and final site in Khulna, which the team reached in late-June.) In October 2015, 9 out of the 34 water sources—about a quarter of the sample—exceeded 3,000 µS/cm. (Results not depicted.)

Figure 9. Surface and groundwater salinity testing results by site in June 2015[16]



[16] Note that water sources that appeared to have a value of 20,000 µS/cm could have salinity in excess of that value, as 20,000 µS/cm was the maximum value that could be registered by our meter. On the other hand, soil salinity values greater than 20,000 µS/cm are shown above because there is a conversion multiplier used to derive adjusted EC from the meter reading of $EC_{1:5}$.

Household Food Production Practices and Impacts of Salinity

Gardening

Across our study households, the amount of land used for cultivation of food-producing plants (grains, vegetables, fruits, and herbs), including owned and rented land, ranged from 0.0 to 3.0 acres, with a median of 0.05 acre. All recruited households, except for one, reported that they had one or more homestead gardens. Commonly grown vegetables included leafy greens, gourds, okra, radish, turnip, pumpkin, chili, melon, and arum. Fruit-bearing plants included banana, coconut, dates, guava, papaya, sapota, wood apple, tamarind, and pomegranate.

The extent of vegetable and fruit production varied significantly by season. Interviews and field observations revealed that gardening was most curtailed during hot season, which corresponded roughly to March through June. Salinity was cited as a barrier, as were heat and drought. Households noted that soil on their homestead was powdery and infertile, and seeds would not sprout. During this season, the research team observed that many gardens lay fallow or partially fallow, and vegetation appeared wilted and sparse. Only a few households attempted cultivation, sourcing irrigation water from ponds farther away perceived as less saline, reserved rainwater, kitchen wastewater, or tubewells. Although the team did not systematically measure the salinity of all irrigation sources, linking household questionnaire data with testing results revealed that a few households attempted irrigation with water as saline as 6,000 to 7,000 µS/cm. As the overall salinity testing results demonstrate, quality irrigation water was limited, especially during the time of year when it was most needed—i.e., when there was less precipitation.

Most households recounted that salinity was less problematic two to three decades ago, and attributed the increase in salinity to conversion of agricultural land to saltwater shrimp ponds (see also Chapter 4). Prior to this, rice cultivation was much more prominent, and vegetable and fruit production was abundant and diverse. A few participants described fruit trees growing so thickly that one could stand naked by his or her house and not be seen from the road. Many community members echoed the following narrative, told by a woman from Khulna:

> *There was no salinity before the saltwater shrimp ponds were started. Crops grew a-plenty. My father-in-law told us a story about a time when there were many huge trees bearing jackfruit, lychee, rose apple, and more. All of these died when saltwater shrimp ponds were introduced….Now, fertility is decreasing because of salinity caused by them. Crops don't grow well. We need to work hard and apply more fertilizers…. We didn't used to suffer so much.*

Although many households reported that salinity hindered cultivation and obliged them to buy produce from the market year-round, some families said they were able to grow enough to eat and sell produce during winter and rainy season. Precipitation during rainy season, from June to October, helped to irrigate the crops and reduce soil salinity, and this season was considered the most productive. However, too much rain—which occurred across all three sites the year data collection was conducted—could harm crops, especially ones planted low to the ground. In winter, from October/November to February, many households continued gardening by using their own ponds—which were less saline then—for irrigation.

Livestock

All recruited households, save one, owned livestock, with the most common being ducks and chickens (raised by 21 of the 25 households), and cattle (raised by about half of the households). Livestock ownership was generally small in scale. For example, only five of the households owned more than 20 heads of poultry and only four had more than four heads of cattle. Some households also owned goats and geese, but these animal species were less common among the participants and similarly tended to be few in number.

Poultry were fed rice and rice husk (the outermost layer of the grain separated during the milling process). The use of manufactured poultry feed or fishmeal was very rare. Cattle were typically fed straw, grass, rice husks, and rice. Most households from Bagerhat and Satkhira obtained these feed materials from the market, while households in Khulna reported procuring them through their own homestead crop production or from nearby pastures, rice fields, and rice mills. This was attributed to more agricultural land and cultivation around the Khulna site.

In interviews, community members reported that it was much harder to raise animals in a saline environment. The lowland areas where rice used to be farmed provided pastures for grazing, but salinity rendered those areas barren, especially during the hot season. Families were obliged to purchase straw or spend time taking their animals, particularly ruminants, to find other places for grazing. Some households paid a caretaker to look over their cattle for several months in another area. In rainy season and winter, grass was more readily available, and animals could remain closer to their homes. Nonetheless, many families had given up raising large ruminants. One household in

Bagerhat, for example, recalled having “a shed full of cows,” from which they could obtain milk and make ghee. The family had given up this source of food production, as nobody in the family had time to travel with the cattle to find pastures suitable for grazing.

A further challenge was obtaining drinking water for livestock, and animals often drank saltwater. A few households said that their animals had adapted to living in a saline environment and drinking saltwater, but most reported that consumption of saltwater caused diarrhea, fever, gas, or convulsions in animals. Several respondents also mentioned that the increase in salinity meant that more chemicals, such as pesticides and fertilizers, had to be applied to the land, and these chemicals triggered illnesses in animals that grazed or drank there. There were also reports that scarcity of quality water and feed caused animals to be generally weak and more susceptible to disease. Poultry, in particular, were said to fall ill with high mortality especially in hot season, developing symptoms such as dizziness, diarrhea, and stiff/paralyzed legs.

Aquaculture

All but two of the recruited households owned and/or rented land for aquaculture, but the amount of land varied greatly, from less than a hundredth of an acre (360 square feet) to 5.6 acres, with a median of 0.20 acre. Households raised fish in homestead ponds, as well as *ghers*—larger, excavated ponds, where the dug soil was used to make an embankment around the border.

In general, salinity of the ponds was perceived to be high or medium during hot season and low or negligible during rainy season. The majority of our respondents attributed increasing salinity to the conversion of land into saltwater *ghers*, from which saline water would seep out and infiltrate surrounding lands and waters (see Chapter 4). Higher salinity was reported to have curtailed fish production, rather than enhance it, at least in terms of species diversity. As a woman from Bagerhat recalled, "*There was no limit in fish. Whatever type of fish you wanted, you used to be able to get it before there were saltwater* ghers." Community remembers reported that various varieties of catfish, carp, tilapia, and other freshwater fish, used to grow more abundantly. These species were sometimes raised in less saline ponds or during rainy season, but would die off when the water became too saline, as one farmer from Khulna lamented:

> *You would be stunned to see how my fish died. Today, I threw away another two fish. How large those fish were! One was a* shoil *and another a* datina*. The price of the two fish would have been 500 taka.*

On the other hand, cultivation of *bagda* shrimp was possible in the higher salinity of saltwater *ghers*, and a few other species, such as *golda* shrimp, crab, mullet, and Asian seabass were known for tolerating some salinity. However, even saltwater fish reportedly died in excessive salinity, such as the levels found in hot season. This applied even to *bagda*, whose cultivation served as the primary motivation for converting land to saltwater *ghers*. Many households that raised *bagda* speculated that salinity had increased to such a point that it was causing the disease outbreaks recently observed in shrimp stocks.

Overall food security

In general, community members felt less food secure due to salinity, not only because of the physical impact of salinity on crop production, livestock, and aquaculture, but also because of reduced economic opportunities. In hot season, men and women had fewer livelihood opportunities, as agricultural activity—rice cultivation and *gher* aquaculture—decreased. Males left the villages to find work, sometimes traveling to other parts of Bangladesh where there was more crop production or to urban centers, while females who were equipped to do so engaged in non-agricultural activities, like sewing. These options were not readily attainable or lucrative.

Those who are relatively successful in undertaking saltwater aquaculture in *ghers* could still feel food insecure. One household from Satkhira, for example, now made 20,000 taka (about $250) per *bigha* of land (approximately a third of an acre) devoted to saltwater aquaculture, compared to 5,000 taka per *bigha* when the land was previously used for rice plantation. Despite this gain, the male head of the household emphasized:

> *The plants and trees and fruits that used to grow in the past, they do not grow now. Does that give us peace? No. We don't feel at peace. Now, we may have more money. But in order to eat, we have to buy food…. Before, even though we made less money, we used to grow food at home. We could also sell produce.*

In addition, although the income earned from *bagda* production and other alternative livelihood activities could be used to buy food, market produce was widely perceived to be poorer in quality than homestead-grown vegetables. Community members stated that market produce was insect-ridden or grown with fertilizers, which they perceived to cause diseases and reduce nutritional value.

Some indicated that women were particularly vulnerable to food insecurity in this context. For example, during the female focus group in Satkhira, women pointed out that they experienced greater insecurity because of having to feed their children before they themselves could eat. In Bagerhat, a female villager reported that women from poorer households suffered disproportionately from diarrhea because they had to eat rotten food or leftovers, as they could not afford to throw them away. A member of an NGO pointed out that women from the area often had difficulties breastfeeding from being malnourished.

Adapting Food Production Practices to Respond to Salinity

Community members, NGO representatives, and government officials discussed strategies for adapting food production and other livelihood options considered viable in the context of soil and water salinity. Resource constraints limited the extent to which households experimented with adaptation strategies, not only because they might lack money for purchasing necessary inputs, but also because they lacked time to experiment with new techniques or felt that it was not worthwhile if they only owned a small amount of land. The main types of strategies discussed by communities and stakeholders were increasing/decreasing saltwater aquaculture, improved cultivation techniques, saline-tolerant plants, non-agricultural livelihoods, and migration.

1. *Increasing/decreasing saltwater aquaculture*

Saltwater aquaculture was portrayed as both an adaptation response to salinity and a cause of salinity. A common narrative arising from interviews with community members and stakeholders was that saltwater *gher* aquaculture—*bagda* farming, specifically—was started initially because there was 'natural' salinity in the area, and there were few other livelihood possibilities during hot season. As *bagda* farming expanded and became the predominant activity year-round—a controversial development described in detail in Chapter 4—saltwater was deliberately brought in and allowed to remain in the area, exacerbating salinity.

Communities and stakeholders took strong stances on whether saltwater aquaculture should be increased or decreased as a response to the current salinity situation. At the community level, some poorer households believed that saltwater aquaculture still had a role to play in adapting to salinity and desired economic assistance from NGOs in obtaining inputs (e.g., *bagda* fry, crabs for fattening, etc.), because the activity was otherwise inaccessible to them. However, the majority view, supported by both poorer and average households, was that the appropriate response would be to reduce saltwater *gher* aquaculture. They stated that eliminating *ghers* and closing sluice gates to prevent saltwater from entering by way of rivers would allow the land to restore itself. They forecasted that restoration might take several few years, but with each rainy season, salinity would decrease and agriculture would eventually be possible.

The Khulna site was an example of an area that had been partially restored. Saltwater shrimp farming had been prohibited in 2009, reportedly leading to notable decreases in soil and water salinity. Trees like coconut, guava, lemon, and mango had recently started growing, vegetable cultivation was more abundant and diversified, cows could now be raised for milk and fuel, and rainy season rice cultivation was once again possible. At that site, persisting challenges with food production were attributed to residual salinity from high tide and low tide, insufficient water during hot season, and bordering villages that had not yet prohibited saltwater *ghers*.

Across all three sites, a common perspective amongst community members was that eliminating saltwater *gher* aquaculture where it still remained would require government intervention. At the same time, there was skepticism about whether this would happen, since both the local and national government were said to benefit from the saltwater aquaculture industry. In Satkhira, for example, villagers reported that many unsuccessful efforts had been undertaken to stop saltwater from entering the area. One focus group participant described how his grandfather and uncles had filed a court case and gathered signatures for a petition for that purpose, but those supporting saltwater *ghers* had bribed the magistrates.

Nevertheless, political action against saltwater aquaculture could be possible, given ongoing challenges with disease outbreaks in shrimp stocks and low profit margins. Various participants described saltwater aquaculture as a "bad business nowadays," given the costs of leasing land for a *gher*, hiring guards, and purchasing inputs. However, larger-scale shrimp farmers could survive because of their economies of scale and capacity to absorb shocks, and were perceived as resistant to converting land back to crop production.

At the NGO level, many representatives we interviewed expressed the idea that, as one put it, "*pragmatically you couldn't get rid of commercial shrimp farming*" because of natural salinity and the economic importance of the activity. Several NGO representatives argued that saltwater shrimp farming could be done in an environmentally friendly way, while several more advocated for freshwater, rather than saltwater, aquaculture. A couple NGOs mentioned that they were implementing programs to promote freshwater and/or saltwater aquaculture, offering assistance through loans, trainings, and facilitating inputs. Such programs selected beneficiaries who, though not necessarily the wealthiest, had some resources and education.

At the government level, there was a range of views on saltwater aquaculture. The Ministry of Fisheries claimed that inhabitants of the Southwest Coastal Region were adapting to salinity successfully through saltwater shrimp farming, and described this as a very positive development, while one Ministry of Agriculture representative refused even to consider saltwater aquaculture as an adaptation option. Other government officials, including the Ministry of Environment, proposed zoning lowland areas for saltwater aquaculture and designating higher ground for crop production. These officials considered *bagda* farming too important of an economic activity and maintained that it could be done in an environmentally sustainable way. However, across both the NGO and government sectors, participants pointed out challenges in implementing regulations. For example, an NGO representative stated that there was already a Ministry of Fisheries regulation requiring *ghers* to be located at least 1,000 feet away from residential areas, but the policy was not being enforced (nor was it clear whether such a buffer would be enough to protect residential areas from salinity).

Regarding the elimination of saltwater shrimp farming, in contrast to the community perspective that government action was needed, one Ministry of Water official from the Water Development Board declared that the government could *not* stop it; rather, it was up to “the people” to make this decision. Similarly, a Ministry of Agriculture claimed that *gher* owners were more powerful than the government, and that the government could not stop saltwater shrimp cultivation since so much agricultural income derived from it.

There was also disagreement over the extent to which the Ministry of Water controlled the sluice gates, which would need to be closed at the appropriate times to block saltwater from entering the area. Many community members and NGO representatives believed, as one representative described it, that the Ministry of Water was the "*informal lord [of the region because] the entire coastal ecosystem was somehow governed or monitored*" by the embankment system. On the other hand, the Ministry of Water officials that were interviewed claimed that their institution had a limited role. They stated that local politicians formed committees to supervise the operation of the sluice gates. When communities wanted saltwater or not, they directly engaged the corresponding committee. The Ministry of Water could intervene to facilitate discussions if there were disagreements, but purportedly did not control the gates.

2. *Improved cultivation techniques*

Various strategies for adapting cultivation to saline environments were undertaken by households in the three sites. Many of these techniques were directly observed in the field by the research team, or explained by community members in interviews and focus groups. A few NGOs also showed the team projects they were undertaking, which employed some of these techniques. (See pictures provided in the appendix.)

i. Improved irrigation

The most salient technique described in interviews and focus groups was improved irrigation. Many community members considered access to freshwater as pivotal. Irrigating with freshwater, crop production was possible; without freshwater, no other technique would help. As described earlier, household pondwater was used most often in the winter months, because in hot season the water became too saline and in rainy season there was less need for irrigation. Other sources of water—such as less saline community ponds and rainwater harvested in tanks—were potential sources of irrigation; however in light of the severe drinking water crisis (see Chapter 5), water from these sources was not prioritized for irrigation. Many villagers expressed: "*We can't even manage drinking water. How are we going to manage water for irrigation?*"

One solution proposed by some households and the Ministry of Agriculture was to excavate silted ponds, canals, or rivers, and use them to collect and store rainwater, which could be used for irrigation or drinking year-round. There were two challenges, however: first, the water would need to be delivered from the reservoirs to individual homesteads and croplands. Second, the reservoir could be susceptible to salinity infiltrating in from nearby bodies of saltwater. This reinforced the idea, expressed by many community members, that permanent access to freshwater required eliminating saltwater *ghers*. Groundwater was another option, with some participants suggesting that new tubewells be built to search for freshwater.

ii. Fertilizers

Next to improved irrigation, fertilizers featured prominently among methods attempted to adapt crop production to a saline environment. Households used both chemical and organic fertilizers. Among the chemical fertilizers, urea, sulfate, gypsum, potash, diammonium phosphate (DAP), and triple superphosphate (TSP) were used to reduce salinity with mixed success. There was some concern, however, that chemical fertilizers were harmful when consumed. Moreover, they were costly. As a woman from Satkhira recalled:

> *My husband planted rice for two years but did not succeed… The agricultural officers suggested applying sulfate, gypsum, potash, urea. The officers suggested many more fertilizers I can't name. We used everything. The rice didn't grow. After talking to the officers again, they suggested more fertilizers, and we followed their advice. After that, our pockets were empty, and we didn't go to the agricultural office again. How would the poor have so much money?*

For organic fertilizer, households used animal manure, such as chicken waste or cow dung, compost, ash, decomposed grass, seeds, shells, or some combination of these. Cow dung appeared to be a preferred option, but was less available given that many families had given up raising cows. When mixed with soil, the organic matter helped reduce salinity, though irrigating with freshwater was still considered paramount.

iii. Elevating land

Another method for improving cultivation was to raise the land before sowing, ideally by at least two feet using fresh soil. Elevating the land could happen at various scales: the embankment around a *gher*, a garden, a homestead, or an entire village. To raise a homestead or garden was considered costly. A household with resources could hire laborers to accomplish the task. One NGO sponsored a program whereby groups of villagers would be paid to work together to raise the homestead of each group member. Raising the land provided the additional benefit of protecting it from waterlogging. However, fertilizers and irrigation were still considered necessary. Moreover, elevating the land was not considered a permanent solution; soil could become salinized or the roots of plants would eventually reach a saline layer of soil.

At the village level, government intervention would be required to raise land. At an even larger scale, officials reported that a project known as "Tidal River Management" was being undertaken by the Ministry of Water, which used sluice gates to promote land accretion in lowland areas, elevating and filling them with fertile silt. That land could then be used for agriculture. Some informants reported, however, that *gher* operators had attempted to obstruct Tidal River Management projects.

iv. Soil isolation

Households used various means to isolate soil to grow plants on their homestead, including jute sacks, plastic or Styrofoam containers, and raised beds. These methods were believed to help preserve freshwater content of the soil and prevent saltwater from entering. However, they were suitable for only a few plants at a time. Related to isolating soil was the method of vertical horticulture, whereby vine plants were grown on the roof or on a net raised off the ground. In addition to separating the plants from saline soil, plants were also protected from flooding and waterlogging.

3. *Saline-tolerant plants*

Saline-tolerant plants, particularly crop varietals that had been bred to be saline-tolerant, featured prominently in discussions with government officials and some NGO representatives, who ranked them as one of the most promising salinity adaptation strategies (see Chapter 4). However, they were less emphasized at the community level: some households described growing certain plants that could naturally withstand higher salinity, but few had experience with saline-tolerant hybrid varietals of rice or other crops.

