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Refereed article

Land Use Change in the Coastal Regions of Bangladesh: A Critical Discussion of the Impact on Delta-Morphodynamics, Ecology, and Society

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Summary
The article discusses various internal and external factors influencing the environmental and socioeconomic changes that have occurred in the coastal regions of Bangladesh, changes that have led to significant human displacement and migration. The transformation in traditional land use patterns, and specifically from rice farming to export-oriented shrimp cultivation for the growing global market, can be identified as having both created serious environmental and socioeconomic livelihood threats and decreased local resilience. Consequently this reduction of household resilience has forced certain vulnerable groups to leave their villages. Those affected have a clear understanding that the environmental and socioeconomic changes that they readily perceive are not linked to the effects of global climate change; rather, they clearly identify human interventions and changes in land use as the main causes of their now calamitous situation. Ironically enough, those who are eventually forced to migrate into the slums of Dhaka by an increasing global demand for cheap shrimps find new employment opportunities as low-paid workers in the country's rapidly developing garment sector — itself also linked to global production chains. In addition to this social dimension of change, the large-scale deforestation of fringing mangrove forests that has been occurring since the early 1980s has severely altered the geomorphological structures in Bangladesh's coastal sedimentary environments.
The observed social and environmental problems in southern Bangladesh result from various impact factors, and as such to blame global climate change alone is a far too simplistic argument. Even the observed and further predicted global sea level rise might not increase the vulnerability experienced in coastal environments in a geomorphological context of undisturbed natural conditions. On the contrary, the delta complex would actually benefit from increased sedimentation rates and thus grow even further. As the continuous expansion of aquacultures has by now gone far beyond the capacity of the local environment to support that, the production process has ultimately proved unsustainable. A second economic transition phase has thus recently begun, with more and more industries like shipyards, textile factories etc. now replacing the former shrimp farms.

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Introduction

The line of argument in the following text is divided into three parts. At first, various aspects of physical geography in the regional context of coastal Bangladesh are discussed. To explain morphological trends and to meaningfully analyze recent environmental changes, an understanding of the Holocene delta development is essential.

In the second part the economic, social, and ecological effects of aquacultures are discussed. During the last four decades certain economic activities — namely the extensive use of land for export-oriented shrimp farming — have led to dramatic environmental changes that have been unprecedented in nature. The loss of arable land and the rapid emergence of economic systems adhering to the competitive rules of a global market have particularly challenged local traditional societies. Temporary migration is one of the predominant coping strategies adopted. Based on findings that have been collected in coastal Bangladesh during the last five years, two key assumptions will be discussed: 1. A loss of arable land and income opportunities for the rural population resulting from a transformation in land use in the context of shrimp farming is one of the key factors in migration 2. Land use change has led to severe environmental degradation, and mainly to the loss of fringing mangrove forests. As a matter of fact, the vulnerability of Bangladeshi citizens living in coastal rural environments has increased dramatically in the last thirty years. The traditional adaptation strategies and economic capacities of the majority of the country's rural dwellers are no longer sufficiently able to meet the challenges that they now have to face. As their resilience potential becomes exhausted, people are forced to seek alternative coping mechanisms so as to protect their livelihoods — which frequently leads to social disruption and even migration (cf. Azam and Falk 2013).

Third and finally the text refers to the most recent processes of post-shrimp land use, based on field observations made in 2013 and 2014. A combined methodological approach that includes the interpretation of satellite images, field surveys, interviews, and focus group discussions with local people has been chosen for this.

Research concept

Based on personal field observations, many informal discussions, the analysis of satellite images, and a meticulous literature review, a number of locations between Khulna in the north and the Sundarbans in the south have been identified as particularly affected by land use changes in Bangladesh's coastal regions. So as to identify the extent and impact of land use changes on these coastal environments and on local society mixed research methods are applied. These include field investigations (qualitative interviews), participative observation, desktop research, and the regular monitoring of the selected locations — altogether covering six consecutive years of field visits there (as documented through photographs). In addition, numerous discussions with representatives of NGOs, political decision makers, and scientists

helped in being able to gather extensive background information. The interviews are based on semistructured qualitative questionnaires, the nature of which provided room for in-depth discussion with the interviewees. Some of the interviews were led in Bangla by local scientists from our research project group while some took place in English, being facilitated by interpreters. The transcripts were empirically analyzed following Mayring's (2008) qualitative content analysis approach.

If not otherwise indicated by references and quotation marks, the ideas and findings presented in this paper document a compilation of research results collected from several different studies undertaken by the author and by members of the related research project group.

An amphibious depositional environment — Holocene delta formation

The Holocene formation of the Ganges–Brahmaputra Delta has been predominantly influenced by a postglacial sea level rise, the development of dense mangrove forests along the coast, massive sediment load being transported down from the Himalayas by large streams, changes in the affluence structures of these river systems, and the overall climatic impact of varying monsoonal precipitation patterns. Immediately after the last ice age the global mean sea level was more than 120 meters below today's average (cf. Falk 2001; Freund and Streif 2000), while the early Holocene coastline was located several hundred kilometers further south to where it is found today. Due to rising temperatures melting glaciers unleashed a large amount of fresh water into rivers, which caused intense marine transgression during the late Pleistocene and the early Holocene — leading to marine ingression into the Bengal Basin and a northward shift of the coastline.

Another coinciding effect of deglaciation processes in the mountainous environments of the Himalayas and elsewhere was a higher sediment load entering local rivers. In addition an intensifying monsoon season gradually increased run-off rates, which led to more erosion in the mountainous catchment areas of the main local rivers and to higher sediment yields being transported downstream. As a matter of fact, Goodbred and Kühl (2000) have described in detail high submarine sedimentation rates and an initial delta formation on the developing shelf. Up until the climatic optimum reached in the Atlantic period, fast-rising sea levels dominated the geomorphological process in the Bengal Basin and in adjacent coastal environments. Marine ingression reached its maximum level at about 7000 ka BP, and tidal environments characterized by extended mudflats could be traced about 100 km further inland as compared to the location of the current coastline (Allison et al. 2003).