Regarding the first type, many naturally salt-tolerant plants were not food-producing plants, such as *golpata* (whose leaves were used to construct the roof of a house), *shirish* (a wood-producing tree), Napier grass (which could serve as fodder for livestock), and sunflower (grown for oil). In the study area, the research team observed a few fruit-producing trees known for tolerating some soil salinity, such as sapota, wood apple, date palm, and reportedly to a lesser extent, coconut. Vine plants that could grow above the soil, such as bottle gourd, were also popular in homestead cultivation.

Some NGOs distributed seeds or saplings of plants, sometimes for free, other times for sale through agents. Community members reported mixed success cultivating them and sometimes returned the seeds to the NGOs. Several participants felt that the seed vendors affiliated with NGOs were pressuring them to buy seeds, even though the prices charged were higher than what they would pay purchasing them directly from the market.

In terms of saline-tolerant varietals of cereals (rice and wheat) and vegetables (eggplant, tomato, and pumpkin), these were being researched and promoted by the

Ministry of Agriculture, through the Bangladesh Rice Research Institute (BRRI), the Bangladesh Agriculture Research Institute (BARI), the Soil Research Development Institute (SRDI), and the Department of Agricultural Extension (DAE). Although popular as an adaptation strategy among NGO and government stakeholders, there was still skepticism that technology could keep pace with rising salinity levels. Officials stated that current saline-tolerant rice varietals could tolerate up to 10,000 to 12,000 μS/cm, at most, and further scientific progress was needed. For example, one Ministry of Agriculture official from Bagerhat District stated that over a third of the land in his jurisdiction (about 400 km^2) had salinity between 10,000 and 16,000 μS/cm. Another official from Khulna District cited salinity levels of 25,000 to 30,000 μS/cm in his area between January and April, noting that in such a setting no existing technology was effective.

Various stakeholders referenced an additional challenge—the time needed for a varietal to be piloted and scaled up, which could be five years or more, during which salinity may have increased to a point beyond the varietal's tolerance. One NGO representative emphasized that it was important for researchers to anticipate what the salinity level would be in five years so that the varietal would still be successful. His organization attempted to expedite the dissemination process by partnering with the DAE and pairing land-poor farmers with landowners who owned fallow land, so that the land-poor farmers would pilot the seeds in "farmer field laboratories."

A further issue was the use of chemical inputs needed to cultivate the new saline-tolerant varietals. Traditional rice species, such as *shada mota*, *kachra*, *basmati local*, *kasrail*, *chinikani*, and *ghumshi*, were naturally salt-tolerant, but their yields were lower than the high-yielding salt-tolerant varietals developed and promoted by the Ministry of Agriculture. However, one NGO representative cautioned that these new varietals required chemical fertilizers, which would deprive the land of fertility in the future. At the community level, participants voiced concerns about the health impacts of using fertilizers, as well as the cost of chemical inputs. As one farmer from Khulna described:

> *In the past, we grew varietals that had a lower yield, but their taste was better than these new varietals…. The traditional varietals required fewer fertilizers, fewer pesticides. These new varietals have a high production cost… Previously, we used to grow rice in the lowland areas, and there was no noticeable expenditure at all.*

Some villagers with no experience with new salt-tolerant crop varietals expressed willingness to try them, though many continued to stress that having rain or improved irrigation was crucial.

4. *Non-agricultural livelihoods and migration*

Among NGO and government stakeholders, the options of non-agricultural livelihoods and migration received much less support than the other strategies described above. However, at the community level, these options were already being adopted, at least seasonally. As one villager observed:

> *People go wherever they can find work. They are going, they are coming home, and they are leaving again. They return during vacation. This is what has been going on…. They are making their earnings elsewhere. If they sit at home, no one will feed them.*

For example, one man from Bagerhat reported that in rainy season, salinity was still too high for rice to be grown in his village. In another village in the Barisal District, there was rice cultivation, so he worked there for three weeks to one month during the harvest, and was paid in rice by the landowner. Other villagers pursued extractive activities in the Sundarbans mangrove forest, catching fish and crabs, cutting wood, and collecting honey.

In terms of rural-to-urban migration, some households reported that the males went to the Mongla port area to work on shipyards, or to Dhaka city to work as rickshaw pullers. However, various participants described more permanent migration or relocation of the entire household as undesirable, given their uneducated and impoverished status. They doubted they could find work and navigate urban areas, at least without NGO or government assistance.

At the NGO and government level, rural-to-urban migration was nearly universally rejected as an option. The main justification was that it would exacerbate overcrowding in cities. There were also concerns about the ability of rural inhabitants to adapt, and about who would carry on agricultural production in the coastal region if the rural population left. Only one government informant, a former Ministry of Environment official, endorsed the idea of migration, arguing, "*People have the right to live wherever they want*."

In the NGO sector, some organizations did not reject the idea of providing assistance to those who had already migrated, but did not want to do anything that would encourage migration. Two representatives actively supported the migration option, with one individual reasoning that it was inevitable, so NGOs should assist with the process and the government should invest in creating alternative livelihoods and developing industries. The other pointed out that prohibiting the construction of single and two-story buildings, which “wasted space”, could alleviate urban crowding

There was some support from stakeholders for developing off-farm or non-agricultural livelihoods. For example, a former Ministry of Environment suggested that investing in fish and food processing plants would be an appropriate strategy for the country. An atypical perspective among our respondents was offered by one grassroots NGO representative, who linked the development of non-agricultural livelihoods to sustainability, as follows: “*Adaptation is very much needed, no doubt, but at the same time we should transition to economic activities that are not dependent on the climate*.”

Discussion

Using a range of ethnographic and environmental testing methods, this study illustrates in detail how household food production is a multifaceted cornerstone of rural livelihood in the Southwest Coastal Region, and virtually every component of it is being affected by salinity. Our research expands upon previous work, which documents some of the impacts of salinity on food production in the region. These include declines in crop production [27, 106]; reduced agricultural diversity across rice, vegetable, and fruit tree species [25, 27, 107]; and difficulties in managing livestock feed and animal health [108]. In recent years, researchers and governmental and non-governmental organizations have proposed various projects to help farmers cope with salinity. These include saline-tolerant crop varietals [101, 102, 109–113], modifications of cultivation systems [75, 101, 102, 110, 111, 113, 114] and shifts to different animal and plant species [75, 102, 109, 111, 113]. However, while making a compelling case about the impact of salinity, the existing literature provides less insight into what is required for implementation of these adaptation options and what communities and stakeholders perceive as barriers and facilitators to adapting.

Research on the determinants of agricultural adaptation has been conducted in other low-resource settings beyond our study region, focusing on household-level socioeconomic characteristics, with mixed results. For example, in a survey of 718 farmers in Northwestern Bangladesh concerning adaptation to drought, Habiba et al. found that those who were owners of land had more capacity to adopt new technology than those who were owner-cum-tenants or tenant farmers [60]. The conclusion supported the relevance of land ownership, though the findings were based on descriptive statistics only. Sarker et al. expanded on this line of research with micro-econometric analysis of a survey of 550 rice farmers in the same region, and demonstrated that farm size, land ownership, and household assets were all statistically significantly related to the adoption of different rice varietals [115]. However, only 1% of the sample had chosen that as their adaptation method. None of the aforementioned variables were statistically significantly related to increased irrigation, the strategy used by the majority—75%— of their sample.[17] Results from two studies in Africa have also been mixed, with one multi-country study concluding that farm size, but not land tenure, was related to the propensity of farmers to adapt [67], and another study finding that farm size was not related to adaptation in Ethiopia's Nile basin [65].

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[17] Sarker et al.'s methodology, however, relied on the assumption that the probability of adopting one of eight adaptation strategies was independent of the probabilities of selecting another strategy.

Given the specificities of environmental challenges and regional contexts, generalized conclusions may be elusive. One study conducted by Szabo et al. addresses salinity in the Southwest Coastal Region [116], but does not focus on adaptation *per se*; nonetheless its findings may be informative. Researchers examined the relationship between soil salinity and household food security, and found that although salinity was negatively associated with food security, this association was not statistically significant after adjusting for household wealth. More significant predictors of food insecurity were wealth, education, and remittances received by the household. Szabo and colleagues interpreted these results to mean that environmental conditions can exacerbate food insecurity but socioeconomic factors remain crucial. However, an alternative interpretation that we would offer is that adaptive behaviors (not surveyed in their study) may be serving as mediators, and the afore-mentioned predictors facilitate those behaviors.

In contributing to the literature on adaptation, our findings suggest that salinity adaptation efforts have been limited in their uptake and/or success, and highlight the issue of access as a principal concern. On the one hand, there are some low-cost innovations that households claim to have devised themselves or followed in the example of their neighbors, such as raised beds and growing plants in containers, but these are regarded as useful for only a fraction of their cultivation. On the other hand, innovations that households perceive to be more promising, such as improved irrigation and elevating cropland, are considered unattainable because of the time and money required to pursue them. In our structured household visits, we found that in hot season, in particular, many gardens displayed poor growth or lay partially or completely fallow, and production was insufficient to meet the households' consumption requirements. The vast majority of households manifested never having received any assistance or advice from NGOs or government workers regarding the cultivation of their homestead gardens. While some researchers have suggested that homestead cultivation itself is a strategy to adapt or cope with salinity [71, 102, 108], our data indicate that more proactive and widespread support is needed to improve the success of this activity. For example, Abedin and Shaw suggest that rapid and deep tillage may help regulate soil salinity, moisture, and permeability [102]. However, such a modification to tillage would require mechanized tilling equipment, and again external assistance would likely be needed to make the adaptation readily attainable.

Improved irrigation was another strategy generally found to be inaccessible to households. At the community level, numerous participants emphasized the importance of improved irrigation above all other potential methods for adapting agricultural production to salinization. However, very few households had the means to irrigate their crops during the months when irrigation was most necessary, as an adequate groundwater supply was generally unavailable and most families lacked capacity for storing freshwater (they had no rainwater-harvesting tanks, their ponds were insufficiently large to maintain a supply of water through hot season, or they did not have a way to insulate their ponds from salinity). This finding is reinforced by a survey conducted by Jodder and colleagues, in which 100 Khulna-based farmers reported that lack of freshwater for irrigation near their cultivated areas was the biggest obstacle they faced in addressing salinity; over 90% of the respondents deemed this a problem of "high" or "medium" importance [71]. At the same time, 70% of respondents identified the lack of NGO and government support as a factor of "high" or "medium" significance.

A recent study by Bernier et al. in eight villages located in Bagerhat and Satkhira Districts documented community perspectives on irrigation in further detail [117]. On the one hand, in a structured activity whereby participants ranked "water challenges," cyclones, drinking water, drought, and flood were all deemed more important than irrigation. However, irrigation was widely perceived to have clear and positive impacts on the livelihood strategies adopted by survey respondents. This seeming contradiction could be explained by weaknesses noted in irrigation schemes as they currently existed: irrigation was costly, such that agriculture was not profitable, even with irrigation; there were doubts about whether sources of irrigation water, now plentiful, would be sustainable; efficiency in irrigation, not just access to water, was also a concern, especially given uncertainty about sustainability; irrigation required pumps (and sometimes tubewells for extracting water), creating disparities between those who could afford the infrastructure and those who could not; and finally, irrigation and water management generally were encumbered by manipulation of sluice gate infrastructure. Bernier and colleagues thus concluded that irrigation expansion should be prioritized only after water governance and equity were ensured.

Our results, which similarly reflect the importance of equity/access and governance especially over sluice gate infrastructure, provide additional support for this recommendation. The resource-intensive nature of improving irrigation postulates the involvement of various external actors. Supposedly, the Government of Bangladesh has prioritized the Southwest Coastal Region for investment in irrigation expansion [117].

Yet interviews with the Ministry of Agriculture and the Ministry of Water suggest that efforts to excavate silted ponds, rivers, and canals to create reservoirs for holding rainwater, which could then be used for irrigation and drinking water, are still incipient. A plan to deliver the water and make it physically accessible at the village or household level appears even more inchoate. This raises the question of who would be benefitting from the expansion of irrigation infrastructure, were it to be realized.

Another adaptation option, now actively promoted by scientific experts [18, 25, 58] and by at least two of the NGOs we interviewed in the region, is freshwater prawn cultivation (*golda*, or *Macrobrachium rosenbergii*), as a replacement for saltwater shrimp (*bagda*) aquaculture. Rahman, Lund, and Bryceson, for example, point to *golda* cultivation as a promising "environmentally-friendly" adaptation strategy that has been successful in other Asian countries because *golda* predate on insects that harm rice cultivation and increase soil fertility [25]. Moreover, the shift away from *bagda* cultivation could help lower salinity levels, contributing to restoration of the land. In this regard, Belton [118] and Faruque et al. [119] conducted case studies in Khulna and Bagerhat Districts, respectively, in which they compared a village with *golda* farming to one with *bagda* farming, and found that the former, which allowed for mixed rice-prawn-fish cultivation, seemed to provide greater well-being, food security, and nutrition security for those aquaculture-farming households. However, researchers have also noted that *golda* are relatively capital-intensive, as they feed on larger food items than *bagda* do and require supplementary feed [118, 120]. While Belton found that gains from freshwater prawn production were distributed relatively equitably at the village level [118], Johnson and colleagues [120] concluded otherwise from conducting a geospatial analysis to examine salinity, shrimp farming, and poverty at the union level. Covering our three districts and others in the south central and southwestern coastal zones, Johnson et al. demonstrated that poverty clustered strongly with intensity of salinization, but neither saltwater nor freshwater shrimp farming was significantly associated with poverty. They deduced that both types of aquaculture might produce economic benefits for intermediaries and external investors, but not for the poor and marginalized. Rather, poverty was associated with salinization, waterlogging, infrastructure, education, employment, and other variables that suggested the need for more area-specific targeted interventions.

In short, accessibility would be an important consideration in the promotion of ‘eco-friendly shrimp farming’ as an adaptation strategy. Across our study sites, the option was infrequently discussed or observed. This may be partially due to the fact that *ghers* and ponds were considered too saline for *golda*; however, only about a quarter of households cultivated any amount of *golda* in either season, including in rainy season when salinity of surface water decreased enough for the cultivation of other freshwater fish.

Another general concern highlighted by our results is distinguishing whether salinity in the Southwest Coastal Region is truly a limit, as opposed to a barrier, to adapting agricultural livelihoods. Moser and Ekstrom provide an analytical framework for understanding the challenges to adaptation, which emphasizes the distinction between limits and barriers [121]. Limits are obstacles that are ‘real’ in the sense that they invoke “*thresholds beyond which existing activities, land uses, ecosystems, species, sustenance, or system states cannot be maintained, not even in a modified fashion,*” whereas barriers are "*seeming limits…that can be overcome with concerted effort, creative management, change of thinking, prioritization, and related shifts in resources, land uses, institutions, etc*."

As stakeholder and community discussions on saltwater shrimp aquaculture revealed, salinity at least to some extent can be conceptualized as a barrier, whose parameters are modifiable with a change in land use and improved natural resource management. However, the study results described above (and discussed in greater detail in Chapter 4) revealed no coherent state policy to tackle salinity as a barrier. Regulations to restrict saltwater shrimp farming were not in place, not being effectively enforced, or mentioned only tentatively; regulatory agencies discussed reducing salinity as a political, if not physical, impossibility; and several ministerial representatives described salinity as an immutable characteristic of the region and advocated for increasing saltwater shrimp farming as an adaptation strategy. This contrasts with positions of researchers, such as Johnson and colleagues, who caution, *"[s]hrimp farming in itself induces salinity and might, therefore, be considered a maladaptation…. Some saline shrimp farming has predominantly been branded as an adaptation, whilst failing to address the needs of the poorest in society*" [120]. Similarly, while acknowledging Bangladesh's vulnerability to sea level rise, land subsidence, and sedimentation—issues deemed as research priorities—Sarwar and Islam recommend facilitating long-term desalinization of the land by ending saltwater shrimp cultivation and mangrove deforestation in the region [19].

In the case of salinity, it may be more appropriate to conceive of the barrier-limit distinction as a spectrum, rather than a dichotomy, in light of the complicated conjunction of natural and manmade factors that reportedly contribute to salinity (see Chapter 4).

Moreover, where it lies upon the spectrum is likely very location dependent. More so than any previous study, our salinity testing results provide a glimpse into just how localized salinity can be; therefore site-specific analysis is recommended to determine the extent to which salinity could be reduced by removing barriers to effective natural resource management. To address 'residual' salinity as a *limit* to agricultural production, technology can indeed play a role, though as of yet technology has not advanced and salinity not been reduced such that they are meeting in the middle. Progress in science and governance can both contribute to closing this gap.

Where gaps remain, alternatives such as migration and non-agricultural livelihoods are still perceived as options of last resort. In this vein, the perspectives documented in our research (particularly related to relocation) tend to be reactive, rather than proactive—a stance, which going forward, may warrant adjustment. For example, Rabbani et al. examined adaptation by 360 rice farmers in a salinity- and cyclone-affected area of Satkhira District, and found that farmers adapted by planting saline-tolerant rice varietals, adjusting irrigation practices, and raising seed beds, among other methods [106]. However, 64% of those who had adapted by one or more of these means deemed it ineffective. Consequently, 70% of the sample resorted to non-agricultural changes, specifically taking out loans, reducing household expenditures, and modifying eating habits. Migration was reported by 30%, and researchers envisaged future increases in rural-urban and coastal-central relocation. A more in-depth analysis of the program and policy needs in the areas of migration and non-agricultural livelihoods is pending, and lie beyond the scope of our study. We posit that the "managed retreat" framework could be useful for future work analyzing the prospect of out-migration from the region and comparing it with other case studies: in this framework, the favorable/unfavorable stance toward relocation of two groups of actors—residents and implementing parties—form two axes, creating quadrants with four potential outcomes [122].

Limitations

Limitations of our study pertain to the measurement of salinity in soil and water across our sites. First, given resource constraints and the ethnographic focus of our study, sampling more locations at more times was not possible, but would be recommended to create a more complete picture of salinity at a given locality. Second, the method used to measure soil salinity, which entailed the creation of a 1:5 soil-to-water suspension and estimation of salinity based on a conversion factor, was relatively inexpensive and easy. However, this method may produce overestimates of adjusted salinity values, given that salts may be present in the saturation-extract that are not present or absorbed by the plant roots in actual field conditions [123]. The soil salinity data are nonetheless useful for understanding relative severity and serve to complement findings from the broader study, as well as the literature.

Conclusion

Salinity threatens the food security and livelihoods of the inhabitants of the Southwest Coastal Region, affecting multiple spheres of food production activity, including rice plantation, homestead gardening, livestock cultivation, and aquaculture. Despite a variety of adaptation strategies being proposed, negotiated, and implemented, effective adaptation remains a critical challenge. The general sentiment across our study sites is that those affected do not feel they are receiving the assistance they need. State and non-state actors who are responsible for or otherwise invested in improving the well-being of communities in the region are urged to increase the accessibility of adaptation options, especially targeted irrigation infrastructure. Moreover, ecologic approaches to desalinization, to the extent possible, are strongly recommended. In this regard, salinity in the Southwest Coastal Region is a case study of how successful adaptation to the limits of our physical world will likely require removing political, social, and other barriers to good environmental stewardship.

Chapter 7. Implications for Adaptation Funding: From Perspectives to Policies

The Global and National Context

Situated on the fragile Ganges-Brahmaputra-Meghna Delta, Bangladesh is considered one of the countries most at risk in the world for experiencing the effects of climate change and natural hazards.[18] Regardless of the extent to which one believes increasing salinity is attributed to sea level rise, natural geophysical characteristics, or more proximate human actions that exert environmental impacts, there is one certainty: funding channeled through multilateral, bilateral, and internal mechanisms will be designated for interventions designed to facilitate adaptation and build resilience of those living in salinity-affected areas. An estimated one billion US dollars have already been spent over the past decade on several hundred projects in Bangladesh to address climate change.[19]

Within the framework of the United Nations Framework Convention on Climate Change (UNFCCC), developed countries have committed to providing at least $100 billion USD annually to the Green Climate Fund (GCF) starting in 2020 [124]. The Green Climate Fund allocates funding to "*low-emission and climate-resilient projects and programs*" in developing countries, with a focus on the needs of Least Developed

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[18] The World Bank – Bangladesh: Building Resilience to Climate Change, *available at* http://www.worldbank.org/en/results/2016/10/07/bangladesh-building-resilience-to-climate-change, last visited April 2, 2017.

[19] Huq, Saleemul. "Climate finance in Bangladesh." The Daily Star. April 16, 2016.

Countries (LDCs), Small Island Developing States (SIDS), and African States.[20] Given its status as one of the most climate-vulnerable LDCs, it is anticipated that Bangladesh will receive a substantial part of this funding.[21] The Government of Bangladesh estimates that it requires $40 billion USD between 2015 and 2030 for adaptation measures it has identified, with $3 billion and $8 billion specifically targeting "*salinity intrusion and coastal protection*" and "*food security and livelihood and health protection (including water security)*," respectively [125].

The crucial ethical and practical question that arises is how the funds Bangladesh receives can be spent most effectively. How do we ensure that programs and policies promote concrete gains in the physical and mental well-being of affected populations, as well as environmental sustainability? How do we guarantee that the most vulnerable are prioritized to the fullest extent possible?

Between 2011 and 2013, Transparency International Bangladesh conducted an assessment of climate finance governance in Bangladesh, noting several major concerns: (1) there was no consolidated database of climate financed projects in Bangladesh, which made it difficult to deduce the amount of funds being spent; (2) there was a lack of transparency on governmental and non-governmental projects that were receiving funding channeled through the country's internal mechanisms; (3) entities trying to apply for available funding did not know the decision-making processes behind selection of projects, and there had been recent scandals in the press about corruption and conflicts of interest; (4) civil society had limited involvement in helping ensure that there was

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[20] Green Climate Fund – The Green Climate Fund Mission, *available at* http://www.greenclimate.fund/about-gcf/global-context#mission, last visited April 2, 2017.
[21] Huq, Saleemul. "Climate finance in Bangladesh." The Daily Star. April 16, 2016.

transparency or that funds were being spent on their intended purposes; and (5) no independent mechanism existed for the denouncing of cases of fraud and corruption observed in executing climate change funding [126]. Transparency International associated these problems particularly with the Bangladesh Climate Change Trust Fund,[22] which allocated national funds for climate activities, and the Bangladesh Climate Change Resilience Fund,[23] which was set up by donors and managed by the World Bank to channel bilateral aid for climate activities in Bangladesh.

The landscape of climate finance in Bangladesh has evolved since the publication of Transparency International's report. In a controversial move, the World Bank and donors decided to shut down the Resilience Fund, which had been a politically controverted mechanism since its inception.[24] Currently, a new requirement imposed by the GCF stipulates that each developing country appoint a National Designated Authority (NDA), which will serve as an interface between the country and the GCF, and which will approve the national organizations allowed to apply for funding from the GCF, known as National Implementing Entities (NIEs).[25] NIEs can be governmental, private sector, or civil society organizations. The Economic Resources Division of the Ministry of Finance was recently appointed as Bangladesh's NDA and is now entrusted with accrediting organizations that wish to attain NIE status.[26] Local experts emphasize that in

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[22] Ministry of Environment and Forests – Bangladesh Climate Change Trust, *available at* http://www.bcct.gov.bd/, last visited April 3, 2017.
[23] The World Bank – Bangladesh Climate Change Resilience Fund, *available at* http://www.worldbank.org/en/news/feature/2012/05/22/bangladesh-climate-change-resilience-fund-bccrf, last visited April 3, 2017.
[24] McVeigh, Karen. "Climate finance dispute prompts Bangladesh to return £13m of UK aid." The Guardian. Nov. 10, 2016.
[25] Green Climate Fund – About National Designated Authorities, *available at* http://www.greenclimate.fund/partners/countries/about-ndas, last visited April 2, 2017.
[26] Huq, Saleemul. "Bringing Global Climate Finance to Bangladesh." The Daily Star. Jan. 25, 2017.

order for Bangladesh to attain global climate funds it must demonstrate the ability to execute funding with "transparent and robust monitoring systems."[27] Moreover, unless the problems noted by Transparency International are redressed, they are likely to be compounded by the challenges observed at the local level during our research.

Local Perspectives on Funding and Aid

Throughout our study, representatives from communities, NGOs, and government entities cited significant challenges related to interventions to address the impact of salinity on water and food security. The main types of challenges involve (1) corruption/nepotism in allocating resources and choosing recipients of aid; (2) unfair or ineffective criteria for selecting beneficiaries; (3) abuse of funds in executing projects; (4) ineffective projects; (5) deficiencies in sustainability of interventions; and (6) minimal intra- and inter-sectorial coordination.

Corruption and Nepotism

In our study areas, government and NGO aid reach communities and households through local politicians, who are in charge of identifying beneficiaries. These local politicians include "chairmen" at the union level (the next jurisdictional unit smaller than a sub-district) and "members" at the ward/village level.[28] According to numerous community respondents, local politicians largely favor their family members and political party supporters when assembling lists of aid recipients or deciding where a given

[27] Huq, Saleemul. "Bringing Global Climate Finance to Bangladesh." The Daily Star. Jan. 25, 2017.
[28] A ward is essentially a village, and typically nine wards form a union.

intervention will be situated. On occasion, they may agree to designate someone as a beneficiary in exchange for receiving a bribe.

Accounts of nepotism were provided not only by members of the general community, but also by key informants, including village-level politicians and NGO fieldworkers. For example, one respondent, who had worked on an NGO's tank distribution program, admitted that some beneficiaries received tanks due to having a good relationship with the local politicians, despite being relatively well off. A former NGO fieldworker pointed out that NGO fieldworkers in charge of distribution might also accept bribes in exchange for selecting someone as a recipient.

Even a few of our respondents who had benefited from close connections with local politicians spoke of corruption and nepotism. One villager recounted that her mother was selected to receive a RWH tank both because she was a widow with no son, *and* because her husband used to work closely with the union chairman as a member of his political party. Another said she often received opportunities to work as a local supervisor of NGO projects because of her close connections with the member and chairman. Her perspective was that local politicians did designate the poor as recipients of aid, but as they were elected to their positions, it was natural for them to also give "favors".

Distribution of aid may be perceived as less susceptible to corruption if done directly by the NGOs, rather than the government. Some respondents recognized that the extent of nepotism in the region has decreased due to public pressure against it and journalists bringing cases of corruption to light. Nevertheless, study participants still manifested little trust in local politicians.

Various recommendations were made about how to control corruption. The primary idea was for NGOs to go door-to-door and visit every household to determine the initial list of recipients based on who was vulnerable. Local politicians could then add to that list, but they could not remove names; in this way, at least some aid would reach those in need. Many of our NGO respondents insisted that they allow a list to be made by local politicians or in an open community meeting, but then subsequently verify the status of every household appearing on the list before distributing the resources. However, in light of the widespread criticism that aid is not reaching the vulnerable, it is unclear to what extent this method functions in practice. A former NGO fieldworker noted that in some cases the NGO, rather than conducting door-to-door visits, delegates that task to someone else in the community. Another participant presented an example of the ward member accompanying an NGO while it conducted door-to-door seed distribution to indicate which families should receive seeds.

Another recommendation offered by respondents is for the NGO to work through a village committee or a trusted intermediary from the village, such as a religious leader or schoolteacher. For example, a schoolteacher in Khulna described how she had been tasked with making a list of beneficiaries because of her position in the community. However, after making the list, the chairman and members reportedly disregarded it, and replaced poorer households she had identified with wealthier ones.

At the root of the problem seems to be the fact that NGOs generally are not permitted to work in the area without local politicians' approval; thus, it is difficult to shield the distribution process from their influence. A key informant from Satkhira told us that the members and chairmen would inform NGOs that there was no need to do a survey, claiming superior knowledge of the community. According to a few NGO representatives, NGOs that would try to work without coordinating with the local politicians would be kicked out of the area.

However, the extent to which local politicians insist on serving as ‘gatekeepers’ may depend on the type of intervention and resource being distributed. According to one respondent who has worked on various NGO projects in Khulna, providing loans for tanks does not require vetting, while providing tanks directly as aid does. A few informants also pointed out that permission to work in the area could be obtained from the central government, rather than the local government, such that contact with the local officials consists more of a “courtesy call.”

Selection Criteria

While it appears that NGOs employ some criteria related to vulnerability (such as widowhood, female-headed households, living on government land, being landless, or earning less than 100 taka per day), most villagers perceive that NGOs are failing to reach the truly vulnerable. A large part of the problem stems not from the criteria themselves but from the corruption issues mentioned above. For example, it was noted in a focus group in Satkhira that someone who was not a widow could bribe local officials to certify her status as a widow.

Another complaint derives from the fact that situations of need are often relative, and many ‘middle-class’ families note that they are left out because they are neither the outright poorest, nor the political elite or wealthy enough to manage on their own. Loans are often the only option available to these families.

A common criterion, which some view with ambivalence, consists of membership in the NGO's *samity*, a cooperative group where members make regular savings deposits and apply for loans. On the one hand, having this criterion could be preferable to giving local politicians complete discretion to determine who is a beneficiary. On the other hand, some villagers are members of multiple *samitys* and can benefit more than once, while others who do not belong to any are left out. Participating in most *samitys* requires having some financial wherewithal, often to the exclusion of the ultra-poor.

On only one occasion did an NGO representative mention that exposure and sensitivity to climate change, and capacity to adapt are factors in selecting beneficiaries. One villager, with experience as a fieldworker on various NGO projects, recommended that surveys be conducted to assess the resources available to every household for water and food production. Items would include distance to freshwater sources, amount of land owned, and proportion of elevated land.

Abuse of Funds in Project Execution

Embezzlement of funds devoted to government projects is reported by communities to occur with some frequency, with local politicians only spending part of the budget on project expenses and pocketing the rest. Infrastructure, as a result, is not properly constructed. NGO respondents echoed concerns about corruption on government projects, perpetrated at all levels, but especially local levels. One NGO representative noted that sub-district and union-level officials in his area "*are constantly thinking about how to make money off of projects*" introduced by NGOs. He noted that NGOs are forced to go through these leaders in order to work there, and implored community members and higher levels of government to hold local government officials accountable. Even some ministry representatives we interviewed noted embezzlement of donor funds on government projects.

There were also examples of NGO workers or contractors embezzling project funds, such as NGO workers writing down fake names of beneficiaries and pocketing the money themselves, or collecting and absconding with cost-sharing contributions from beneficiaries. As a result, respondents urged NGO offices, donors, and auditors to monitor project execution more closely. However, the overall perception is that embezzlement is more common in the government sector, than the NGO sector.

Ineffective Projects

Some criticisms of ineffective projects were directed at NGO interventions, with reports that agricultural inputs provided by them do not yield much success, such as flocks of poultry that die within a year or seeds that are unsuitable for the area. Families taking out NGO loans to purchase inputs for a livelihood activity meet with mixed success, and this may cause “tension” when repayment becomes challenging.

Most concerns, however, relate to poorly planned and ineffective programs at the government level, which was highlighted by both NGO and government respondents. One issue is the perceived lack of competence or integrity on the part of functionaries. For example, an official from the Ministry of Environment critiqued the hiring of unqualified individuals for government positions, and moreover noted problems with unethical behavior at every level of government. An engineer with the Ministry of Agriculture remarked that even the institution’s own officers, who have worked there for

30 years or more, could not tell the difference between a shallow tubewell and a deep tubewell. We directly observed that a high-level Ministry of Health representative based in the Southwest Coastal Region was unaware of the basic purpose of a pond sand filter.

A second issue concerns the problem of top-down planning, with minimal input from those with local or regional expertise. For example, a Ministry of Agriculture engineer described how funds are being allocated by the planning wing of his institution, whose officials are based in Dhaka or Khulna city and infrequently visit affected areas. Another Ministry of Health representative, based in Dhaka himself, reported that policies are being established in the capital without accounting for what the coastal population wants or what health workers in the coastal region think is necessary.

NGO respondents pointed to top-down planning, on the part not only of the government, but also international donors and organizations. The director of a regional NGO criticized the government for rarely consulting affected communities, incorporating local knowledge, and assessing environmental and social impacts before implementing a project. He emphasized that projects funded by the World Bank, US or EU-based donors, UN agencies, and other international NGOs do not consider local perspectives; with few exceptions, these entities view the local population as "foolish or stupid." Similarly, a representative from another small-scale local NGO recounted that in the past, donors used to conduct "head-hunting" to find local organizations working in an area and solicit project proposals from them. Accordingly, this helped to ensure that the projects addressed vulnerability in the target areas. However, as of seven or eight years ago, donors shifted to conducting open bidding, allowing any organization to apply. Organizations not based in the area, who have personnel fluent in English or high-profile experts, have had greater success winning funding. However, these organizations lack a permanent local presence, which purportedly reduces their chances of implementing a successful project. One local grassroots NGO said that while it attempts to partner with NGOs based in Dhaka to apply for grants jointly, either many organizations prefer to work independently or the funding opportunities are only suitable for a single organization.

The director of another NGO noted the need for more "bottom-up" adaptation planning, and some of this has started to occur through the creation of Local Adaptation Plans of Action (LAPAs), which draw on participation of local communities and then become officially endorsed by the necessary authorities so they can be factored into government budgeting. The approach, however, is relatively new in Bangladesh.

Sustainability of Interventions

Maintenance of infrastructure, particularly community-level infrastructure, was perhaps one of the most salient challenges observed. Community and NGO representatives alike described the state of disrepair of many large RWH tanks and PSFs. One NGO representative, for example, noted that several 20,000-liter RWH tanks in the area provided by another NGO were all dysfunctional, and expressed doubt whether his own NGO's tanks would still be operational a few years after the end of the project.

According to several NGO respondents, poor long-term maintenance of hardware derives from communities' "mentality of dependency" on NGO and government actors. The mentality was precipitated or exacerbated by the cyclones that devastated the Southwest Coastal Region in 2007 and 2009, which led to an influx of international humanitarian assistance. Representatives from another NGO, which recently installed PSFs in several sub-districts as part of an $18 million dollar USAID-funded food security enhancement project, even suggested that the government should fine community members for failing to maintain the PSF system. However, the representatives could not tell us how many of the installed PSFs were still operational.

Cost-sharing is widely perceived by stakeholders to contribute to longevity of the intervention, and even many villagers agree with this perspective. However, the amount required on the part of households is sometimes prohibitively high, as discussed in Chapter 5.

The idea that no intervention would be sustainable unless linked to the local government was endorsed by the founder of one NGO. However, various stakeholders pointed to problems of centralization and lack of local government capacity: unions do not have the authority to collect revenue, and therefore it is not in their interest to take on extra responsibilities, such as maintaining a community PSF system. One NGO mentioned that as part of its working procedure, it forms a development plan and seeks validation of the plan from the sub-district government. In theory, validation means that the plan can be factored into the budgeting process at the sub-district level, and the local government at the union and ward levels will take ownership of the plan when they realize there are funds to be obtained.

In light of continued difficulties with hardware interventions, some NGOs are now placing more emphasis on “software,” based on the idea that empowering people through skills training, knowledge, and rights education will produce longer-term impacts. According to representatives from World Vision, donors are also promoting this type of thinking, and almost all NGOs are shifting in that direction. However, one CODEC fieldworker who conducted trainings as part of an aquaculture and nutrition intervention observed that communities have grown accustomed to receiving material support from NGOs, making it difficult for NGOs providing only trainings to engage them.

Other NGOs, such as Rupantar and World Vision, have focused on conforming village committees and community-based organizations, which can attain official status, apply for government aid, and demand their rights from the state. Their goal is that these entities will continue to exist after the NGOs have to withdraw from the area, enduring as an "interface" between communities and the government.

Coordination

NGO and government stakeholders identified the need to strengthen coordination both between and within their own sectors. In terms of inter-sectorial coordination, some NGO representatives encouraged the government to view NGOs as implementing partners, rather than favoring businesses. A Khulna-based Ministry of Agriculture representative pointed out that lack of coordination between government and NGO sectors is leading to duplication of efforts, and recommended that donors play a greater role in promoting NGO-government collaboration.

In terms of coordination within the government sector, according to an official from the Ministry of Environment, it is more difficult to have inter-ministerial coordination at the higher levels (ministerial level or policy-setting level) because the ministries have different strategies, while coordination at the field level among the local representatives of the ministries is less problematic. However, from what we observed, different ministries have disparate positions at the regional and local levels, as well. (See Chapters 4 and 6.)

NGO sector coordination is also considered lacking, and duplication of efforts is an issue, according to several NGO stakeholders. A WaterAid representative noted how each NGO working in a given ward formulates a separate action plan with the ward officials, rather than coming together to form a single coherent plan, while another NGO is aiming to change this scenario by getting their plan endorsed at the sub-district level as the "official" plan.

Lessons Learned

These perspectives, combined with the findings of previous chapters, point toward several recommendations, which may help guide those with capacity to shape the direction of future climate adaptation funding. In the first place, a bottom-up approach to adaptation planning appears to align well with the fact that the salinity situation can be highly location-dependent. In addition, localized needs assessments taking into account social and environmental characteristics relevant to adapting to salinity could indeed help fill some of the gaps in identifying those in need. However, 'bottom-up' does not imply 'uncoordinated.' While specific actions may be location-dependent, different institutions should not be implementing programs and policies in a given location that are contrary to one another.

Second, more scientific processes for evaluating project impacts are required. These would serve the dual purposes of documenting experiences about ineffective versus effective interventions and learning from them, as well as promoting political accountability. Increased partnerships between health research organizations and development actors would be fruitful, given that many of the latter are currently providing infrastructure related to health outcomes (e.g., tubewells, PSFs) but lack expertise and capacity to track them rigorously.

Third, there is an urgent need to promote the capacity of local branches of government ministries to work with local organizations on projects and take ownership of projects, even if these were initially led by NGOs. The burden of maintaining infrastructure is currently falling to communities, which appears to be an unrealistic expectation, especially in areas that lack strong, pre-existing community organizations. Funding should account for joint NGO-government initiatives or ownership transfer, and this is particularly important as interventions become increasingly sophisticated (e.g., MAR systems and perhaps, eventually, desalination).