Rising temperatures during the subsequent Atlantic period further stimulated the intensity of the southwest monsoon and upstream erosion in the catchment areas of all major local rivers, leading to a dramatic increase in downstream sediment deposition rates. The early Atlantic period marked a dramatic turning point in postglacial

geomorphological coastal development, as sedimentation would now begin to outweigh marine ingression — although the mean sea level was still rising, by a rate of 8–12 millimeters annually. Consequently the ongoing seaward progradation of the delta plains now began. Expanding over a front of several hundred kilometers, a gradual seaward shift of solid land has been documented. Apart from high sediment loads and downstream material accumulation, expanding mangrove swamps stabilizing the coastline also played a decisive role in accelerating deposition rates and in the development of the recent form taken by the delta plains. As Allison et al. describe, regular monsoonal flooding deposited layers of sand, silt, and clay, which provided the fertile ground needed for intense land cultivation to occur; during the dry season "saline water [...] penetrates 100 km or more inland along [rivers] and distributary channels" (2003: 319). The average altitude of the most southern parts of Bangladesh, namely the lower delta plains, is less than 3 meters above sea level, making the area prone to flooding during cyclones.

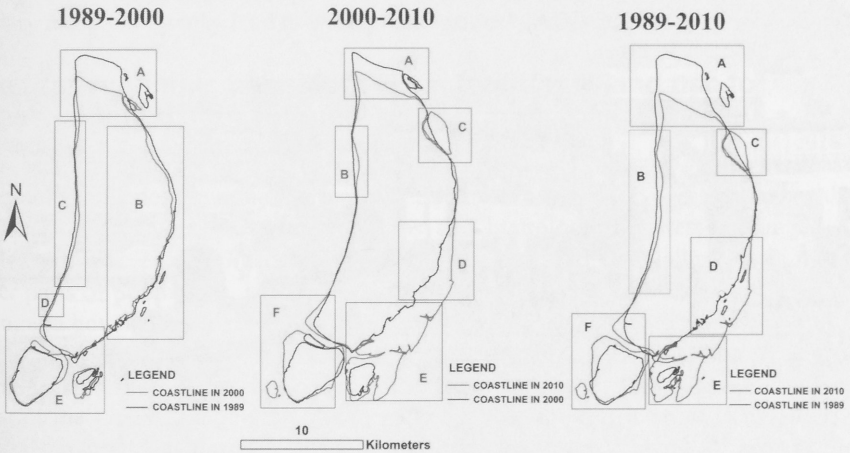
In general, seaward delta progradation can be observed as a commonly occurring global trend in the wake of the increase in the mean sea level — with it gradually slowing down from the mid-Holocene onward. As the Ganges–Brahmaputra Delta complex has developed under transgressional conditions, which have been characterized by similar rates of increase in sea level during their observation over the last 40 years and by more or less comparable climate conditions, there is no clear evidence that delta growth and accumulation would come to a halt under natural, undisturbed conditions. Even the observed, primarily tectonically induced, annual 1–4 mm subsidence of the Delta region was vastly overcompensated for by clastic deposits. Due to backwater effects and regular flooding, even the now predicted global sea level rise scenarios might not actually lead to massive sediment deficits and permanent land loss.

Recent morphological processes

At present more than 1 billion tons of sediment are transported into Bangladesh annually (cf. Khan and Islam 2008: 393), while according to Allison "the entire lower delta plain is still receiving sediment by seasonal (monsoonal) and episodic (cyclonal) inundation at rates that [range] from 4 to 7 mm per year near the Bay of Bengal" (Alison 2003: 320). These findings are confirmed by the satellite images documenting massive sediment gain in the central and eastern parts of the lower delta plains. Here, numerous highly dynamic islands, peninsulas, and permanently shifting riverbeds indicate the rapid nature of the progradation process occurring. Some of the islands have previously moved several kilometers seaward during a single discharge episode, and erosion and accumulation are omnipresent along the coastal rivers (cf. Falk 2011; Kumar and Gosh 2012). The analysis of related satellite images reveals that islands located in the mouth of the Meghna system are undergoing permanent changes to their coastline shape and are also rapidly gaining

in landmass (Kumar and Gosh 2012). These images were used to quantify the spatiotemporal developments as well as land cover changes that had taken place in the coastal zone. Hatiya Island for example, one of the larger sedimentation complexes, has gained nearly 3500 hectares of land since 1989.

Figure 1: 1989–2010 erosion and accretion ratio of Hatiya Island, located in the Southern Meghna



Site	Erosion (in hectares)	Accretion (in hectares)	Overall Change (in hectares)	Dominant Process
A	4920.48	0	(-) 4920.48	Erosion
B	1049.94	0	(-) 1049.94	Erosion
C	193.32	500.49	(+) 307.17	Accretion
D	0	2848.41	(+) 2848.41	Accretion
E	146.88	4500.99	(+) 4354.11	Accretion
F	165.15	2066.04	(+) 1900.89	Accretion

in total: Erosion: 5970,42 ha Accretion: 9410,58 ha

Source: Kumar and Gosh (2012).

All in all "shoreline progradation is presently occurring in the Ganges–Brahmaputra lower delta plain in the Meghna estuary at rates of 5.5–16 km² annually" (Martin and Hart 1997: 20, quoted in Allison 2003). More recent studies have documented even higher rates thereof, indicating that "during the last 36 years, the rate of net annual accretion has been about 17 km²/y, which is much higher than the long-term accretion rate" (Asian Development Bank 2010: 4). As Sarker also reports, "satellite images dating back to 1973 and old maps earlier than that show some 1,000 square kilometers of land have risen from the sea. A rise in sea level will offset this and slow the gains made by new territories, but there will still be an increase in land" (2010).