Finally, we suggest critically examining the tendency for NGOs (and most likely their funders) to favor community-level infrastructure, on the assumption that these interventions more cost-effectively benefit a larger number of individuals. Given communities' perspective that personal ownership would increase responsibility and maintenance, as well as NGO accounts of dysfunctional community-level infrastructure, we see a basis for revisiting that assumption. Regarding water—which is a basic human necessity and fundamental right—it does not seem so far-fetched to recommend that funding be directed toward achieving universal, household-level coverage for the provision of water in poor, rural settings affected by salinity.

Chapter 8. Conclusions

This research has shown that salinity is a serious public health concern in the Southwest Coastal Region, and there is currently no coherent state policy to respond to it. Different government ministries and non-governmental development organizations have assisted affected communities through dispersed efforts, focusing mainly on redressing the impacts of salinity rather than its potentially modifiable causes. From the community perspective, the aid being provided is vastly insufficient against the backdrop of widespread need that exists. Freshwater scarcity causes significant hardship, and aid offered to alleviate water insecurity is often perceived as being unfairly distributed, poorly maintained, or simply non-existent. Food production is another major challenge for most households. Ranging in degree of technological sophistication, various methods to improve cultivation in a saline environment are only partially successful, at best.

This study has aimed to be both comprehensive in covering the multiple facets of the problem of soil and water salinity, and in-depth in understanding the perspectives of those on the ground who are affected by it or working to address it. While this research has focused on salinity as a challenge specific to low-lying coastal areas, some of the study's overall themes provide a glimpse into what we can expect to see, or at least risks to be aware of, as adaptation becomes increasingly necessary in a climate-disrupted and environmentally degraded world.

The first risk is conducting research that is preoccupied with the scientific and technical, while paying less attention to the social and economic. The pace of scientific innovation over the past few decades has been remarkable, and indeed the challenges of climate change and environmental degradation will demand further advances if we wish to survive. However, progress on issues like inequality, marginalization, and corrupt governance, has failed miserably to keep apace. Considering that these factors inhibit equitable environmental adaptation, some re-prioritization of resources on a larger scale is needed. On the smaller scale of what we may do, as public health researchers at the very least our intervention design should take as its starting point formative research to attain authentic understanding of social and economic dynamics.

Related to the first theme, the second is the risk of attributing the 'unnatural' to the 'natural,' or deeming what can be mitigated, immutable. As climate change and other environmental factors are invoked (hopefully in good faith) to marshal resources and spur action, the task of distinguishing limits from barriers is one that will require constant vigilance. Not only should public health professionals ensure that their interventions do not further entrench noxious barriers, but they can also lend their research expertise to elucidating what is technically possible in terms of preventing environmental harm and addressing its root causes.

A final theme is the continued failure to take the realization of social and economic rights seriously. While it is impossible to predict how much resources are required to address the impacts of climate change in least developed countries, such as Bangladesh, it seems likely that the estimates will only increase as the impacts of climate change and other environmental hazards become clearer. Yet already, the realization of the rights to food and water seems merely aspirational, and we can probably expect to see a growing emphasis on cost-effectiveness rationales going forward. While this occurs, those of us believing that food and water are universal human rights will have to act and argue more strategically. Whether this tide will ever turn is a subject for another day.

Epilogue

The dilapidated buildings of provincial government offices in the developing world often appear luxurious compared to the mud houses, mottled leaf roofs, and pit latrines that form the rural dwellings of the outlying countryside. This certainly seemed to be the case in the Khulna region of coastal Bangladesh. These offices were easy to get to, even within walking distance of our guesthouse. It was a complete contrast to the prior months of fieldwork, during which we spent a couple hours every day reaching villages, traversing rutted, unforgiving roads on vehicles that were some variation of a wooden platform mounted on hard metal and attached to a clunky, rudimentary motor. We had completed community-level data collection, and had moved on to collecting information from government and NGO stakeholders. In meeting after meeting with local government officials, the steady stream of tea served to us tasted quite normal—not like tea steeped in saltwater, which we had shared with community members. It might have made it easy to forget the ecological crisis of water and soil salinization that was devastating the local food system and agricultural livelihoods beyond the outskirts of town.

We did not forget this crisis, though, as it was the primary topic of conversation—the topic of my dissertation research carried out over the prior two years. Nearly two hundred hours' worth of recorded conservations with farmers, fishermen, and community leaders had revealed one common theme: that commercial saltwater aquaculture instigated by elite, large landowners—namely, shrimp farming—had exacerbated the intrusion of saltwater into the region, contaminating sources of drinking water, seeping into agricultural land, and depleting the deltaic landscape of its fertility for many months of the year. It was both a social and environmental catastrophe, as the rich became richer, subsistence agriculture became unattainable, and the land-poor grew evermore food insecure. We were thus anxious to hear the views of local officials and engage with them on how these problems might be addressed.

We weren't walking into this phase of stakeholder interviews naïvely. Between the three members of the team, we had local expertise, prior experience engaging with Bangladeshi policymakers, and an appropriate dose of cynicism derived from protracted confrontations with corrupt and/or inept officials in several countries. And we knew the various ministries would have different interests: Agriculture, at least within Ag Extension, would probably be the most sympathetic to the peasant farmers; Water would favor large-scale coastal engineering projects that would suffer from bureaucratic hold-ups; Environment might profess concern, but prioritize more visible problems, like brick kiln pollution and deforestation; and Fisheries would be the most difficult to confront, as it favored the development of an aquaculture industry and increasing Bangladeshi shrimp exports. We would be careful not to mention the controversial topic of shrimp farming as a cause of salinity, unless the officials did so first; rather, we would focus on the impacts of salinity, from a public health perspective.

Yet somehow we were unprepared for the most antagonistic response we would receive in Khulna, perhaps because it came from the entity we thought would be our most likely ally: the Ministry of Health. We had requested, in-person, an interview with the local representative, giving him a brief overview of what we planned to discuss. The next day, when we entered his office at the scheduled time, seated beside him was his "friend," a man from the Fisheries Department, whom he had invited to our meeting. The two were adamant. From our questions about the impacts of salinity on health, they had assumed we were there to stop shrimp farming and demanded to know why. *Shrimp farming provided an income and made everyone better off*; *salinity was a completely unrelated problem, a 'natural' phenomenon attributed to climatic changes and proximity to the sea*. Nothing was being done by the Ministry of Health to help communities cope with the salinity-induced food and water crises, or with the health impacts of climate change for that matter. The Ministry only stocked the health clinics with some ointment, bandages, and oral rehydration solution, a seemingly meager response to the likely occurrence of a natural disaster, such as a major cyclone. Impatient and dismissive, the representative claimed that after such a disaster, the situation would return to normal after one month—an absurd statement that not only revealed the extent of his (willful?) ignorance but also contradicted farmer reports of reduced soil fertility, attributed to tidal flooding from the last major cyclone 7 years ago, which to this day affects the region's food security.

Out of over a hundred interviews, this was the one that left me most stunned, most dismayed. Partly, it was the (if only informal) collusion between Health and Fisheries. Mostly, it was the fact that the one institution charged with protecting the public's health so categorically rejected any constructive dialogue on how to face the dramatic food and water crises caused by salinity—regardless of what one thought were its causes. And so, as I completed my fieldwork, as I completed my time in Bangladesh, and as I completed what would most likely be the last year of formal education in my lifetime, I was increasingly convinced that the truest, hardest-to-reach populations were those most centrally located, situated comfortably at the locus of power, and *not* the dispersed, distant rural villages beyond the outskirts of town.

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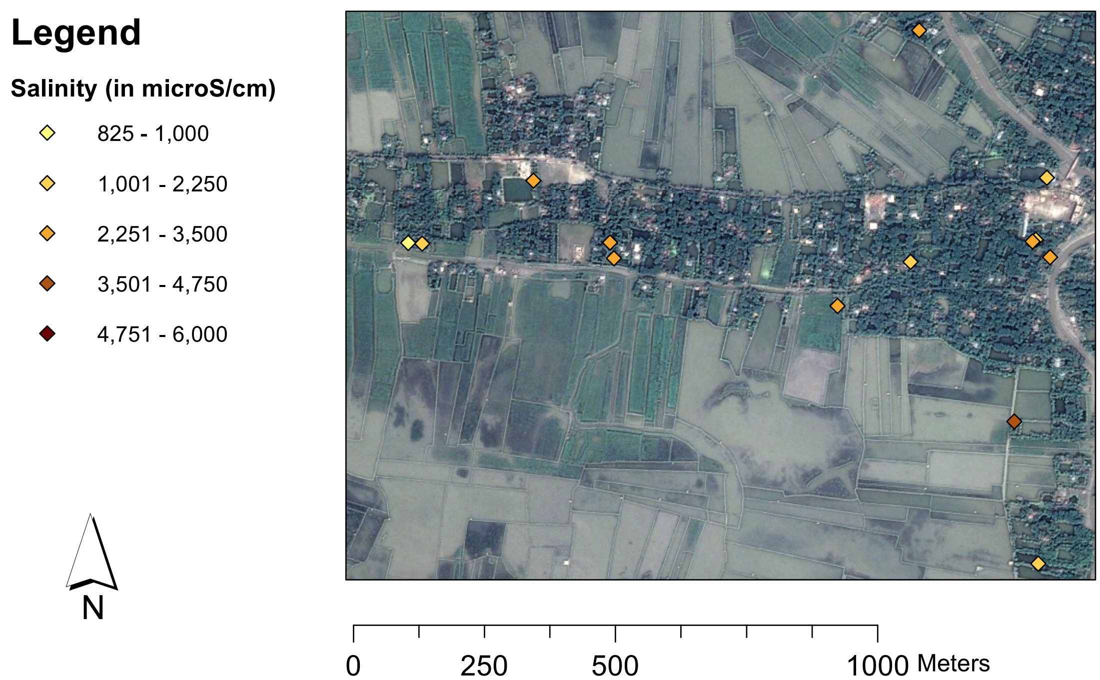
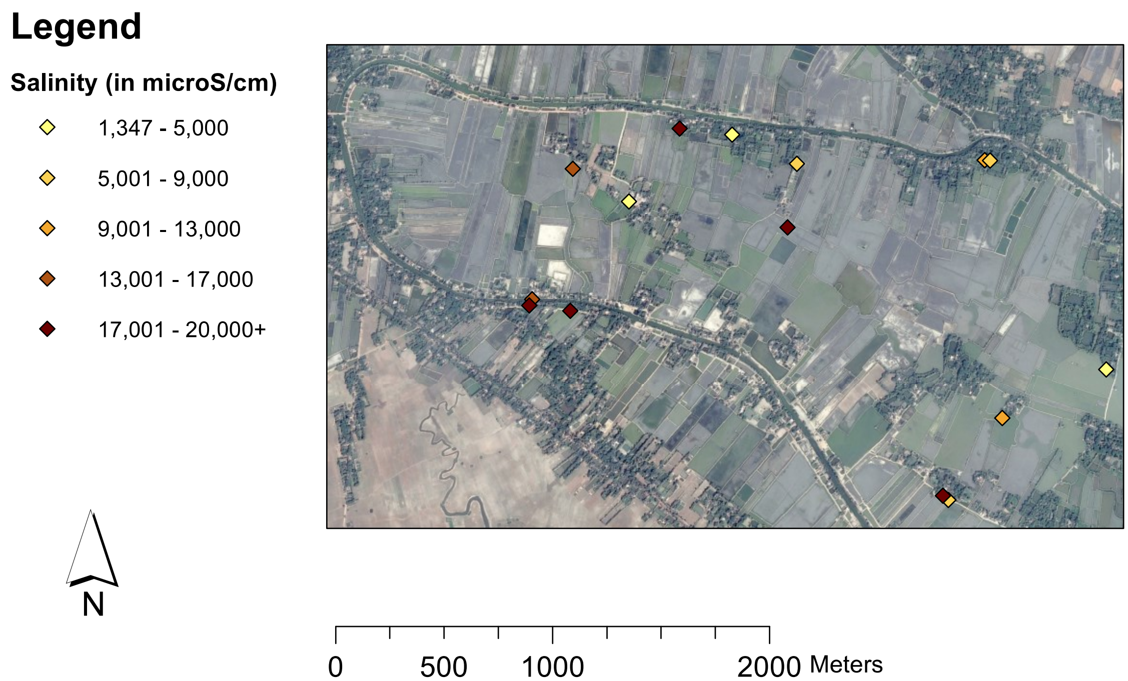
Appendix

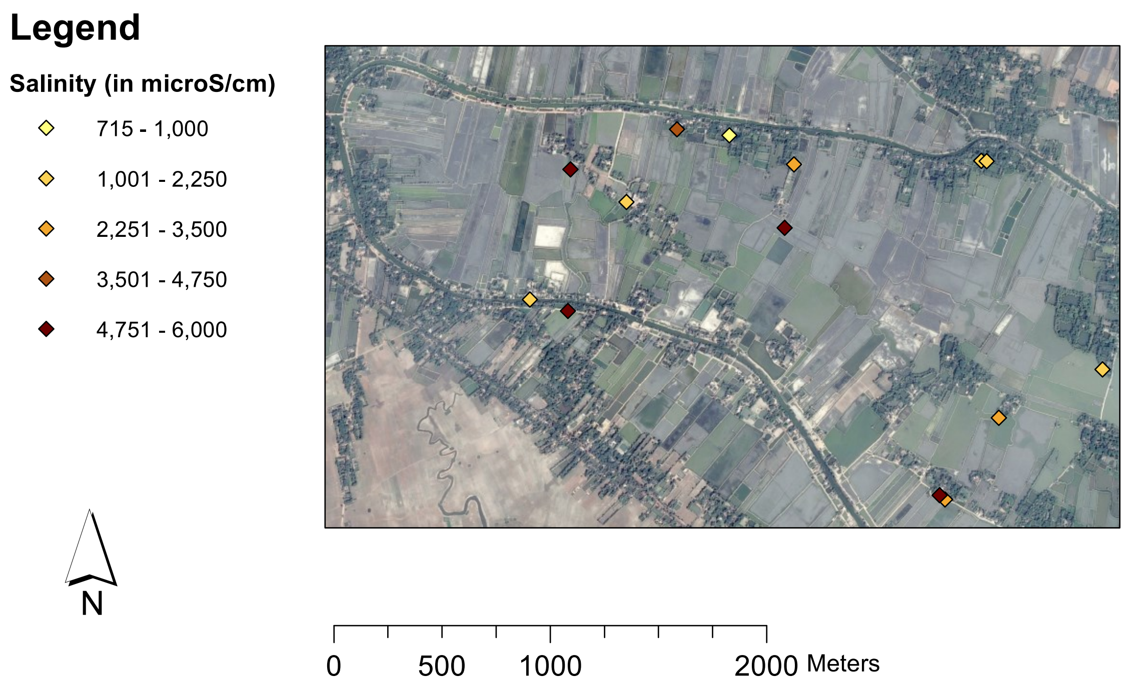
Google Earth Image of Bagerhat site surface water salinity, October 2015



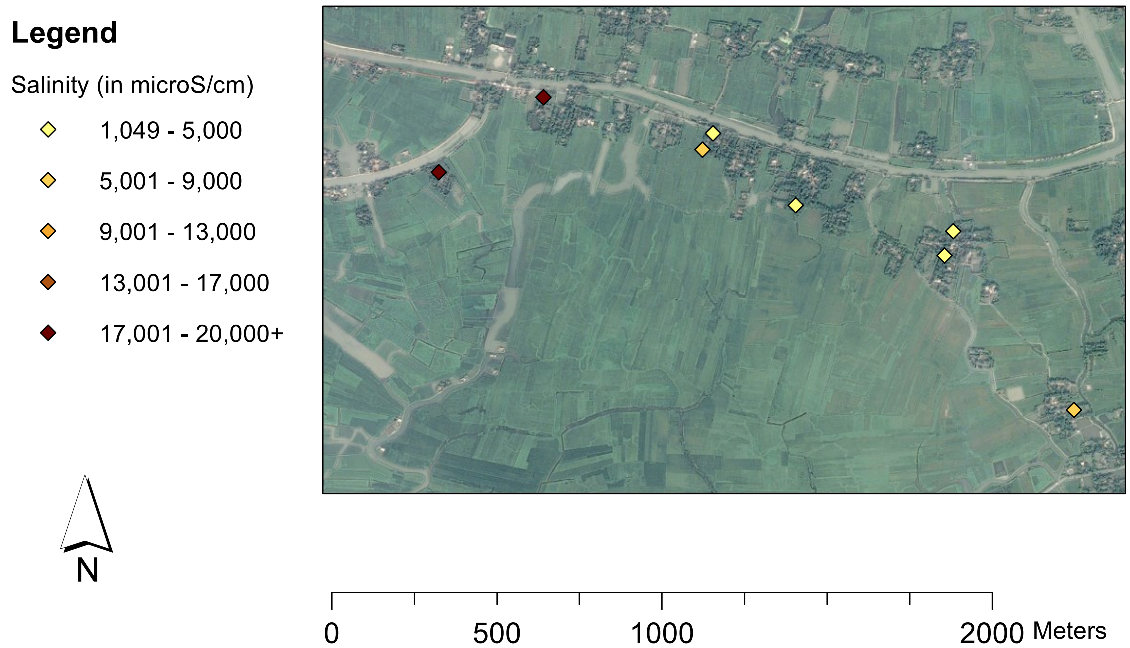
Google Earth Image of Satkhira site surface water salinity, June 2015



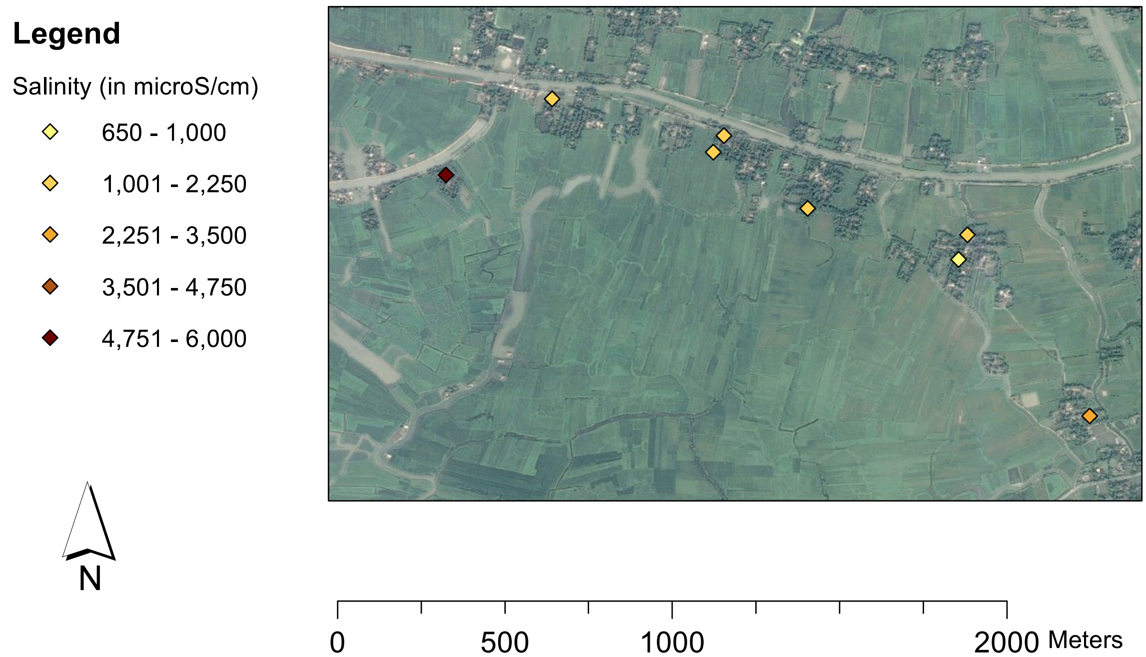
Google Earth Image of Satkhira site surface water salinity, October 2015



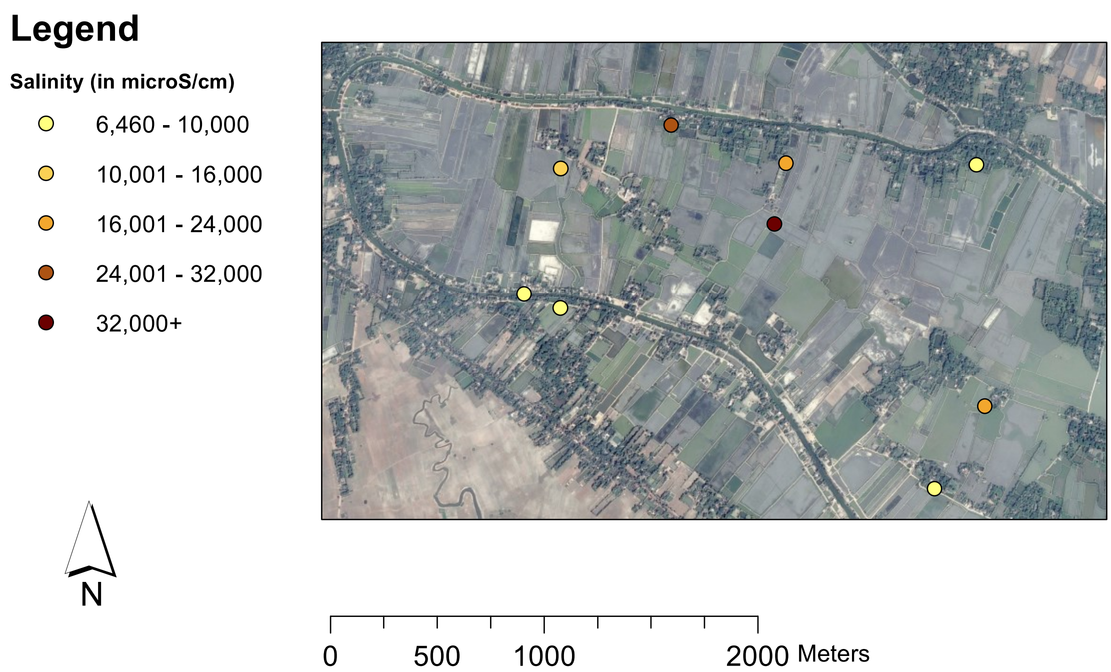
Google Earth Image of Khulna site surface water salinity, June 2015



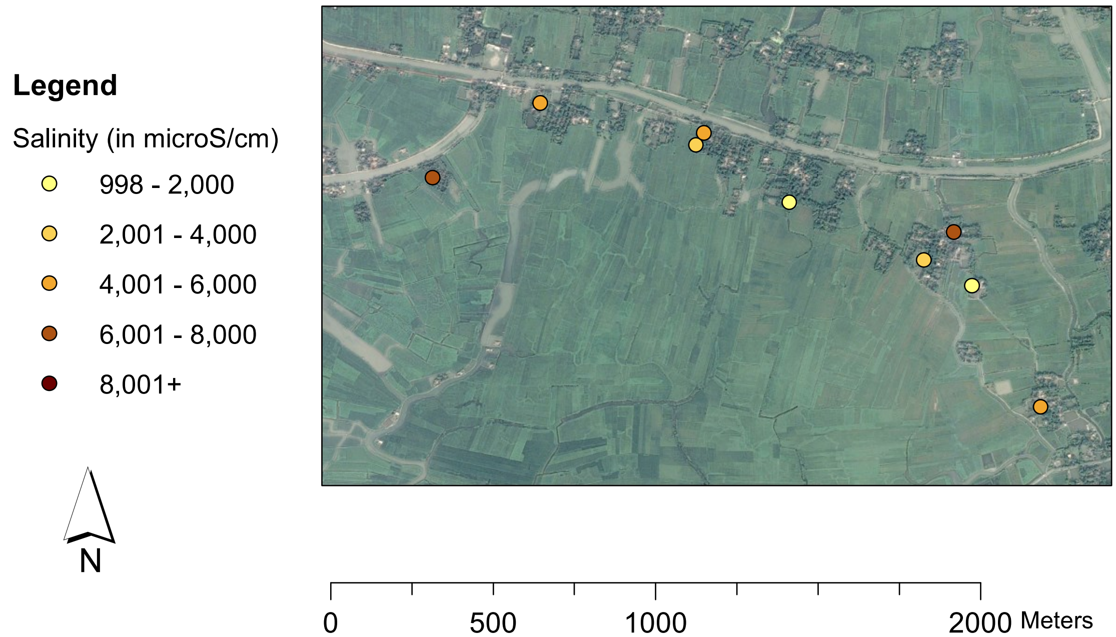
Google Earth Image of Khulna site surface water salinity, October 2015



Google Earth image of Satkhira site soil sample locations



Google Earth image of Khulna site soil sample locations



Initial Household Interview Guide

[*Please note that the same interview guide and visit instrument will be used for the follow-up interviews and visits, with the researcher probing with greater emphasis about seasonal differences and new developments. After obtaining consent and permission to record the interview, proceed with the following introduction.*]

Thank you for meeting with me today. I'm interested in learning about how rural households in this region make a living, how they produce food, where they get water, and any challenges they face due to environmental conditions. I'm also interested in hearing what you think NGOs and governmental institutions should be doing to improve food production or access to water for your household or community.

We will start with an interview. After the interview, I will ask you to show me different parts of your household related to the topics we are discussing. The questions I am going to ask don't have right or wrong answers. Remember that this conversation is completely confidential, and we can skip any question you prefer not to answer.

Do you have any questions before we proceed? [*Answer any questions.*]

PART 1: Interview Guide

Topic #1: Basic Information

How old are you?

What is your relationship to the household head?

How long have you lived in this community?

What do you do for a living?

Topic #2: Seasonality

[*The following activity is meant to elicit participants' understanding of seasons and seasonal events, and the terms used to describe them. The steps are as follows:*]

i) Start with a month pile sort. We present the twelve months of the Bengali calendar to the participant and ask him/her to pile sort those months into seasons according to their experience. Since participants' inclination may be to sort into the six official seasons, give them specific instructions to sort into piles according to what *they* consider most important nowadays (they might think there are fewer/more than six seasons, etc.).

ii) For each pile, ask the participant to describe: (1) what that period would be called; (2) the temperature; (3) amount of rainfall; (4) degree of salinity in general (i.e., considering soil, water, all sources of groundwater and surface water).

iii) Confirm with the participant during which period salinity is the most severe, and during which period salinity is the least severe.

[***Important note****: In the subsequent questions in this interview guide and visit instrument, the time of most severe salinity is called "dry season" and the time of least severe salinity is called "rainy season," but the interviewer should replace these terms with the terms used by the participant. The terms "dry season" and "rainy season" always appear in brackets below to remind the interviewer to do this. If the participant says that the salinity situation is the same year-round, then use the terms used by the participant to describe the periods with least and greatest rainfall. Some of the other questions also tell the interviewer to probe about seasonal differences. In those cases, the interviewer should use the names of the seasons, periods, or transition intervals elicited here. The word, 'season', itself may be replaced with a more culturally relevant term.*]

Topic #3: Water

Drinking water

Would you please list the different sources of the household's drinking water during the [dry season]? Can you please describe these sources? [*Ask specifically for location of each source, distance to the source, a description of the type of source it is.*]

How is this water collected? [*Probe who is responsible for this, and how long it takes the person to get the water.*]

How is the water stored?

How long is it stored there?

Is anything done to the water before drinking? [*See if the participant mentions any kind of treatment or boiling.*]

How would you describe the <u>quality</u> of water during the [dry season]? [*Probe about appearance, taste, and safety.*]

[*See if the participant mentions salinity in describing the taste of the water. If the participant says that the drinking water has a salinity problem, then ask the participant the following things:*]

- How do you know that the water is saline?
- What do you think causes the salinity problem in drinking water during the [dry season]?
- How long (for example, how many years) has salinity in your drinking water during the [dry season] been a problem? Have there been any changes over time?
- What happens if someone drinks water that is saline? [*Probe about whether they perceive any negative health outcomes due to drinking salty water.*]
- Has your household done anything differently because of salinity in drinking water during [dry season]?[*If so, get details on what they did, why they did it, how was it made possible, who made the decision, do they feel like it worked. Try to get a detailed story.*]
- [*After letting the participant explain strategies they have tried, probe about specific strategies that were not mentioned, such as the following:*]
    - Not drinking tubewell water
    - Rainwater harvesting
    - Saving water [*ask when and how*]
    - Drinking less water
    - Using the household's own pond water [*ask if filtered or not*]

- Using a community pond water source [*ask if filtered or not*]
- Using a different type of tubewell
- Purchasing water [*probe about where it is from, how much it costs, how is the quality of this water*]
- Finding some other source of water

- Is there any <u>new strategy</u> to deal with salinity that you have not tried, but perhaps you have seen other people use? Would your household be interested in trying it? What would help your household do so? [*Probe on whether they think they need outside help, from whom, and what kind of help – like receiving something for free, getting a loan, training, or other technical support.*]
- How would the decision to try this new strategy be made by your household? Would permission from a specific household member, neighbors, or someone else in the community be needed?

How would you describe the <u>quantity</u> of the water during [dry season]? [*See if the participant indicates that the water is not enough. If quantity is insufficient, what has the household done to address this?*]

Would you please list the different sources of the household's drinking water during the [rainy season]? Can you please describe these sources? [*Ask specifically for location of each source, distance to the source, a description of the type of source it is.*]

How is this water collected? [*Probe who is responsible for this, and how long it takes the person to get the water.*]

How is this water stored?

How long is it stored there?

Is anything done to the water before drinking? [*See if the participant mentions any kind of treatment or boiling.*]

How would you describe the <u>quality</u> of water during the [rainy season]? [*Probe about appearance, taste, and safety.*]

[*See if the participant mentions salinity in describing the taste of the water during "rainy season." If the participant says that the drinking water has a salinity problem, then ask the participant the following things:*]

- How do you know that the water is saline?
- What do you think causes the salinity problem in drinking water during the [rainy season]? [*Probe on why the rain is not enough to help dilute the salinity.*]
- How long has salinity in your drinking water during the [rainy season] been a problem? Have there been any changes over time?
- Has your household done anything differently because of salinity in drinking water during the [rainy season]?[*If so, get details on what they did, why they did it, how was it made possible, who made the decision, do they feel like it worked. Try to get a detailed story.*]
- Is there any <u>new strategy</u> to deal with salinity that you have not tried, but perhaps you have seen other people use? Would your household be interested in trying it? What would help your household do so? [*Probe on whether they think they need outside help,*

from whom, and what kind of help – like receiving something for free, getting a loan, training, or other technical support.]

- How would the decision to try this new strategy be made by your household? Would permission from a specific household member, neighbors, or someone else in the community be needed?

How would you describe the quantity of the water during [rainy season]? [*See if the participant indicates that the water is not enough. If quantity is insufficient, what has the household done to address this?*]

Water for other domestic uses

Would you please list the different sources of your household's cooking water? Can you please describe these sources? [*Ask specifically for location of each source, distance to the source, a description of the type of source it is.*]

How is this water collected?

Can you describe the quantity of this water? [*Find out if the water is enough. If it is not enough, how has the household addressed this?*]

Can you describe the quality of this water? [*Probe about appearance, taste and safety. Wait to see if the participant mentions salinity as a problem. If the participant does not mention salinity, then you can ask directly whether the participant notices salinity in the water used for cooking. If salinity has been noticed in the water, ask the participant how he/she knows that the water is saline. Then ask what he/she thinks are the health impacts of using saline water to cook with.*]

Between [dry season] and [rainy season], are there differences in the quantity or quality of the water your household uses for cooking? Please describe how things are different between [dry] and [rainy seasons].

Has your household done anything differently because of salinity in water used for cooking?[*If so, get details on what they did, why they did it, how was it made possible, who made the decision, do they feel like it worked. Try to get a detailed story.*]

Would you please list the different sources of water used by your household for bathing and personal hygiene? Can you please describe where people in your household get water for bathing and personal hygiene? [*Ask specifically for location of each source, distance to the source, a description of the type of source it is.*]

Can you describe the quantity of this water? [*Find out if the water is enough. If it is not enough, how has the household addressed this?*]

Can you describe the quality of this water? [*Probe about appearance and cleanliness. Wait to see if the participant mentions salinity as a problem. If the participant does not mention salinity, then you can ask directly whether the participant notices salinity in the water used for bathing and personal hygiene. If salinity has been noticed in the water, ask the participant how he/she knows that the water is saline. Then ask what he/she thinks are the health impacts of using saline water for bathing and personal hygiene.*]

Between [dry season] and [rainy season], are there differences in the quantity or quality of the water your household uses for bathing and personal hygiene? Please describe how things are different between [dry] and [rainy seasons].

Has your household done anything differently because of salinity in water used for bathing and personal hygiene?[*If so, get details on what they did, why they did it, how was it made possible, who made the decision, do they feel like it worked. Try to get a detailed story.*]

Is there any new strategy to deal with salinity in water used for cooking, bathing or personal hygiene that you have not tried, but perhaps you have seen other people use? Would your household be interested in trying it? What would help your household do so? [*Probe on whether they think they need outside help, from whom, and what kind of help – like receiving something for free, getting a loan, training, or other technical support.*]

How would the decision to try this new strategy be made by your household? Would permission from a specific household member, neighbors, or someone else in the community be needed?

Topic #4: Crops and other plants

What kinds of plants or crops does the household grow or used to grow? [*We are also interested if there is a plant/crop that used to be very important to the household's livelihood. Make sure you probe for fruit, vegetables, cash crops, fodder and tree crops. Get a sense of which are the most important for the household's livelihood. Then, starting with more important to less important, probe for details:*]

- Does your household still grow this plant/crop? If not, how long ago did you stop?
- Who in the household is/was responsible for it? Who does/did most of the work?
- Where is/was it planted? (Household's garden? Household's own farm? Someone else's farm?)
- What time of year does/did planting occur? [*Use terms elicited during Topic #2 on "Seasonality."*]
- Is/was it irrigated, and if so, how?
- When is/was it harvested? [*Use terms elicited during Topic #2 on "Seasonality."*]
- How much is/was harvested?
- What is/was done with the harvest? (Consumed by the household? Given to relatives? Sold? If sold, then when was the last time it was sold? Some other outcome?)
- What would be considered a 'good' harvest versus a 'bad' harvest? [*Ask in terms of quantity and quality of the produce.*]
- What factors contribute to a good growing season?
- What factors contribute to a bad growing season?

[*If salinity comes up as one of the influential factors, then probe for more details:*]

- Is it a problem with soil salinity, the salinity of the irrigation water, or both?
- How can you tell that the soil is saline?
- How does/did soil salinity affect the plant or crop?
- How long has soil salinity been a problem? What changes have you noticed over time? [*To aid memory of dates, refer to events such as cyclones Aila in 2009 and Sidr in 2007.*]
- What changes are there in soil salinity by season? [*Use terms elicited during Topic #2 on "Seasonality."*]

- How can you tell that the irrigation water is saline?
- How does/did salinity of irrigation water affect the plant or crop?
- How long has salinity of irrigation water been a problem? What changes have you noticed over time? [*To aid memory of dates, refer to events such as cyclones Aila in 2009 and Sidr in 2007*.]
- What changes are there in salinity of irrigation water by season? [*Use terms elicited during Topic #2 on "Seasonality."*]
- Has your household done anything differently because of <u>either</u> soil salinity or salinity of irrigation water? [*If so, get details on what they did, why they did it, how was it made possible, who made the decision, do they feel like it worked. Try to get a detailed story.*]
- [*After letting the participant explain strategies they have tried, then probe about specific strategies that were not mentioned, such as the following:*]
    - o Irrigation or improved irrigation [*Get details on <u>sources of irrigation water</u> and whether irrigation water itself has a salinity problem.*]
    - o Introduction of new plants or varietals of plants [*Get details on the new crops, if the crops are saline tolerant, why they made that decision, who decided, did anyone help them, do they feel like it has been successful.*]
    - o Stop growing a crop completely or during a certain time of year [*Get details on why they did, who made the decision, what they are doing instead.*]
    - o Raised beds or tower gardens
    - o Improved drainage
    - o Changing timing of planting
    - o Mixing organic matter into soil, such as grape seed or cow dung
    - o Adding minerals (such as gypsum), chemical fertilizers, or some other material to the soil
    - o Bringing in soil from some other area that is not saline
    - o Pocket ghers [*ask the participant to explain what this is*]
- Is there any new strategy to deal with salinity that you have not tried, but perhaps you have seen other people use? Would your household be interested in trying it? What would help your household do so? [*Probe on whether they think they need outside help, from whom, and what kind of help – like receiving something for free, getting a loan, training, or other technical support.*]
- How would the decision to try this new strategy be made by your household? Would permission from a specific household member, neighbors, or someone else in the community be needed?

Topic #5: Animal agriculture

What kinds of food-producing animals does your family keep or used to keep? [*Get a sense of which are the most important farm animals for the household, and then starting with the most important ones, probe on the following details*:]

- Does your household still have this type of animal? If not, how long ago did you stop raising this type of animal?
- How many animals of that type does the household keep at one time, on average?
- Who in the household is/was responsible for those animals?
- What is/was the purpose of raising those animals? (Is/was it for the household's own consumption? Is/was it sold? Where is/was it sold? When was the last time it was sold?)
- Where are/were the animals kept?