Figure 2: Intensive sedimentation in the Rupsha River

Note: Sedimentation is an omnipresent phenomenon all over southern Bangladesh. To ensure navigability dredging is necessary.

Source: Falk (2013).

Even in the very western parts of the delta, where erosion has become the prevailing process (Allison 2003: 320), sedimentation continues to cause problems with regard to the navigability of the rivers. However, very recently sedimentation rates have altered for a number of reasons. On the one hand large dams erected midstream in some of the major rivers located far inland have reduced discharge rates, while on the other embankments and dams created along their lower courses have modified affluence patterns — with the primary effect of increasing average annual erosion rates, due to the now more linear layout of their riverbeds. In addition, the "construction of embankments [...] started in the early 1960s [to] prevent sediment-laden tidal waters from inundating the plains. The present reduced rates of sedimentation [...] are creating water logging problems due to continuous subsidence and weak sedimentation" (Khan and Islam 2008: 398). Furthermore massive deforestation is having a negative impact on sedimentation processes and is thus destabilizing depositional environments in extended coastal regions. This aside, saltwater intrusion — and consequently increased groundwater salinization — is another observed effect.

As a direct consequence of reduced sediment input, the predicted future trends for the central and western part of the delta indicate that even the expected global sea level rise of 2 mm per year — a very conservative estimate given the most recent IPCC report — may lead to marine ingression. In any case, as "sediment input from the upstream catchment is very high, the responses of the river and estuary to climate change will also be very rapid. Thus, an assessment of the impact of climate change on flooding and salinity intrusion without considering the role of river and estuary morphology may lead to wrong conclusions" (ADB 2010: 4).

The first economic transition: From traditional land use to export-oriented aquacultures

Manmade changes are having a significant influence on coastal systems both in southern Bangladesh and in other parts of South Asia besides. Never before has the landscape, particularly vegetation patterns and hydrological systems, changed to such a dramatic extent. Since the early 1980s the coasts of Bangladesh, as in many other parts of South Asia, have been affected by extensive — almost wholescale — change in how land is used. While up until thirty years ago thick mangrove swamps, small rice fields, and widely scattered rural settlements defined the landscape of Bangladesh's rural south, nowadays extensive aquacultures have come to replace most of the forests. Large-scale deforestation is not only restricted to Bangladesh's coastal environment but is a phenomenon commonly experienced all around the globe, particularly in the Philippines, Thailand and Vietnam. Up to 30 percent of the world's mangrove forests have disappeared due to shrimp cultivation alone (cf. Azad et al. 2009). For South and Southeast Asia Burbridge and Hellin go even further, documenting that "over 15 million ha of mangrove has been cleared. This accounts for approximately half of the mangroves that had previously existed" (2002: 21).

Apart from their importance in the context of the global carbon cycle, mangroves covering intertidal zones in tropical and subtropical regions also play a crucial role in local coastal environments. Thick vegetation, particularly aerial roots, catches large amounts of sediment and thus stabilizes the coastline. As a natural coastal defense system, forests that border tidal rivers protect the hinterland from storm surges and thus reduce the adverse effects of cyclonic flooding. As documented for the Khulna Region, at the start of the 1980s the mangroves extended about 40 km inland from the outer coastline — thereby functioning as a giant sediment trap and a natural barrier that would protect the hinterland during tropical storms. The described forest loss thus increases the vulnerability of those people living in the coastal regions. First, without any natural obstacle in the way, storm surges intrude into the flat tidal plains with full force. As a consequence, the water table can rise much faster and waves are significantly higher. Second, the lack of higher trees dramatically increases average ground wind speeds due to the lack of friction. The

degradation of the fringing mangrove forests has not only increased the natural threats to human beings however; it has also resulted in the extinction of rare species and brought about a general loss of habitats for such animals as birds, crocodiles, tigers, fish, and various types of insect (cf. Falk 2011: 10).

As a rich coastal resource, mangroves are not only a unique habitat for rare species but have also traditionally provided local residents with manifold options for earning a living. Fishing, hunting, firewood logging, and the harvesting of honey are only some of the traditional means of using these once abundant resources. However, traditional farming practices, locally known as *bheri*, as well as the subsistent economic systems of the rural population have been reduced to marginal sources of income, while traditional local adaptation strategies are incapable of overcoming the burdens imposed by export-oriented industrial shrimp farming. *Bheri* culture as a more or less sustainable form of land use was previously locally established in the low-lying tidal areas of the floodplains. Young giant tiger prawns (*Penaeus monodon*) and small fry were traditionally caught in small basins at high tide, wherein they matured into adults. To keep the water within the ponds at low tide, they were surrounded by simple mud dikes — that aside, no major hydroengineering measures were ever implemented. Intermingling natural tidal channels remained undisturbed, and agriculture coexisted with the natural surrounding habitats. The productivity of these "early" aquacultures was not really predictable beforehand, as many unwanted species could also intrude into the ponds during the maturation process. It is posited that these traditional methods were first applied in the Sundarbans at the beginning of the 19th century. Up to the 1970s household-related traditional forms of agriculture — like growing vegetables, livestock herding, and cereal cropping — were combined with the practice of alternating between rice and shrimp farming in small compartments.