- What foods/grains/forage do/did the animals consume?
- Does/did the household grow anything to feed to the animals?
- Does/did the household give anything else to the animals, such as medicines, supplements or anything else? [*If yes, ask if they have the medication/supplement container(s) to examine and note the name and ingredients, and ask the following questions:*]
    - Why did you use the product? What was the outcome of using the product? [*For example, if the animals were sick, did they get better?*]
- [*If the household still currently raises that animal, then ask:*] How do you describe the current situation of those animals? Are they healthy? Do they produce good quality meat / eggs / whatever food product they are raised for?
- What are/were the biggest challenges in raising those animals?
- Does/did salinity have any impact on those animals' health? If so, how? [*Give the participant an opportunity to answer the question. Then when he/she is done, you can probe specifically about these things if they are applicable:*]
    - Does/did salinity affect the availability of pastures for grazing? [*Probe: How severe is this problem? During what times of year is this a problem? Use the terms elicited during Topic #2 on "Seasonality."*]
    - Does/did salinity affect the amount of fertile land used for growing fodder to feed the animals? [*Probe: How severe is this problem? During what times of year is this a problem? Use the terms elicited during Topic #2 on "Seasonality."*]
    - Does/did salinity affect the availability of freshwater for the animals to drink? [*Probe: How severe is this problem? During what times of year is this a problem? Use the terms elicited during Topic #2 on "Seasonality."*]
- Have you changed any aspect about the way you raise/raised those animals due to salinity? [*If so, get details on what they did, why they did it, how was it made possible, who made the decision, do they feel like it worked. Try to get a detailed story.*]
- [*After letting the participant explain strategies they have tried, then probe about specific strategies that were not mentioned, such as the following:*]
    - Has the household switched or considered switching to a different type of animal?
    - Has the household stopped or considered stopping raising that type of animal?
    - Has the household reduced or increased the number of animals of that type?
    - Has the household changed or considered changing what the household feeds the animals?
- Is there any new strategy to deal with salinity that you have not tried, but perhaps you have seen other people use? Would your household be interested in trying it? What would help your household do so? [*Probe on whether they think they need outside help, from whom, and what kind of help – like receiving something for free, getting a loan, training, or other technical support.*]
- How would the decision to try this new strategy be made by your household? Would permission from a specific household member, neighbors, or someone else in the community be needed?

Topic #6: Aquaculture

What kinds of food-producing aquatic animals —including crab, shrimp, and fish— does your family keep or used to keep? [*For the sake of brevity, the term, 'fish,' in this guide will include crab and shrimp. If the participant uses the word, 'shrimp,' then make sure you probe to see if* *he/she is referring to golda, bagda, or other type of shrimp. Probe to get a sense of which are the most important fish for the household, and then starting with the most important ones, probe on the following details*:]

- Does your household still have this type of fish? If not, how long ago did you stop raising this type of fish?
- How many fish of that type does the household keep at one time, on average?
- Who in the household is/was responsible for those fish?
- What is/was the purpose of raising those fish? (Is/was it for the household's own consumption? Is/was it sold? Where is/was it sold? When was the last time it was sold?)
- Where are/were the fish kept?
- What is fed to the fish?
- Does/did the household give anything else to the fish, such as medicines, supplements or anything else? [*If yes, ask if they have the medication/supplement container(s) to examine and note the name and ingredients, and ask the following questions:*]
    - Why did you use the product? What was the outcome of using the product? [*For example, if the fish were sick, did they get better?*]
- [*If the household still currently raises that fish, then ask:*] How do you describe the current situation of those fish? Are they healthy? Do they produce a high quality food?
- What are/were the biggest challenges in raising those fish?
- Does/did salinity have any impact on those fish's health? If so, how? [*Give the participant an opportunity to answer the question. Then when he/she is done, you can probe specifically about these things if they are applicable:*]
    - Does/did salty water affect the fish's ability to survive or reproduce? During which times of year do these problems appear? [*Probe using the terms elicited during Topic #2 on "Seasonality."*]
    - [*If applicable, probe specifically about virus in bagda, golda, and crab*.]
- Have you changed any aspect about the way you raise/raised those fish due to salinity? [*If so, get details on what they did, why they did it, how was it made possible, who made the decision, do they feel like it worked. Try to get a detailed story.*]
- [*After letting the participant explain strategies they have tried, then probe about specific strategies that were not mentioned, such as the following:*]
    - Has the household switched or considered switching to a different type of fish?
    - Has the household stopped or considered stopping raising that type of fish?
    - Has the household reduced or increased the number of fish of that type?
    - Has the household changed or considered changing what the household feeds the fish?
- Is there any new strategy to deal with salinity that you have not tried, but perhaps you have seen other people use? Would your household be interested in trying it? What would help your household do so? [*Probe on whether they think they need outside help, from whom, and what kind of help – like receiving something for free, getting a loan, training, or other technical support.*.]
- How would the decision to try this new strategy be made by your household? Would permission from a specific household member, neighbors, or someone else in the community be needed?

Topic #7: General strategies related to food security

Because of salinity, is there an impact on the household's ability to produce food? [*Ask them to elaborate on the consequences.*]

- Are there specific health impacts, such as poor nutrition? [*Ask them to explain*.]
- Which family members are most affected? [*Ask them to explain why.*]

What has the household done to try to have better food security? [*Ask <u>if they have considered</u> or <u>if they actually already do</u> any of the following:*]

- Household members switching jobs or livelihood activities (e.g., agriculture to another type of activity) [*Probe for details. Who switched jobs? When? Has it been successful? Try to get a detailed story.*]
- Migration by some or all household members, either seasonal, temporary, or permanent [*Probe for details about the pattern of migration. When does migration occur? If seasonal, probe using terms elicited during Topic #2 on "Seasonality."*]
- Changing consumption practices regarding food, such as eating less or eating different things. [*Ask who makes these decisions, and who is eating less/differently?*]

How can food security be improved for your household, given the salinity situation? Are there any strategies that your household would be interested in trying? What would help your household do so? [*Probe on whether they think they need outside help, from whom, and what kind of help – like receiving something for free, getting a loan, training, or other technical support.*]

How would the decision to try this new strategy be made by your household? Would permission from a specific household member, neighbors, or someone else in the community be needed?

Topic #8: Perspectives on salinity

[*If they have talked about salinity already, acknowledge this and say that you want to understand more about how they view salinity. If they have not yet mentioned salinity, then say that you have heard that salinity can be an issue in this southwest area, and you are interested in hearing about the respondent's views on this*.]

- Please describe the salinity situation in this community historically. [*You can ask about 20 years ago. Alternatively, you can ask what year the participant arrived in the community and how the situation was when he/she first arrived. Ask the participant to clarify whether he/she is referring to soil salinity or water salinity. Also ask the participant to be specific about which times of year he/she is referring to, using terms elicited during Topic #2 on "Seasonality."*]
- What changes in salinity in the water have you noticed since this time? How can you tell that water is becoming more/less saline? [*Ask the participant to be specific about which times of year he/she is referring to, using terms elicited during Topic #2 on "Seasonality."*]
- What changes in soil salinity have you noticed since this time? How can you tell that soil is becoming more/less saline? [*Ask the participant to be specific about which times of year he/she is referring to, using terms elicited during Topic #2 on "Seasonality."*]
- What factors do you think increase or reduce salinity? [*Ask the participant to clarify whether he/she is referring to soil salinity or water salinity.*]

- What have you heard or what do you know about climate change? How did you get this information? (e.g., news, NGOs, other community members, personal observations, other researchers that have visited this community, government officials)
- Do you think that climate change is related to salinity? If so, how?
- Besides the impacts of salinity that we already discussed, are there any other consequences that you think will occur because of salinity?
- Do you think there is anything the community can do to control salinity levels, for example to prevent them from increasing? If so, what?
- Do you think there is anything the government or NGOs can do to control salinity levels, for example, to prevent them from increasing? If so, what?

Topic #9: NGOs and local government

- How are the NGOs that work in this area? What kind of things do they do for the community? What negative or positive impact to these have on the community?
- What help is offered by NGOs regarding the salinity situation?
- Do you think there is anything NGOs can do to help households like yours respond to the salinity situation? If so, what?
- How are the governmental institutions or officials that work in this area? What kind of things do they do for the community? What negative or positive impact to these have on the community?
- What help is offered by the government regarding the salinity situation? [*See what the participant mentions. Get details about which governmental institution is doing what. Then probe specifically about what the agricultural extension office is doing, if the participant has not mentioned the agricultural extension office.*]
- Do you think there is anything that the government can do to help households like yours respond to the salinity situation? If so, what?

Initial Household Questionnaire

PART 2: Visit Instrument

[*Get informed consent from the household head or his/her representative for taking photographs. Before anyone from the research team takes any soil or water samples, ask if it is okay to do that.*]

1. Persons currently living in the household (*khana*):

Member and relationship to others in the household (e.g., "wife of household head's son," "daughter of 1 & 2" or "friend of 1")	**Sex**	**Age**	**Occupation & informal jobs**	**Put X for person who gives the tour**
1. Head of household				
2.				
3.				
4.				
5.				
6.				
7.				
8.				

2. Number of households (*khana*) in this compound (*bari*): ________________

3. Household religion: _______________________

4. Highest level of education attained by any household member (circle one):

[No formal education] / [Primary] / [Secondary] / [Post-secondary]

5. Housing improvements (*mark the answers as reported by the participant*):

Electricity?	[Yes] / [No]
Improved roofing (tiles, tin roof, etc.)?	[Yes] / [No]
Running water (piped water from outside source)?	[Yes] / [No]
Tubewell or borehole on household premises?	[Yes] / [No]
Water storage tank for domestic water at least 500 liters?	[Yes] / [No]
Improved storage facility for crops (food or feed)?	[Yes] / [No]
Improved sanitation facility (any kind of latrine)?	[Yes] / [No]

Solar panel?	[Yes] / [No]

6. **Land Use** (*mark answers as reported by the participant*)

	Owned	**Rented**	**Communal land**
How much total land did your household have access to (besides the land the house is on)? [Circle units.]	___________ [decimal / bigha / acre / katha]	__________ [decimal / bigha / acre / katha]	___________ [decimal / bigha / acre / katha]
How much of each type of land is used for growing food (including grains, vegetables, fruits, and herbs)?	___________ [decimal / bigha / acre / katha]	__________ [decimal / bigha / acre / katha]	Did you use communal land for growing food? [Yes / No]
How much of each type of land is used for grazing animals?	___________ [decimal / bigha / acre/ katha]	___________ [decimal / bigha / acre / katha]	Did you use communal land for grazing animals? [Yes / No]
How much of each type of land is used for aquaculture?	___________ [decimal / bigha / acre / katha]	___________ [decimal / bigha / acre / katha]	Did you use communal land for aquaculture? [Yes / No]
How much of each type of land is used specifically for growing trees?	___________ [decimal / bigha / acre / katha]	___________ [decimal / bigha / acre / katha]	Did you use communal land to grow or harvest timber or grow tree crops? [Yes / No]
How much of each type of land is not being used?	___________ [decimal / bigha / acre / katha]	___________ [decimal / bigha / acre / katha]	Not applicable.

7. How many **ponds** within the compound does your household use? ______ (as reported by participant)

   [*Ask to see the two biggest ponds. Please mark the answers as reported by the participant. Skip the section if the household does not use any ponds within the compound*. *Remember to use the season terms that we obtained from the month pile sort.*]

	Largest pond	**Second largest pond**
Salinity of water during most saline season [Circle one]	[Low or not saline] [Medium] [High] [Don't know]	[Low or not saline] [Medium] [High] [Don't know]
Salinity of water during least saline season	[Low or not saline] [Medium] [High] [Don't know]	[Low or not saline] [Medium] [High] [Don't know]
During which times of the year is water here used for irrigation? [Use terms elicited during Topic #2 on "Seasonality" or write "None."]		
During which times of the year is water here used for drinking?		
During which times of the year is water here used for cooking?		
During which times of the year is this pond used for bathing?		
Types of aquatic species raised [*list the three most abundant, including crab, bagda, golda, and specific types of fish*]	1) ______________ 2) ______________ 3) ______________ 4) ______________	1) ______________ 2) ______________ 3) ______________ 4) ______________
Types of food-producing plants cultivated around the pond [*list the three most abundant*]	1) ______________ 2) ______________ 3) ______________	1) ______________ 2) ______________ 3) ______________

8. **Animals**

Ask to see the (non-fish) animals that the household is raising, if possible. Fill out the checklist for three kinds of animals; if there are more than three kinds of animals, then choose the three that you can observe directly and appear to have the largest production scale. Please mark the answers as reported by the participant, unless the instructions ask for the researcher's own observations.

	Animal type 1: ________	**Animal type 2:** ________	**Animal type 3:** ________
Current number kept			
Where are the animals housed?			
What do the animals eat?			
How is food for the animals obtained?			
Fieldworker's written observations about condition of animals [*take photo to aid description*]			

Specific Animal Species

Cattle metrics [write N/A if the household has no cattle]	Number of total heads (including males, females, and calves)	
	Current number of calves	
	Number currently in lactation	
	Number contributing work power	
	Number sold or butchered for meat per **year**	
Chicken metrics [write N/A if the household has no chickens]	Number of eggs per **month**	
	Number sold or butchered per **month**	

9. **Gardens**

How many gardens does the household have? ________ (as reported by participant)

[*Ask to see the two biggest gardens. Please mark the answers as reported by the participant, unless the instructions ask for the researcher's own observations. Skip the section if the household has no gardens. Remember to use the season terms obtained during the month pile sort.*]

	Largest garden	**Second largest garden**
Salinity of soil during the most saline season [Circle one]	[High] [Medium] [Low or not saline] [Don't know]	[High] [Medium] [Low or not saline] [Don't know]
Salinity of soil during the least saline season	[High] [Medium] [Low or not saline] [Don't know]	[High] [Medium] [Low or not saline] [Don't know]
During which times of year is this garden irrigated, and what is the source of irrigation water used? [Use terms for the periods of the year elicited during Topic #2 on "Seasonality" or write "None" on line 1.]	1) ____________ (period name) ____________ (source of irrigation water) 2) ____________ (period name) ____________ (source of irrigation water) 3) ____________ (period name) ____________ (source of irrigation water) 4) ____________ (period name) ____________ (source of irrigation water)	1) ____________ (period name) ____________ (source of irrigation water) 2) ____________ (period name) ____________ (source of irrigation water) 3) ____________ (period name) ____________ (source of irrigation water) 4) ____________ (period name) ____________ (source of irrigation water)
Types of food plants (vegetables, fruits, herbs) cultivated in the garden [*ask the participant to show you and then list the three that appear most abundant*]	1) ________ 2) ________ 3) ________	1) ________ 2) ________ 3) ________
Fieldworker's written observations about condition of the garden [*take photo as needed to aid description*]		

10. **Sources of water**

[*Besides the ponds located within the compound, ask household member to show you the other sources of water used for drinking, irrigation, cooking, bathing, and cleaning. If there are more than three sources of water, choose the ones that you can observe directly. Remember to use the season terms obtained during the month pile sort.*]

	Source 1: ____________ (describe)	**Source 2: ____________ (describe)**	**Source 3: ____________ (describe)**
Location	[Only for the household] [Within the compound] [Within the community] [Outside the community]	[Only for the household] [Within the compound] [Within the community] [Outside the community]	[Only for the household] [Within the compound] [Within the community] [Outside the community]
Salinity of water during most saline season [Circle one]	[High] [Medium] [Low or not saline] [Don't know]	[High] [Medium] [Low or not saline] [Don't know]	[High] [Medium] [Low or not saline] [Don't know]
Salinity of water during least saline season	[High] [Medium] [Low or not saline] [Don't know]	[High] [Medium] [Low or not saline] [Don't know]	[High] [Medium] [Low or not saline] [Don't know]
What time of year is this source of water used for irrigation? [Use the names of the periods elicited in Topic #2 or write 'None.']			
What time of year is this source of water used for drinking?			

What time of year is this source of water used for cooking?			
What time of year is this source of water used for bathing?			

Wrap-Up

Can you suggest other people in this community that we should interview? [*If yes, collect names and phone numbers of recommended individuals*.]

That is the end of our visit today. Thank you so much for your time. Do you have any questions for me? [*Answer any questions.*] If you have any additional thoughts or questions, feel free to contact me. [*If applicable, mention that we will return to this household in several months to follow up.*]

Household Follow-up Interview Guide

Phase 1 Follow-up Visit Guide (October 2015)

<u>Interview</u>

- Take consent, get witness signature.
- Turn on recorder.
- Thank them for the time and information they gave last time. Remind them what you talked about.
- Tell them that we are back to get additional information about salinity and to see if anything has changed since we spoke to them three or four months ago.

Changes

- How was rainy season?
- Were you able to grow crops this year?
- Have you obtained any new things for your house to help with drinking water?
- Have you tried any new strategies for drinking water?
- Have you done anything new to help grow crops?
- Have you had any contact with NGOs during the past 3 months or receive anything? Please describe.
- Have you had any contact with the government (like the agricultural extension office) during the past 3 months? Please describe.

Salinity rating exercise

- *Put all the pictures out.*
- *Ask interviewee to pick the picture that he or she wants to talk about first.*
- *Then, ask what he/she sees in the picture. If the interviewee does not get it, try to help a little bit to see if he/she understands. If he/she does not understand, then just put it aside. Even if he/she understands but it seems like this is new information for them, put the picture aside. Write down that the picture was not rated.*
- *If interviewee knows what is in the picture, then ask:* "Do you think that this thing causes salinity?" Yes / No
- *If yes:* "Does it contribute a lot or somewhat?"
- *Write down the answer.*
- *Next, you ask the interviewee to pick the picture that he/she wants to talk about out of the remaining pictures.*
- *Repeat the above steps.*
- *The interviewee will pick the pictures and rate them one by one, until there are no more pictures left.*

After all the pictures are gone, you are done with rating. Put all the pictures away. Ask:

- Do you think salinity is increasing year by year, decreasing year by year, or staying the same? (Or you don't know?)

Climate change

- Have you heard of something called climate change? *If answer yes, then ask:*
    - o <u>What</u> did you hear about climate change? (Probe to see if they relate CC to SLR or cyclones.)
    - o <u>Where</u> did you hear this information from? (Probe about NGOs.)

After finishing climate change questions, the interview is done. Turn off recorder.

<u>Household checklist</u>

Complete the household checklist with the same khana that you did the checklist with during the first visit. This may be a different khana than your interviewee's khana. Use the recorder.

From the household checklist, do the following things:

- Write down who is giving the tour this time
- Find the animals and complete the animal section
- Take pictures of all of the goats and cows
- Find the same gardens that you did the first time and write down: (1) the plants that are planted there now; (2) the condition of the garden from what you observed
- Take pictures of the gardens

Water testing

- Test the water sources that we tested last time
- Take a picture with the whiteboard

Conclusion

Thank them for their time once more. Write down phone number. Say that you hope to return to share results with the community next year, but explain that it will take some time because there is a lot of information to look at.

If there is any names of NGO workers or government contacts that were mentioned, write down the names and ask for phone number.

Make sure you give them one copy of the consent form.