In the late 1970s a fundamental transition began, with export-oriented shrimp farming gaining greater and greater importance in Bangladeshi coastal agriculture. This shift was catalyzed by a number of government programs, defined in the second "five-year plan" for 1980–1985. It was particularly the practice of leasing public land (*khash jamin*) to shrimp farmers that gave impetus to this process of change, with small-scale, self-sustaining businesses having by now all but vanished. Even a brief glance at the figures obtained from the analysis of a series of satellite images makes clear the extensive shift in land use that has occurred, and moreover how it has led to massive deforestation and to related geomorphological changes. At the beginning of the 1970s coastal mangrove forests covered about 80 percent of the lower delta plains; within the space of 40 years, however, the share of forested areas has already been reduced to less than 30 percent overall. In some parts of southeastern Bangladesh deforestation rates stand at higher than 50 percent. At present a considerable part of the converted areas is being used for industrial shrimp farming, while other areas have been degraded by salinization — consequently rendering

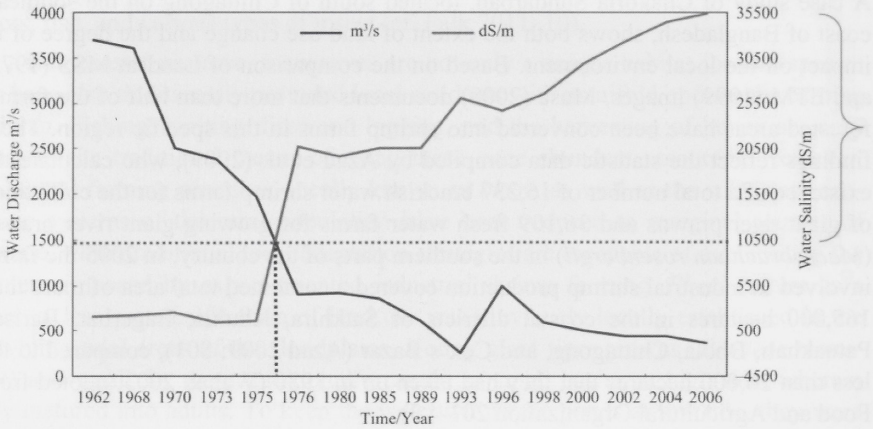
their agricultural use no longer economically feasible (cf. Falk and Ahmed 2008; Gain 2002; Karim 2006; Musa 2008).

A case study of Chakoria Sundarban, located south of Chittagong on the southeast coast of Bangladesh, shows both the extent of land use change and the degree of its impact on the local environment. Based on the comparison of Landsat MSS (1972) and ETM (1999) images, Musa (2008) documents that more than half of the former forested areas have been converted into shrimp farms in this specific region. These findings reflect the statistic data compiled by Azad et al. (2009), who calculate the existence of a total number of 16,237 brackish water shrimp farms for the cultivation of giant tiger prawns and 36,109 fresh water farms for growing giant river prawns (*Macrobrachium rosenbergii*) in the southern parts of the country. In 2005 the farms involved in industrial shrimp production covered a combined total area of more than 165,000 hectares in the coastal districts of Satkhira, Khulna, Bagerhat, Barisal, Patuakhali, Bhola, Chittagong, and Cox's Bazar (Azad 2009: 801), compared to the less than 20,000 hectares that they had taken up in 1980 (Wahab 2003, quoted from Food and Agricultural Organization 2014: 3).

The dramatic depletion of natural resources has gone far beyond sustainable levels and thus has put coastal ecosystems under enormous stress. The most prevalent negative effects thus far have been massive salinization and the exhaustion of soil fertility induced by excessive ground water depletion. Embankments and the loss of smaller tidal flows in the hinterland, due to the construction of large polders, not only negatively influence natural hydrologic systems but also hamper tidal brackish and monsoonal fresh water inundation. Two direct consequences of this are a negative sediment ratio, which cannot sufficiently compensate land subsidence anymore, and increased salt concentrations in the surface layers. Local coastal cause and effect mechanisms are now being overridden by manmade constructions along the middle and upper river courses; as a matter of fact, large upstream dams like the Indian Farakka Barrage are reducing river discharge — particularly during the dry season (cf. Falk 2011: 10). Islam and Gnauck showed that "the Ganges flow was 3700 m^3/s in 1962 whereas it was reduced to only 364 m^3/s in 2006" (2008: 445). As a direct result, saline seawater has seeped into local rivers further upstream — thereby shifting the overall pattern of isohalines northward. In general, gradually falling water tables and reduced discharge rates are now being observed along the lower courses of all major local rivers.

The described effects are not directly caused by global climate change-related factors like rising sea levels or more intense tropical storms but rather result from inadequate land use techniques linked to industrial shrimp farming and the overexploitation of coastal resources, primarily the destruction of forests (cf. IPCC 2007: 318).

Figure 3: Ganges water flow decrease and salinity increase, as measured at Passur-Mongla point



Note: Vertical dotted line indicating building of Farakka dam in 1975.
Source: Islam and Gnauck (2008).

Land use transformation in the coastal regions of Bangladesh — the dominant push factor for rural–urban migration

Bangladesh is one of the most vulnerable geographic regions anywhere on Earth. The highly dynamic delta relief, a variable monsoon-controlled precipitation regime, earthquakes, and frequent meteorological hazards — in the form of cyclones, severe floods, as well as drought and salinization — in particular force the still-growing local population in one of the most densely populated parts of the world to be continuously adapting and always mobile.

At present about 70 percent of Bangladesh's population lives in rural areas (Bangladesh Bureau of Statistics 2011), but now dynamic internal migration to the country's urban centers, and particularly Dhaka, is occurring — with it expected to further increase over the course of the next two decades. According to what can be learned from rural and urban dwellers themselves, the vast majority of permanent or temporary migrants leave their villages for economic reasons — specifically, so as to ensure the basic supply of some form of livelihood to their families. In recent years changes in local environments have forced the vulnerable to migrate to cities in the search for income-generating opportunities, a process that has given rise to a number of serious problems in the country's urban centers — where infrastructural improvements cannot catch up fast enough with the ever-growing influx of those from poorer social groups. In Bangladesh nearly half of the population is supposed to live in coastal zones below a critical altitude of 10 meters above sea level; in other

words, about 70–80 million people are living in more or less flood-prone environments.

The 1987 Brundtland Commission Report entitled "Our Common Future" and the UN Conference on Environment and Development in Rio in 1992 already made mention of the major migration flows that may be expected with increasing climatic events, and the cumulative environmental changes that may ultimately destroy people's traditional forms of livelihood (cf. World Commission on Environment and Development 1987; cf. United Nations 1992). These theoretically discussed causes of migration can also be traced out in Bangladesh. Especially the transformed land use structures have led to a considerable decline in the size of agricultural areas usable for private purposes (cf. Hossain et al. 2013: 324). Due to demographic pressure, poverty, and a lack of education, the scope for restorative action to be taken is even more limited. In the near future the situation could deteriorate considerably under the influence of the wider projected global climatic changes. According to IPCC predictions, 20 million people could be forced to migrate as a result of climatic changes by 2050. Within the same period, a 30 percent decline in food production is also expected (cf. IPCC 2007).

Theoretical embedding

Key research questions related to the processes now occurring in coastal Bangladesh were derived from the different theoretical concepts covering migration and resilience. As a detailed discussion of the reflected upon theories cannot be provided here, some of the classical and more modern approaches will merely be mentioned in passing. The basic reasons for why people leave their original locations, and the related temporal and spatial dimensions of migration, are theoretically discussed in classical migration theories on the macrolevel (cf. Pries 1997). In addition, approaches from an economic perspective on the macro- and microlevels have previously been elaborated (cf. Massey 1990; Stark 1991). Following Stark, migration is one strategy by which to maximize household income. Economic stimuli related to spatial contexts are discussed through concepts dealing with transnational migration. More modern approaches not only reflect on economic factors but also focus on social relations, as defined in the given local framework. In this context "social capital" (strong networks, mutual support, and so on) determines individual decision making (cf. Faist 1997; Portes 1995). However, in the specific context of Bangladesh some of the sociological approaches are not completely satisfying as they primarily concentrate on economic or social determinants. Additionally, social and economic vulnerability play a crucial role in the given ecological context; nevertheless, so far quite a few researchers have attempted to learn about the nature of population displacement as triggered by climatic and/or environmental changes (cf. Siddiqui 2010). To better understand local and regional migration patterns in

Bangladesh, those theoretical concepts reflecting on resilience (on both a micro- and mesolevel) are of core relevance.

Resilience in the theoretical sense refers to the dynamic nature and development of complex socioecological systems wherein adaptation and transformation play crucial roles (Walker et al. 2004; Folke et al. 2010). Resilience describes the coping capacity of individuals and households in the context of their community vis-à-vis tackling both ongoing and future economic, social, and ecological challenges. In this setting adaptation denotes the ability to adjust livelihood strategies to a variety of external and internal drivers of change. As adaptability is finite, the extent of economic challenges might reach a critical threshold and thereby go beyond the individual's coping capacity — eventually leading to out-migration (cf. Folke et al. 2010; Braun and Aßheuer 2011).

Are migrants climate refugees?

The public media continuously implies that a climate change-induced global rise in sea levels will trigger unforeseeable waves of people moving into the megacities of the Global South, and consequently lead to social and physical devastation in extended coastal regions. Following recent estimates, up to 4 million people currently live in the slums of Dhaka under extremely precarious conditions (cf. Angeles et al. 2009) — with urban growth trends set to increase over the coming years. Following Angeles et al., "the rapid growth of urban areas is already apparent in Bangladesh, a country historically characterized by densely populated rural areas" (2009: 32). Dhaka's metropolitan population is likely to grow in size "at an annual average rate of 2.72 percent during the period 2007–2025, making it the fastest growing mega-city in the world" (Angeles et al. 2009: 32). In the context of rural–urban migration, various environmental organizations and NGOs have reported on the existence of a growing number of environmental and climate refugees — particularly from coastal areas. "In Dhaka, migration experts say, climate change already is fuelling urban arrivals. Coastal flooding is occurring with more frequency. Rice crops, in particular, are slowly dying because of creeping salinity levels, and in the worst cases, entire homes and villages are lost to fearsome storms" (Friedmann 2009). Every year about 500,000 people migrate to Dhaka from vulnerable coastal and rural areas (Cities Alliance 2010); according to the International Organization for Migration (IOM), about 70 percent of the city's slum dwellers came to Dhaka after having faced some kind of environmental hardship in their area of origin (Mahajan 2010). In any case, many local villagers have some basic understanding that their local environmental changes might be linked to wider global climate change — but they are in their minds able to clearly differentiate between the global dimension and the immediate local effects of land cultivation practices. Human interventions in rural areas, specifically in the form of the conversion of fields and forests into large aquacultures, are unanimously blamed by these villagers for their

diminishing ability to earn a sufficient living by traditional means. As one local villager stated in a face-to-face interview:

> The natural view of the large area has changed. After the introduction of shrimp farming, it only supports the economic development of very few people and persons who have many lands. The population is growing and farming land has been converted to houses. Salinity is increasing. Livestock are dying due to inadequate grazing places and fodder. All you can see is water, water containing large and pocket shrimp farms — there are so few trees left. Due to the high intrusion of salinity we cannot cultivate vegetables, we have almost zero rice cultivation. So we have to buy everything from outside. Even the price for commodities is becoming higher day by day. I heard about climate change and a sea level rise but do not know the real cause and how it is affecting our community and local environment (southern Khulna region, 2013).

As an immediate consequence those affected are forced to migrate either temporarily or even permanently so as to increase their household capital from outside means; "they migrate to strengthen household capital and savings when regular employment in their local area is not available" (Azam 2011: iii).

Migration can be considered to be an alternative coping strategy utilized if other local options have failed (cf. Azam and Falk 2013: 12). Even though there is a still ongoing extensive debate about climate-induced migration from coastal Bangladesh, no significant relationship between climate change and migration in the country has yet been empirically evidenced. In addition to what can be learned from people living in the rural south, talking to slum dwellers in Dhaka confirms that they have clear concepts of climate change and its predicted effects like flooding, erosion, and increasing salinity. However, the described effects are not regarded to be the driving factors for their urban migration. In fact, those who have already migrated clearly indicate economic considerations as the prime push factor (cf. Azam and Falk 2013:12).