Community Focus Group Guide

[*The questions given in this guide are possible questions that may be used in FGDs. The number of questions given here may be greater than the time allotted for FGDs, but not all questions listed will be used in each FGD. Please note that the same focus group guide will be used in both seasons of data collection, and if it is the second season, then more emphasis will be placed on topics #4 and 5. After obtaining consent, permission to record the focus group discussion, and demographic information from each participant (gender, age, length of residence in the community, and main livelihood activity), proceed with the following introduction.*]

Introduction

[*The members of the research team who are present in the discussion should introduce themselves. The facilitator will explain that the facilitator will help guide the discussion by asking questions and proposing activities. The facilitator will also explain that the moderator will help keep track of the time and ensure that all participants have a chance to say what they want to say.*]

[*The facilitator will explain that we are interested in learning about how communities in Bangladesh's southwest coastal region perceive and respond to the challenge of rising salinity in soil and water. Finally, the facilitator will explain the format of the focus group discussion, as follows:*]

We would like everyone to participate in today's discussion. We would like the discussion to be informal, so there is no need for you to raise your hand before speaking. We encourage you to respond to each other's comments. We just ask that everyone speak one at a time and be respectful of the other participants.

I might interrupt at points during the discussion to ensure that we have enough time to cover all topics. If you don't understand a question, please let us know. We are here to ask questions, listen, and make sure everyone has a chance to share.

Here are a few guidelines before we start:

- I'd like you to speak to each other, not just to me. Just be respectful so that one person is speaking at a time.
- Please do not have side conversations
- There are no right or wrong answers, and we will have different points of view. We encourage you to talk to each other, to agree or disagree with each other.
- You're free to say what occurred at this meeting. Please also respect each other's confidentiality; we will not repeat who was at this meeting or what certain people said.
- If you feel uncomfortable at any point you are free to decline to participate.

We have recording devices to record the discussion. We will not use the recording for any purpose other than the study and your identity will be anonymous in all transcriptions of this session. We also ask that everyone speak up so that the recording can pick up your voice. [*Make sure two recorders are turned on and show everyone where you are putting the recorders. Put the two recorders on the different sides of the group.*]

Are there any questions? [*Answer any questions.*]

Topic #1: Community Characteristics

Let us start by talking about the characteristics of this community. We have some photos here that we want to show you. For each one, we would like someone to tell us about what they see in that photograph.

[*Show each photo. The photos are pictures of landmarks or activities engaged in around the community. Ask the participants to describe what they see, and try to understand the significance of the landmark or activity for the community by probing. The purpose of this exercise is to understand the community's history, the common and uncommon activities agricultural activities that people do, how these activities have evolved over time, and the geographic features of this community. For example, if we show a picture of an abandoned plot of land, we can ask participants to say why they think it was abandoned, how long ago it was abandoned, and what might happen to the land in the future. After this exercise helps get people engaged in conversation, you can proceed to these questions.*]

How does this community produce food? Are there certain people who are especially vulnerable in terms of not being able to produce food?

How does this community access water? Are there certain people who are especially vulnerable in terms of accessing water?

Topic #2: Environmental Challenges

Now we want to hear about your opinions on the topic of environment, climate, and salinity. Let us start by looking at some photographs again. [*Show participants a series of photographs related to environmental challenges in Bangladesh, for example cyclones, deforestation, arsenic contamination, etcetera. For each of the challenges, ask participants whether those challenges are present in the community and how long they have been present. If they have had direct experience with the challenges, then they can share their stories. Moreover, probe on how they think the challenges could have negative impacts on their health and well-being. Finally, probe on whether they feel like there is anything they can do to cope or protect themselves from those harmful impacts. We want to understand how empowered or powerless people feel in the face of climatic and environmental events.*]

Topic #3: Seasonality

Before we start talking about your experiences with salinity, we will first do an activity to help us understand the different seasons that you have in this region of Bangladesh. This way, when we discuss your experiences, we will know the names for the different times of the year and the characteristics of those periods. The information you give us can be different than the official calendar. We are interested in your actual experiences.

[*Conduct this activity by asking for a volunteer to come forward. The first volunteer will then go through all of these steps:*]

iv) Start with a month pile sort. We present the twelve months of the Bengali calendar to the participant and ask him/her to pile sort those months into seasons according to their experience. Since participants' inclination may be to sort into the six official seasons, give them specific instructions to sort into piles according to what *they* consider most important nowadays (they might think there are fewer/more than six seasons, etc.).

v) For each pile, ask the participant to describe: (1) what that period would be called; (2) the temperature; (3) amount of rainfall; (4) degree of salinity in general (i.e., considering soil, water, all sources of groundwater and surface water).

vi) Confirm with the participant during which period salinity is the most severe, and during which period salinity is the least severe.

[*After the first volunteer finishes, then ask the group if people agree with what the person said. See if anyone has anything to add or if anyone else would like to volunteer to do the pile sort activity. Two or three iterations of this exercise should be enough to reveal the areas of consensus and disagreement among the group. Then, in the subsequent parts of this focus group guide, when there is a reference to seasons, use the local terms generated through this exercise for different times of the year.*]

Break-out session: Break into three small groups, with a group devoted to each of the following activities: (a) seasonal calendar showing the different periods of the year and corresponding salinity levels in soil and water sources; (b) seasonal calendar for food production activities; (c) seasonal calendar for water and where it is accessed and stored. Then reconvene. Each small group presents its results from the breakout activity, assess level of agreement from the broader group.

When the salinity calendar is being presented, probe:

How has salinity in water changed over time in this community? [*Probe about increases and decreases, as well as seasonal differences.*] How can you tell if water is becoming more/less saline?

How has salinity in soil changed over time in this community? [*Probe about increases and decreases, as well as seasonal differences.*] How can you tell if soil is becoming more/less saline?

What do you think causes salinity? [*Probe about 'human' and 'non-human' causes – like do they think that salinity is changing because of something specific that people in this area are doing.*]

When the food production seasonal calendars is presented, probe on what things facilitate food production, and what things are obstacles for food production.

When the water seasonal calendar is presented, probe on who has or who controls the different sources of water. Also probe on things like amount of water or water quality.

Topic #4: Salinity Impacts and Solutions

Thank you, please all be seated again. Here, I have a glass of water taken from this bottle of water, and over here I have a cup of salt. [*Indicate the glass of water and cup of salt.*] How much salt could we add to this water before it is no longer drinkable? [*Add salt. Then ask for a volunteer to drink some of it. This should cause some laughter. Thank the volunteer.*]

Let us now talk about how salinity affects the water that this community has access to. Would someone like to share with us his/her view of the situation? [*Probe on quantity and quality of water. Ask participants to clarify whether these impacts occur year-round or only during certain times of the year.*]

Now let us talk about how salinity affects the ability to produce food. How does salinity affect food production? [*Try to get participants to be as specific as possible. For example, if they say that salinity affects their ability to grow crops, then try to understand why they think this happens. Is it because the water used to irrigate the crops is too salty? Or is it because of the salt in the soil? Since there are many different factors that affect soil health, how do they know that salinity is the problem?*]

[*If they have only talked about growing crops, then ask about raising animals for food:*] How does salinity affect your ability to raise <u>animals</u> for food?

Thank you for sharing your perspectives on how salinity can affect food production and access to water. Let us talk about how these impacts can lead to different health outcomes for humans and animals. Can anyone name some ways that humans and animals' health might be affected? [*The participants may mention things related to having less food, such as malnutrition or poor diet. Ask them who is the most affected – in other words, do they think everyone is affected the same or do certain people suffer more? Since they might not mention this, ask specifically about what they think about drinking salty water. Do they think it just tastes bad? Or do they think drinking salty water can lead to other health outcomes? You can also probe about the health consequences of using saline water to bathe and clean yourself. Probe about whether exposing skin or eyes to saltwater is harmful or not.*]

So we have now discussed the impacts of salinity in a lot of detail. Let us think about responses to these impacts. What kinds of strategies have you seen households in this community try to do to address the salinity situation? [*Ask them to describe the strategy in detail. For example, what time of year is it used? What specific problem does it address? What helped the household be able to use this adaptation strategy? Does it work? Is there anyone outside of the community that assisted with the household?*]

[*If people are not responding to the question about strategies, then you can say something like this to stimulate discussion: "*When we study households that are affected by environmental challenges, we can see that some families don't feel like there is much they can do to change the situation so they just try to survive. Other times, we see families that would like to adapt to the impacts and maybe they even have ideas for how to adapt to the impacts – but they can't because they don't have enough resources or expertise or time or things like that. And then finally, we sometimes see households that are already trying different strategies to respond to the environmental challenges they face. Maybe some of these things they have done for a very long time; maybe other things are newer ideas that they are trying. So there are different kinds of households. With this in mind, how would you describe most of the households in this community?"]

What kinds of strategies have you seen this community work together to try in order to address the salinity situation? [*Ask them to describe the strategy in as much detail as possible. For example, what time of year is it used? What specific problem does it address? What helped the community be able to use this adaptation strategy? Does it work? Is there anyone outside of the community that assisted with this?*]

What about strategies that you know about but have not tried? Maybe there are things that you have seen or heard about other communities doing, that you might want to try here. Would anyone like to share their thoughts on this? [*Probe on whether they think they need outside help, from whom, and what kind of help – like receiving something for free, getting a loan, training, or other technical support.*]

How would the decision to try new strategies be made? Would permission from a specific household member, neighbors, or someone else in the community be needed?

Group ranking activity: In this activity, a list of potential adaptation strategies will be presented to the group, including ones just mentioned by the group. A list of criteria for assessing whether a strategy has been successful will also be presented, including criteria just mentioned by the group. Participants will rank/rate the strategies, and then the results will be discussed by the entire group.

When you probe about the ranking decisions, pay special attention to see if metrics like "health" or "income" or other indicators are mentioned.

Topic #5: Needs, Priorities, and Assistance from External Actors

Let us move the discussion forward now to thinking about the future. What do you think are the most urgent needs faced by this community? [*For probing, the facilitator can use this opportunity to remind the group about the answers they gave when they were asked about especially vulnerable people, during discussion of topic #2. The facilitator can also remind the group about the answers the group gave when they were talking about community assets/strengths and vulnerabilities during topic #2. Note if anyone's opinion has changed.*]

We have also talked about salinity adaptation strategies. What specific strategies do you think should be prioritized? [*Probe about why.*]

Are there any prioritized strategies that require external assistance – help from organizations or other experts outside of the community? [*Probe about the kind of assistance required. Who does the community prefer to receive assistance from? Which actors or organizations or governmental entities should provide support?*]

If the community does require assistance from some an outside actor or organization, what should be the appropriate duties of the organization, and what are the responsibilities of the community members?

Wrap-Up

Thank you very much for sharing your thoughts with us today and for giving us your time. Does anyone have any final things they would like to say to us or to the group? [*Give participants a chance to speak.*]

Does anyone have any final questions for us before we leave? [*Answer questions.*]

Thank you. [*If this is the first visit to the community, remind community members that we will come back in a few months, and we might ask some of them to participate in a second focus group to see how the situation has changed.*]

NGO / Government Stakeholder Interview Guide

[*The purpose of this instrument is to gather information about how institutions working to improve rural livelihoods in Bangladesh perceive and respond to the challenge of increasing salinity. The instrument is meant to guide the researcher on the topics that should be covered in an in-depth interview with representatives of NGOs and different governmental ministries. In the first part of the interview, participants will be asked open-ended questions on their experiences and perspectives. In the second part of this interview, participants will be asked to rank or rate potential strategies for adapting food production and water use to salinity. They will use different criteria to rank or rate the strategies, and then they will be asked to explain their assessments.*

The questions will be tailored to participants' particular areas of expertise. They will have the option of declining to respond to any question, including skipping one of the items to be ranked or rated.]

[*After obtaining consent and permission to record the interview, turn on the recorder and proceed with the introduction.*]

Thank you for meeting with me today. We are gathering information about how institutions working to improve rural livelihoods in Bangladesh think about problems related to the soil and water supply in coastal parts of the country. We will focus on the challenge of increasing salinity in both the soil and the water. In the first part of the interview, I will ask you about your perspectives on improving rural livelihoods, promoting food and water security, and addressing salinity in the southwest coastal region. In the second part of this interview, I will ask you to assess different strategies for adapting food production and water use to salinity.

The questions I am going to ask don't have right or wrong answers.

Remember that this conversation is completely confidential, and we can skip any question you prefer not to answer.

Do you have any questions before we proceed? [*Answer any questions.*]

Topic #1: Basic Information

Can you please describe your educational background? Can you please tell me about your work experiences *prior* to your current position?

What is your current organization's mission and purpose? Can you describe the activities of your organization?

What is your current role in this organization? How long have you been in that position?

What are your responsibilities in that position? What activities are part of your routine responsibilities? Are there any other activities?

Topic #2: Salinity in the Southwest Coastal Zone

Next, I am interested in understanding the salinity situation in the Southwest Coastal Zone. I am especially interested in your knowledge about specific places within this zone.

Please tell us about one location you are familiar with, which faces a salinity problem. Tell us about the salinity situation there. [*The participant can choose to describe one village, one union, one upazila, or even one district, depending on his/her level of knowledge.*]

- How does salinity in soil and water change over different times of the year in this area? [*If needed, use follow-up questions to clarify whether the participant is referring to soil salinity, groundwater salinity, or surface water salinity.*]
- How long has salinity been a problem in this area? How has salinity evolved over time? What factors do you think increase or reduce salinity?

How does soil or water salinity affect crop production in this [village / union / upazila / district / region]? [*Probes:*]

- Are there particular sub-populations that are more vulnerable to these impacts? [Probe: Please explain how and why this is the case.]
- How have communities themselves (acting on their own) responded to these impacts?
- What work has your institution done to help manage or prevent these impacts? What has contributed to your [successes/failures]?

How does soil or water salinity affect raising animals for food in this [village / union / upazila district / region]? [*Ask this set of questions first for land animals like cows, chickens, goats and sheep. Then ask the questions again for fish, including shrimp and crab.*]

- Are there particular sub-populations that are more vulnerable to these impacts? [Probe: Please explain how and why this is the case.]
- How have communities themselves (acting on their own) responded to these impacts?
- What work has your institution done to help manage or prevent these impacts? What has contributed to your [successes/failures]?

How does salinity affect freshwater available in this [village/ union /upazila / district / region]? How does this affect drinking water? If you know, how does it affect bathing and other hygiene behaviors?

- Are there particular sub-populations that are more vulnerable to these impacts? [Probe: Please explain how and why this is the case.]
- How have communities themselves (acting on their own) responded to these impacts?
- What work has your institution done to help manage or prevent these impacts? What has contributed to your [successes/failures]?

Topic #3: Ranking/Rating Exercise

[*In this part of the interview, participants will be presented with 7 items – strategies for responding to salinity – and asked to rank/rate them based on the following prompt.*]

Thank you for describing to us the situation in [*insert name of the location that the participant discussed in detail above*]. Imagining that a donor organization is trying to decide what kinds of projects to fund to help communities in that location respond to salinity. Please prioritize these 7 types of projects, according to what you think should be funded. [*Please ask people to rank all 7 of these in order, from highest priority for funding to least priority for funding.*]

- Construct more rainwater harvesting infrastructure
- Train people on special cultivation methods
- Promote saline-tolerant plants
- Promote more saltwater shrimp farming
- Promote non-agriculture-based livelihoods
- Promote reduction of saltwater shrimp farming
- Assist migration away from the salinity-prone area

[Now probe on how the participant made his or her decisions. We want to know the following question:] What criteria should donors be using when they are deciding which salinity adaptation projects should receive priority? [If the participant seems knowledgeable, show them the "List of Criteria," attached at the end of this guide. Ask the participant if he/she would like to comment about that list. Does anything seem missing? Does anything seem particularly important?]

[*Next, if the participant seems particularly knowledgeable about adaptation strategies, show them the detailed "Detailed list of Adaptation Strategies", attached at the end of this guide. Ask if they want to comment on any of those specific strategies in particular.*]

Topic #4: General perspective on rural development and adaptation

Now we have spoken a lot about activities that can be done for adapting to the environmental challenge of salinity. We know that in Bangladesh currently, as well as historically, a lot of work has been done to promote rural development.

In what ways do you think the country has made progress in improving rural livelihoods over the last 20 to 30 years? What about over the last few years?

How do you think rural development activities relate to the challenge of salinity adaptation? If we just promote rural development, can that solve the problem of salinity?

Thinking about other NGOs and governmental institutions besides your own organization, what is your perspective on their contributions to rural development? Have they also helped with the problem of salinity?

[*Ask for specific examples of NGO initiatives or governmental programs. See if the participant describes international and domestic NGOs differently, or if he/she describes governmental versus non-governmental actors differently. Then you can also probe:*]

- What factors have contributed to their [successes/failures]?
- What are some of the limitations they face?
- In what ways do you think they could do things differently to achieve a greater impact?

Wrap-Up

That is the end of our interview today. Thank you so much for your time. Do you have any questions for me? [*Answer any questions.*] If you have any additional thoughts or questions, feel free to contact me.

List of criteria

- Environmental sustainability/ecological footprint
- Resilience to natural disasters
- Economic sustainability
- Cost-effectiveness
- Technical feasibility
- Cultural acceptability
- Likelihood to improve health outcomes
- Alignment with other rural development objectives
- Ability to attract funding support

Detailed list of salinity adaptation strategies

- Installing more household-level rainwater harvesting infrastructure (tanks)
- Installing more community-level water sources (e.g., filtered ponds or larger concrete tanks)
- Constructing deeper tubewells
- Constructing more tap lines to bring in water from an outside area
- Giving trainings on how to reduce salinity in gardens (e.g., adding compost, planting on top of raised beds or in plastic containers)
- Providing money for households to elevate their entire land
- Distributing fertilizer to improve soil fertility
- Distributing seeds for plants known to be saline-tolerant (e.g., certain fruit trees, some hybrid rice varietals)
- Inventing more saline-tolerant plants (e.g., rice)
- Help rural households take up more saltwater aquaculture as their livelihood
- Providing animals (e.g. ducks) that can survive better in saline environments
- Assisted migration away from saline-prone areas
- Job training in non-agricultural livelihoods
- Inventing better water desalination technology
- Organizing people to stop saltwater shrimp farming (ghers)
- Build costal walls to keep out the rising seas
- Mangrove afforestation

Salinity Testing Protocol

Tools

- Notebook/clipboard
- Soil shovel
- One large plastic bucket for mixing soil
- Three smaller buckets for collecting water
- Rags (to wipe off soil shovel and to dry salinity probes)
- Pen or marker with waterproof ink
- Ziplock bags for soil samples
- Stickers for labeling soil bags
- 2 liters of de-ionized water (to wash off salinity probes)
- Water sampling containers
- Nalgene bottle to carry clean water
- Screw top bottles (like Nalgene bottles) for soil suspension testing later
- GPS device
- Extra batteries for GPS device
- Extra batteries for E/C meter
- Bag to carry around the soil samples.
- Ruler
- Extra pH 4.0 solution (to clean off salinity probe and for storage)
- Extra calibration solutions for the three E/C measurements (packets)
- Whiteboard and dry erase marker.
- Measurement log book

Common information to record for each site

- Current weather
- Last time it rained
- Date and time

Naming convention for sample points

- District Code (B for Bagerhat, S for Satkhira, and K for Khulna)
- Village/Site Code (1, 2, 3, etc.)
- W or S for type of sample collected + sample point (1, 2, 3, etc.)
- Example: B1-s1 (first site/village visited in Bagerhat, first soil sample point)
- Use this format for mapping points.
- When denominating samples, mark a letter –a/b/c, etc.- corresponding to batch. Soil will have 2 batches from the collection, and water will have 2 (surface water sources will have the first batch from the top, and the second batch from deeper) or 3 (groundwater will have 3 corresponding to the 5th, 20th, and 5-minute pumps) batches. E.g., 1st site in Bagerhat, 1st location sampled, and 2nd soil packet collected from the bucket would be labeled B1-s1-b.
- And when denominating measurements, mark an extra number corresponding to the measurement. (Since everything will have 2 measurements.) E.g., the 2nd site in Bagerhat, 1st water location sampled, 5-minute pump of water, 2nd reading would be labeled: B2-w1-c-2.