These findings sharply contrast with the persistent misconception that these migrants are climate refugees. Almost all interviewees saw themselves as the victims of the dramatic restructuring of coastal environments, with the overwhelming majority of people defining the land use shift to extensive shrimp farming as the practice that has deprived them of their basis of existence. Furthermore they complained about the fact that most of these farms are controlled by large national companies and influential landowners, even though shrimp farming "only supports [the] economic development of very few people and persons who have many lands" (Azam 2011: 41). In this context it is interesting to mention that "the major cause of the social problems resulting from shrimp aquaculture" seems to be a "lack of planning of coastal land use" (Azad et al. 2009: 804). Bangladesh's land use act of 1989 paved the way for state-owned properties suitable for agricultural use to be given to landless people; however, as Azad states, "most [such land] has gone to sufficiently powerful shrimp farmers [...] who are mostly urban residents" (Azad et al. 2009: 804). As some critics complain, "land in the coastal zone has been illegally occupied" (Azad et al. 2009: 804). However, planning processes flanking and coordinat-

ing the complex introduction of large-scale aquacultures — for example in the form of a master plan for shrimp farming in the coastal zones of Bangladesh or even an integrated coastal zone management system that provides general guidelines and regulations for land use, irrigation, drainage, and the like — have not been enforced.

Local push factors

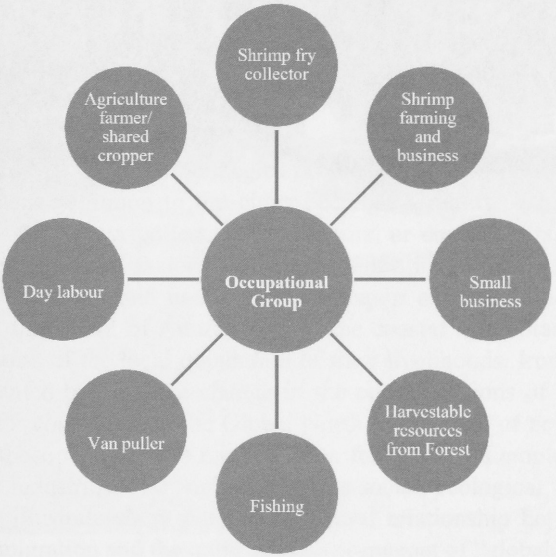
Presently the industrial aquacultures to be found all over Bangladesh extend over a total area of about 275,232 hectares (Department of Fisheries 2013: 34), while the export value of all shrimps leaving Bangladesh amounted to almost 310 million euros in 2011 (CBI 2012: 13). With a continuously growing number of companies, shrimp production — after the garment industry — represents one of the country's most important economic sectors. However, the fact that shrimp farming is far less labor-intensive as compared to traditional economic systems turns out to be highly problematic for the established local social structures. Azam (2011) illustrates that large shrimp farms employ most of their nonpermanent laborers during the preparation of lands period (November to December) and at the beginning of the cultivation period (January). Furthermore local people are able to find jobs during the harvesting period, which starts from April and continues until October (cf. Azam 2011: 62). As Hagler (1997) states, rice cultivation within an area of 100 hectares size could employ about 50 laborers — whereas a similar size shrimp farm needs only a five-person workforce (cf. Hossain et al. 2013: 324). As a result, most the local rural population can only make a living as a day laborer, earning a monthly income of less than 30–40 euros. According to the information that was provided by the local villagers interviewed, the loss of agricultural areas, the contamination of drinking water due to salinization, the loss of timber, the reduction of pasture lands, salt water intrusion, and the increased risk of natural disasters (quicker water surge/floods, higher wind speeds) rank among the negative effects of the aforementioned change in land use (Azam and Falk 2011).

Local resilience and adaptation efforts

Land use change as a gradual process forces the population in many respects to develop suitable adaptation mechanisms. That may prevent, or at least delay, migration. Particularly, the diversification of fields of work is one of the most commonly chosen strategies. About half of the respondents interviewed in the rural south had changed their occupation to day labor work, mainly as rickshaw-van pullers, snail collectors, brick kiln workers, or street vendors. In addition some earn their living in the remaining mangroves of the Sundarbans, where they run small fishing businesses, catch shrimp fry, or collect thatching materials and honey. Those who are forced to work in the dense forests face unforeseeable risks; quite a few have been killed in tiger attacks or fallen victim to piracy or kidnapping. The steadily increasing number of incidents where criminals rob fishing tackles, nets, and even boats or

try to extort ransom from the families of kidnapped laborers can also be regarded as an indicator of how desperate local living conditions have become.

Figure 4: Major occupational groups in Bangladesh's rural coastal environments



Source: Azam (2011).

People living in rural coastal environments harbor a deep reluctance to indulge the idea of migration. Many of the villagers have been living on their lands for many generations, as a result of which they have developed very strong social and ancestral links with their home territory. The replies documented in Azam's and Falk's (2011) research underline the fundamental importance that the local population attaches to remaining in their home region. They say that strong networks inside and outside the family, local cultural practices, and longstanding traditions play a crucial role in influencing their decision about whether to migrate or not. If somehow possible, the vast majority would "against all odds" choose to stay.

Furthermore, diverse discussions about the negative implications of migration could be traced among rural dwellers. As expected, fearing the loss of one's home culture and traditions and the lack of social networks at the point of destination are prominent impediments to migration. Nevertheless, high transaction costs, anticipated problems with finding new housing, and only having the option to take low-paid,

Figure 5: Fisherman catching fry in the Sundarbans

Source: Falk (2013).

short-term employment are also significant hurdles to face in making a final decision for or against migration. Contrariwise, there are some striking arguments underpinning the decision to leave. At first the remittances that will be sent are expected to improve the socioeconomic status of the family and to strengthen household resilience. Second, there is some hope for access to better healthcare and improved education in the city (Azam and Falk 2011).

Patterns of migration

Once local possibilities have been exhausted, migration remains the final, always available, option for sustaining some form of livelihood — although permanent migration is not the preference of most of those leaving their villages (Azam and Falk 2013: 7). The first choice for the vulnerable is instead to seasonally migrate to nearby cities or even other villages when work is not available in their own locality. It is common that only one or two family members and small groups of villagers will leave their places of origin at a time. Many villagers interviewed had previously specialized in short-term contractual work as paddy sowers, harvesting aids, earth work and street maintenance "experts," brick field workers, or wood processors.

Significant seasonal migration is evident during the rainy season. Additionally people use to migrate at any time throughout the calendar year, ranging in duration from one week to a maximum of six months. Those who use to go to the nearby villages mainly stay there for 1–2 days. The observed migration movements show rather different spatial and chronological patterns, whereas permanent migration initially is not at the forefront of people's thoughts. In many cases men leave their families behind for a certain period of time so as to find temporary — and usually seasonally restricted — work elsewhere (cf. Hossain et al. 2013: 324). Due to their limited qualifications, their work opportunities remain scarce and are restricted mostly to the informal sector.

If temporary migration strategies do not turn out to be sufficiently rewarding then permanent migration to the cities becomes a reality. While their husbands earn a living as rickshaw pullers, street vendors, or day laborers, women find jobs in the country's garment factories. A highly cynic interrelationship becomes evident: the rapid change in land use to produce export shrimps in aquacultures not only enhances the extent of natural risks in the coastal areas drastically but also deprives large parts of the local population of their livelihoods. Ironically enough, the losses precipitated by land use change in the coastal regions of Bangladesh brings about gains for consumers in the Global North in the form of new human capital to serve them: those who have to migrate often find low-paid employment in the garment or leather industries. The analysis of these social, ecological, and economic conditions clearly illustrates how there is no causal relationship between Bangladeshi rural–urban migration and the quite abstract scapegoat of "global climate change."

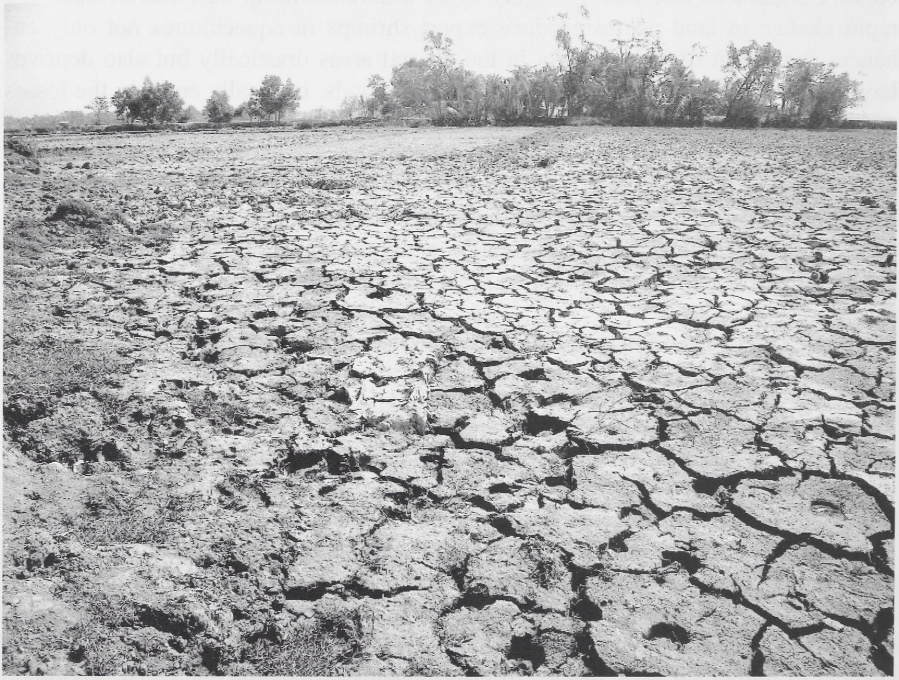
The second economic transition: Post-shrimp land use and industrialization

Salinization, among other forms of soil degradation, limits — due to reduced water influx, resource mismanagement, and inadequate hydrological measures — the overall period of time for which ponds for shrimp cultivation can be used. Furthermore, after some decades the concentration of salt and other minerals has come to exceed a critical rate for shrimp farming and agriculture. In addition, soil density, grain size, and the pedologic structure may have become altered too (cf. Karim 2006). The observations made in Bangladesh match the findings in other coastal regions too, where "poor site selection, coupled with poor management and over-intensive development of individual sites, has led to unsustainable production and often, wholesale abandonment of ponds. [...] The net result is that extensive areas of formerly biologically rich and productive wetland forest are lying idle" (Burbridge and Hellin 2002: 20). From Thailand, where aquacultures have an even longer tradition of use, it can be learned that it may take several years to naturally regenerate the fields — a period of time too long for those farmers who are already socioeconomically deprived. Going by Burbidge and Hellin's discoveries, it is difficult to provide exact

numbers on how many former shrimp farms have been abandoned; however "unofficial estimates of pond disuse have suggested that the percentage of ponds left idle after a period in production can be as high as 70 percent" (Burbridge and Hellin 2002: 20).

This estimation can be indirectly confirmed by the author's own immediate field observations made in the Khulna and Bagerhat regions, which lead him to posit that up to 30 percent of shrimp farms are already in disuse or at least nearly exhausted. Taking all these factors together, the urgent question arises of what will follow on from shrimp farming and how best to use former sites of aquaculture. It is an indisputable fact that a second phase of transition in land use, from shrimp farming to post-shrimp farming, will inevitably occur in the years ahead.