Type of source	Number of Batches	Code for Batch
Pond, gher, other surface water	2	a = water skimmed off the top b = water taken from below
Tubewells	3	a = 5th pump b = 20th pump c = after 5 continuous minutes of pumping
Soil samples	2	a / b = no difference, just fill two bags from the mixture

[First letter of district][# of site visited in that district, so 1 or 2]-[w for salinity/s for soil][that # sample of either soil or water]-[batch letter]-[measurement number, so either 1 for first reading, 2 for second reading]

Water

Where to sample

- Take one from a pond near the beginning of the walk, another from the end of the walk, and then on the way back, pick one in the midpoint.
- Tubewells (shallow and deep)
- Ghers or biehls
- Avoid muddy sediments.

Steps

- Note description of where it is taken from (type of source, etc.)
- Make sure salinity meter reads zero when held in the air.
- Dip water sampling bucket into water to be tested and rinse thoroughly.
- Take the appropriate number of batches (3 for groundwater or 2 for surface water sources), as per the chart above – each batch should go into a different container.
- For each batch, take a testing container, rinse it in that water, and then do one reading. Immerse salinity meter into the testing container up to the raised mark (about 25 mm) and move the probe up and down to remove bubbles from around the electrodes (do not swirl it around as this may actually drive water out of the probe). Make sure the electrodes are covered.
- Allow probe to reach the temperature of the water. The meter has automatic temperature compensation, so wait 30 seconds before taking the reading if the water and probe are about the same temperature and 2 minutes if the water is much colder than the probe. Allow measurement of E/C to stabilize.
- Read number and record reading along with the temperature.
- Rinse the testing container, refill it, and do a second reading. Record with temperature.
- Label measurement in the log book according to scheme set out above.
- Drop GPS point on GPS device and ODK collect according to the scheme set out above.
- Take picture of surroundings. The picture should show someone holding the whiteboard that has the name of the location code used to label the GPS point.

- Wash off lower part of the meter with bottled water (especially electrodes). If storing overnight, then wash off with de-ionized water. If storing for several days or more, make sure cap is moist with pH 4 solution.

<u>Soil</u>

Where to sample

- If walking through the village, take one from garden at the beginning of the walk, another from a garden as close to the end of the walk, and then on the way back take one approximately at the midpoint off of the main road.
- Take other samples as needed (near ponds, etc.).
- Avoid areas or field that have had fertilizers applied within the last 30 days.
- Avoid muddy fields.
- Avoid end rows.
- Avoid areas where livestock congregate.
- Avoid small, very poorly drained spots in the field.

Steps for gathering soil samples

- Note description of where from it is taken from (garden, etc.). Ask if lime or fertilizers have been applied within the last 30 days. Ask if it's an area where livestock congregate. (I've been excluding only for chemical fertilizers, because if I excluded also for cow dung, then I'd end up with no gardens.)
- Take 10 cores from one garden in a random pattern, each core uses a depth of 4-6".
- Mix cores together in the plastic bucket, breaking up the cores, removing roots, rocks
- Take about one cup from the plastic bucket and put into bag
- Take about another cup from the plastic bucket and put into second bag (do this to look at repeatability)
- Label each batch using naming convention.
- Mark on GPS with same label.
- Take pictures of surroundings. Picture should show someone holding the whiteboard that has the name of the sample written on it.
- Rinse out bucket with bottled water and wipe down with rag.
- Move on to next location.

Steps for testing soil samples (adapted from Salinity Note No. 8 by NSW Agriculture's initiative, Salt Action; classification schemes come from NSW Salinity Note No. 8 and GSA Fact Sheet No. 66/00)

- Leave soil sample in a plastic container to air-dry overnight. May need more than one night to air dry so that the grains are dry enough to stay apart, though not bone dry. May still have a damp, cool feel when pressed with fingers.
- Take a picture of the soil sample after it is set up to dry overnight, at the beginning of the night.
- The next day, before testing, take another picture.
- One by one, for each sample do the following:

- Make sure lumps (clods of soil > 2 mm) are broken up, remove twigs, stones and leaves.
- Photograph anything unusual, add in ruler to show scale.
- Measure out one cup of soil (combining a & b from the same code number to get one cup's worth of soil), and put it in the jar that will hold the suspension. Label the jar with one of the labels.
- Perform this soil texture test for one randomly chosen sample per site:
    - Take a sample of soil sufficient to fit comfortably in the palm of your hand.
    - Moisten the soil with water, a little at a time, and knead it until the soil forms a ball approximately 3 to 5 cm in diameter and so the ball just fails to stick to the fingers, adding more soil or water if necessary. The sample should not be saturated (water dripping out of the ball) or too dry (some soil is dusty and not wet at all). Make sure the soil is wet right through (this moisture content is around field capacity) and there are no lumps.
    - Continue kneading and moistening, if necessary, until there is no apparent change in the feel of the soil ball. Do not overwork the ball (no more than 3-4 minutes). Assess the soil for coherence (see table below) by squeezing the moist ball in the hand. Knead ball for a further minute.
    - Assess feel (table below) as you knead the ball.
    - Ribbon the soil ball by pressing it between the thumb and forefinger and squeeze it into a ribbon until it breaks (letting it hang down). Try to make a thin continuous ribbon about 2mm thick.
    - Measure the length of the ribbon. Repeat this a few times to get an average ribbon length. Take a photograph of one of the ribbons, with a labeled container that still has some soil in it showing up in the photo, as well.
    - From the results for coherence, feel and ribbon length, estimate the soil texture group from the table below. Note down the soil texture in the log book based on the 6-category classification schemes (identifying with the code).
- In the jar where there is already one cup of the soil, measure and add five cups worth of de-ionized water. (We are using a volume basis, rather than weight basis.)
- Put on the lid, and then shake the container to make sure the salts dissolve, following this timeline: 4 minutes shaking + 3 minutes waiting + 1 minute shaking + 3 minutes waiting + 1 minute shaking + 4 minutes waiting.
- Test with meter.
- Place the salinity meter in the solution (but not into the soil at the bottom of the jar) and read the display once it has stabilized. Record the temperature, as well. Multiple by the relevant conversion factor.
- Rinse salinity meter electrodes in de-ionized water, ensure the reading is zero in the air.
- Take a second reading on the same suspension.
- Rinse salinity meter again with de-ionized water.
- Rinse the suspension container with filtered drinking water from ICDDR,B's supply. Let the container air dry or wipe down with a towel.

- Clean the empty lunch tray container with regular water from ICDDR,B's supply. Let the tray dry or wipe it down with a towel.
- Proceed to the next container and soil sample. (Try to test the soil samples that were taken from the same sampling location back-to-back – like K1-S1-a and K1-S1-b.)

Codebook Used for Initial Household Interviews, Focus Groups, and Community Key Informant Interviews

"Bookend" quotes		
Salinity as a phenomenon		
	Perceiving salinity	
	Causes	
		Ghers
	Seasonal trend	
	Year-to-year trend	
Salinity impacts		
	Flora	
	Water	
		Drinking
		Bathing
	Cultivation	
	Livestock	
	Aquaculture	
	Food security	
	Socioeconomics	
	Other	
Salinity adaptation prospects		
	Livestock	
	Doing ghers	
	No time as a barrier	
	No money as a barrier	
	Water	
		Sharing as a barrier/facilitator
		Tubewells
		Filtered ponds
		RWH and storage
	Migration	
	Cultivation	
		Improved irrigation
		Saline-tolerant plants
		Fertilizers
		Planting on high land
Salinity mitigation		
	Khulna site story	
NGO/Govt issues		
	Embezzlement on community projects	
	Noone comes here to help	
	Must take what you get	
	Sustainability	
	No money, no voice	
	Intervention success and failure	
	Distribution	
Climate change		
	Climate change knowledge	
	Seasons evolving	

Codebook Used for Follow-up Household Interviews

Health impacts	
Quotes about mitigating salinity	
Quotes about climate change	
Quotes about salinity trends	
Quotes about salinity causes	
	Quotes - Alternative explanations
	Quotes - Cyclones as cause
	Quotes - Ocean as cause
	Quotes - Sluice gates as cause
	Quotes - Dams in India as cause
	Quotes - Sea level rise as cause
	Quotes - Ghers as cause

Codebook Used for NGO and Government Stakeholder Interviews

"Bookend" quotes			4
Salinity as a phenomenon			1
	Perceiving salinity		1
	Causes		4
		Ghers	5
	Seasonal trend		1
	Year-to-year trend		2
Salinity impacts			2
	Food security/nutrition		2
	Flora		0
	Water		0
		Drinking	2
		Bathing	0
	Food production		2
		Aquaculture	1
		Livestock	2
		Cultivation	1
	Socioeconomics		3
	Other		1
Salinity adaptation			7
	Livestock feeding practices		1
	RWH infrastructure		2
	Special cultivation methods		2
		Improved irrigation	1
		Fertilizers	1
		Planting on high land	0
	Saline-tolerant plants		7
	More saltwater shrimp		3
	Less saltwater shrimp		9
	Non-agricultural livelihoods		5
	Migration		7
	Other water strategies		3
		Tubewells	1
		Filtered ponds	3
	Doing ghers in a controlled way		5
NGO/Govt issues			9
	NGO multiplicity and lack of coordination		1
	NGO microcredit activities		1
	Govt not concerned with salinity		1
	Intra-governmental coordination		6
	NGO-govt coordination		7
	Criteria for funding		2
	Ineffective use/abuse of funds by government		4
	Effective use of funds by government		0
	Ineffective use/abuse of funds by NGOs		6
	Effective use of funds by NGOs		3
	Embezzlement on community projects		1
	Noone comes here to help		0
	Sustainability		10
	Distribution/selection of beneficiaries		7
Climate change			2
	Climate change vs. rural development		1
	Climate justice/reparations		3
	Climate change knowledge		4
	Seasons evolving		2

Pictures of Special Cultivation Methods – Raising Land

Pictures of Special Cultivation Methods – Styrofoam Containers

Pictures of Special Cultivation Methods – Raised Beds

Pictures of Special Cultivation Methods – Compost Fertilizer

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EDUCATION

Johns Hopkins Bloomberg School of Public Health — Baltimore, MD
PhD, Dept. of International Health – Social & Behavioral Interventions — 2017
Dissertation: Adaptation to Soil and Water Salinity in Southwest Coastal Bangladesh
Certificate in "The Food System, Environment and Public Health," Dept. of Environmental Health & Engineering

Harvard Law School — Cambridge, MA
JD, *cum laude* — 2007
Thesis: Effective and Ineffective Criminal Justice Polices: Lessons from Abroad

Massachusetts Institute Of Technology — Cambridge, MA
BS, Physics. Phi Beta Kappa, Sigma Pi Sigma (National Physics Honor Society) — 2004
Thesis: Dark Energy and the Cosmic Microwave Background

TEACHING AND MENTORING

- Teaching assistant for courses at Johns Hopkins Bloomberg School of Public Health:
  - Spatial Analysis for Public Health (2016)
  - Qualitative Data Analysis (2014)
  - Human Rights and Health Seminar (2013)
  - Principles of Epidemiology (2013)
  - Food Systems and Public Health (2016)
  - Formative Research for Behavioral and Community Interventions (2015)
- Guest lectures for International Health Doctoral Student Seminar; Research Methods in Applied Medical Anthropology; Global Health Principles and Practices; Global Sustainability and Health
- Mentor for the Young Researcher Program at the International Centre for Climate Change and Development, in Dhaka, Bangladesh (2015)
- Advisor and mentor for Ford Foundation-funded scholarship program for Afro-Colombian lawyers to pursue Masters of Law degrees in the United States (2010-2012)
- Course instructor in physics for Project Interphase, a program for incoming underrepresented minority students at MIT (Summer 2004)

PUBLICATIONS

Y. Lam, J. Fry, E. Hu, B. Kim and K. Nachman, *Industrial food animal production in low- and middle-income countries: a landscape assessment*, Johns Hopkins Center for a Livable Future (2016).

Y. Lam, R. Westergaard, G. Kirk, A. Ahmadi, A. Genz, J. Keruly, H. Hutton, and P. Surkan, Provider-level and other health systems factors influencing engagement in HIV care: a qualitative study of a vulnerable population. *PLoS ONE*, *11*(2016), 7.

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Y. Lam, E. Broaddus, and P. Surkan, Literacy and healthcare-seeking among women with low educational attainment: Analysis of cross-sectional data from the 2011 Nepal Demographic and Health Survey. *International Journal for Equity in Health*, *12*(1) (2013), 95.

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Y. Lam, Prioritizing judiciously? Reflections on the debate over the role of the Inter-American Commission on Human Rights, *Aportes, Quarterly Magazine of the Due Process of Law Foundation*, Issue 16 (Mar. 2012).

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C. Abreo, E. Antonio, **Y. Lam**, and C. Rodríguez Garavito, *The Dispute over Natural Resources in Afro-Colombian Territories: The Case of Buenos Aires and Suárez from a Human Rights Perspective*, Los Andes University (2011).

C. Rodríguez Garavito and **Y. Lam**, *Ethno-reparations: Collective Ethnic Justice and Reparations for Indigenous Peoples and Afro-Descendant Communities in Colombia*, DeJusticia (2011).

J. Cavallaro, J. Kopas, **Y. Lam**, T. Mayhle, and S. Villagra-Biedermann, *Security in Paraguay: Analysis and Responses in Comparative Perspective*, Harvard University Press (2008).

CONFERENCES & OTHER PRESENTATIONS

Poster presentation: *Salinity impacts on food and water security in Southwest Coastal Bangladesh*, Y. Lam, P. Winch, P. Surkan & F. Nizame, American Public Health Association, Oct. 29-Nov. 2, 2016, Denver CO.

Conference presentation: *Local understandings and potential solutions to soil and water salinity in Southwest Coastal Bangladesh*, Y. Lam, P. Winch, P. Surkan & F. Nizame, Association for Environmental Studies and Sciences, June 8-11, 2016, Washington DC.

EXPERIENCE

INTERNATIONAL CENTRE FOR DIARRHOEAL DISEASE RESEARCH, BANGLADESH (ICDDR,B) (Dhaka)
International Field Experience Researcher, Environmental Interventions Group, January 2015 – February 2016

- Designed and led research project on rural adaptation of food production and water use to salinity intrusion in southwest coastal Bangladesh.

JOHNS HOPKINS CENTER FOR A LIVABLE FUTURE (Baltimore, MD)
Research Assistant, January 2015 – Present

- Conducted a major landscape assessment of industrial food animal production in ten low- and middle-income countries. Elaborated report characterizing trends in practices, associated regulations, environmental impacts, and public health concerns related to livestock production. Prioritized future research and intervention topics.

JOHNS HOPKINS UNIVERSITY CENTER FOR COMMUNICATION PROGRAMS (Baltimore, MD)
Student Researcher, June 2013 – June 2014

- Analyzed interview, focus group, and survey data from the Uganda Culture of Net Use Study, to elucidate how households prioritize family members when allocating insufficient bed nets. Drafted manuscript for peer-review journal publication.
- Analyzed sleeping behaviors and nighttime activities that increase risk of malaria in Uganda and Ghana.

WORLD RELIEF (Chokwé, Gaza Province, Mozambique)
Student Consultant, August 2013

- Conducted research to improve the Vurhonga Community-Based Tuberculosis Detection and Treatment Program in six districts of Gaza Province. Interviewed the program's community health volunteers. Assisted statistical analysis of project indicators and the mid-project Knowledge, Practices, and Coverage survey.
- Authored an implementation guide based on the Vurhonga program, to facilitate scale-up of community-based TB programs to other districts and provinces.

CENTER FOR LAW, JUSTICE AND SOCIETY (Bogotá, Colombia)
Senior Researcher, February 2010 – July 2012

- Supervised and coordinated projects through the Racial Discrimination Watch coalition, involving socio-legal research on the collective rights of ethnic groups, the impact of industrial mining on communities, and racial discrimination against Afro-Colombians.
- Conducted research and advocacy on social and economic rights, such as the impact of intellectual property protections on access to medicines in Latin America, and the socio-environmental consequences of large dams and natural resource extraction.
- Led legal education workshops for Afro-Colombian and indigenous communities.

COLOMBIAN COMMISSION OF JURISTS (Bogotá, Colombia)
International litigation lawyer, October 2007 – January 2010

- Documented, researched and advocated on behalf of human rights victims in Colombia. Emphasis on cases of extrajudicial violence, discrimination based on race and sexual orientation, and environmental justice for rural communities. Litigated before the Inter-American Commission on Human Rights.
- Advocated before and negotiated with the Colombian government for adequate implementation of decisions handed down by the Inter-American Court of Human Rights, including the creation of a national plan for medical and psychosocial attention for victims of extrajudicial violence and armed conflict in Colombia.

FELLOWSHIPS AND AWARDS

Johns Hopkins School of Public Health, International Health Departmental Doctoral Scholarship (2012-2016)
Johns Hopkins Center for a Livable Future-Lerner Fellowship (2014-2017)
Center for Qualitative Studies on Health & Medicine Dissertation Enhancement Award (2015)
Johns Hopkins University Environment, Energy, Sustainability and Health Institute Fellowship (2014-2015)
Johns Hopkins School of Public Health, Baker, Reinke, Taylor Award (2013)
Delta Omega Public Health Honor Society Scholarship (2013)
Johns Hopkins School of Public Health, Center for Global Health Established Field Placement Award (2013)
Harvard Law School Henigson Human Rights Fellowship (2007)
Harvard Law School Kaufman Public Service Fellowship (2007)
Merage Institute for the American Dream Fellowship (2004)
Massachusetts Institute of Technology Orloff Award for Best Undergraduate Physics Thesis (2004)
American Physical Society's LeRoy Apker Award Finalist (2004)

LANGUAGES

Spanish – fluent	Cantonese – basic oral fluency
Portuguese – advanced (Brazil's Certification of Proficiency Exam)	Mandarin – basic oral fluency

RESEARCH SOFTWARE Stata, ESRI ArcGIS, MaxQDA

OTHER

Admitted as lawyer to the Massachusetts Bar (2008 – present)
Reviewer for PLoS ONE (2015)
Abstract reviewer for the American Public Health Association's annual meetings (2016 & 2017)
Harvard International Law Journal, Managing Editor and Submissions Editor (2005 – 2007)