Figure 6: Land degradation: A shrimp polder showing high concentrations of salts and other minerals during the dry season



Source: Falk (2013).

The country's rivers, as a natural resource and an important network for the national transport infrastructure, are the backbone of the society, ecology, and economy of Bangladesh. Some of the country's major rivers are developing into the main axes for the aforementioned second economic transition. In the Khulna and Bagerhat Divisions decisive restructuring processes are already taking place, being backed by

different both private and government development initiatives. With an estimated 1.4 million inhabitants, Khulna is the third-largest city in Bangladesh and one of the oldest industrial centers in the southern part of the country. On the one hand traditional industries in and around Khulna — like jute processing, steel and paper mills, or match factories — are being revitalized by their privatization and expansion, while on the other new processing plants along the Rupsha and Pasur Rivers are also being developed. In addition a decisive role has fallen to the increased production of vessels for the national navy in one of Bangladesh's largest shipyards located near the city.

The efforts to develop various industries in these districts are being supported by a number of either already realized, ongoing, or planned infrastructural improvements. Rupsha Bridge (completed in 2005), the construction of dual carriageways in the vicinity of Khulna (Khulna City Bypass), and the improvement of the national highway (N7) connecting Khulna with Mongla Port are only some of the key projects involved in this. Another indicator for the economic transition ahead is the construction of Rampal, a coal-fired power plant — located in a (still) rural area north of the Sundarbans, it is one of the most controversial contemporary energy projects in the whole of Bangladesh at present. According to Bangladesh's Power Development Board, the "development of this project may induce local and regional infrastructural development. It is very likely [that] power security along with [the] Mongla Port facility will attract industrial development, and thereafter industrialization will take place. Accordingly, present land use will be changed; more township and industry will be developed on existing agricultural land" (Centre for Environmental and Geographic Information Systems 2013: 276). According to what can be learned from local landowners and former farmers, "the internationally operating companies pay a good price for the land" — the land that, for the aforementioned reasons, eventually became useless for shrimp farming and indeed for any kind of agriculture (per oral information gathered in February 2013 by the author). At present, new cement mills, dockyards, container terminals, and plants for processing liquefied natural gas (LNG) are under construction on the sites of former shrimp farming. Those who manage to earn a living in the coastal regions as day laborers or small farmers, as well as those who have to seasonally migrate so as to guarantee their family's livelihood, are now hoping for a more prosperous future. Expectations of finding solid job opportunities in the newly developing industries are high among local residents, but it remains to be seen whether the economic transition unfolds in accordance with environmental needs and social requirements.

Figures 7a, b: Industrialization along the Rupsha River, where industrial production sites are now replacing former shrimp farms

Source: Falk (2013).

Conclusion

Increased vulnerability and social disruption in the coastal regions of Bangladesh have been caused by various environmental calamities resulting specifically from human interference with local ecosystems, and not so much from global climate change. Higher ground wind speeds, higher storm surges, more frequent floods, soil erosion, and higher salinity rates can be observed in the central and southeastern parts of the country's low-lying delta plains (cf. UNISDR/UNEP 2012). Analysis supported by Geographical Information Systems and satellite imagery documents how the observed changes in Bangladesh's coastal ecosystems have been both directly and indirectly induced by local or regional human environmental interventions — primarily deforestation, irrigation, and the building of dams (cf. Kumar 2012). The oft-discussed global climate change patterns have played only a subordinate role herein, and it continues to surprise how projected effects of climate change that have not been scientifically scrutinized are mixed in unreflectively with questions about the causes of current Bangladeshi rural–urban migration. The negative effects of global shrimp consumption — such as large-scale deforestation, the transformation of arable land into aquacultures, and out-migration of the vulnerable from their ancestral lands — sets free human capital that can be employed in other growing industrial sectors located in and around the country's major urban agglomerations. Unsurprisingly many employees working in the garment sector, the fastest-growing one in Bangladesh, share the same migration pathways — ones that eventually lead them from their local villages to the informal settlements that they now inhabit above all in Dhaka.

Following on from the first phase of transformation in traditional land use practices toward aquacultures for the production of shrimps for export, Bangladesh's coastal zones are now undergoing a second phase of transition — one characterized by the expansion of a range of industries. The country's coastal regions will soon face dramatic short- and medium-term changes, ones that will have far reaching consequences for infrastructure, rural and urban communities, agriculture, shrimp farming, and industrial production. However, any such economic transition and social development has to take place in accordance with environmental needs. Hence, effective risk-reducing mitigation strategies must now be developed. To reduce possible negative impacts on natural habitats and to assure the future wealth and health of local societies, as well as their economic prosperity, the establishment of an effective integrated approach for coastal zone and environmental management (ICZEM) is of fundamental importance. An integrated system that respects and addresses different, sometimes contradictory, interests will have to consider the attitudes of all involved stakeholders, such as representatives of local communities, national and local government authorities, industrial bosses, project planners, and NGOs to mention just a few. The local dimension aside, the outer coastal zones also demarcate international boundaries (India to the west, Myanmar to the east) — thus

cross-border dialogue and friendly cooperation will be essential for effective management that results in mutually beneficial economic growth.

Local communities represent a rich potential resource for the development of local solutions to all these challenges, and they will be able to provide particularly useful input if local knowledge can be (re-)empowered so as to strengthen resilience and help find creative adaptation strategies. The close involvement of these communities implies bottom-up development processes occurring, instead of centralized top down approaches being taken. To ensure that as many people as possible participate in these processes it will be essential to provide education that results in greater awareness of the issues involved and that furthers the development of democratic structures. As Waheduzzaman has identified, the failure thus far to take into account the value of local people's participation alongside a nonexistent "robust legal system to ensure that people's participation is legitimate at the rural level" (2010: iii) are currently key obstacles to sustainable development.

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