Title

Local social-ecological context explains seasonal rural-rural migration of the poorest in a rural community in southwestern Bangladesh.

Abstract

Bangladesh is one of the countries most affected by climate change. Internal migration is often presented as a response to environmental degradation in rural areas. Here, we test the hypothesis that climate-induced changes and adaptations impact local production and the local labour market, pushing out unskilled landless workers. We focused on different categories of livelihoods and their interactions to understand the local socio-ecological context for such workers. We conducted fourteen semi-directed interviews and six focus group discussions with villagers in March-April 2022. We used a configurational approach considering changes>impacts> and responses>impacts of responses to analyze our data for agricultural farmers, fish farmers, independent fishermen and unskilled workers. We conducted rainfall analysis on Chirps data for the period 1981-2021.

Villagers reported that increased waterlogging was the most significant change and that covid-19 lockdowns were cited as an aggravating factor. Most climate-induced changes have progressively begun to occur over the past 25 years. Climate data compared with emic perception confirm these results. We found that changes, particularly climate-induced changes, increase local inequalities. The shift in land use to fish farming, partly driven by the motivation to adapt to waterlogging and salinisation, increases locally the effects of waterlogging. As a result, farms are submerged, production is lost, and fewer jobs are available locally. Smallholder farmers suffer more than wealthier farmers and have more difficulty covering the losses associated with these changes and the costs associated with adaptations. Fishermen are

thus converting to unskilled work, and unskilled and landless workers migrate to other rural destinations to find work.

Key words:

Climate change, livelihood, rural-rural migration, inequality, pathways, Bangladesh

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Introduction:

Bangladesh is among the fastest-growing economies in the world and show improvement for numerous development indicators (1). However, it is also one of the countries the most vulnerable and affected by climate change (2). Local rural livelihoods are undergoing many, often interrelated changes, from socio-economic and demographic changes to environmental and climate-induced changes. For example, waterlogging, land and water salinization, cyclone, drought, heavy rainfall, land use change, are among the challenges experimented by the coastal population (3–6). More recently the Covid-19 pandemic crisis also strongly impacted coastal populations (7).

Several studies have pointed out the role of internal migration in supporting rural livelihoods in southwestern Bangladesh, with migration being cited as a response to environmental degradation (8,6,5). The phenomenon is expected to increase with pessimistic scenarios about climate change projecting the number of 13,3 million climate migrants by 2050.

The climate change-migration nexus is increasingly covered in academic research while still being debated (9). Migration is complex in form, origin and destination, temporality, investment and outcome (10) and pathways connecting climate to migration are multiples and non-linear (11). In short, climate-induced migration decision and pathways are part of a complex socio-economic, behavioral, and environmental context (12,13).

Past studies in southwestern Bangladesh have shown various migration strategies depending on contexts, sectors or socio-ecological systems (8,6). Our study aims to contextualize the migration of the poorest as the result of a local limitation of their livelihood adaptations. To do so, we consider the impact of change and response to change for different categories of livelihood. We argue that local heterogeneity of livelihood and wealth is important to consider locally because socio-political and institutional contexts, including local power

dynamics, values and interests, interact with the environmental context and limit or frame the possible choice of responses to changes for households and individuals (4,14–16).

Here, we hypothesize that climate-induced changes, in interaction with local adaptations, are impacting local productions and local labour markets, expulsing unskilled landless workers seasonally.

Most recent studies have been multi-sites, thus providing a sub-regional perspective on the most degraded area of Bangladesh, the exposed coast. While the effect of climate change are intensifying, waterlogging and salinization are also increasing in the interior coast (17,18), showing the need to focus further inland. We propose a qualitative approach combined with rainfall analysis, on one of the most rural communities in Tala upazila, located on the south side of the interior coast.

This work will contribute to the growth of the limited research based on people-centred perspective within the area of environmental science, climate change, and adaptation (6) necessary for a better understanding of local experiences of social-ecological systems, and specifically to the poorest and most vulnerable population.

On this paper we address the following questions:

- What significant changes do villagers believe to have impacted their community and livelihoods over the past five years, do these perceived changes correspond to reality?
- In what ways are differential livelihoods impacted and what are the precise changes?
- What are the connections between climate-induced changes and unskilled seasonal migration of the poorest members of the rural community
- What recommendations can be identified to inform future policies?

Methodology

This study is part of an interdisciplinary exploratory project on climate change, migration and health system resilience, for which the protocol has recentl been y published (19). We use a social-ecological perspective drawing on previous studies using ecosystem services (i.e. ecosystem providing food, water and income) as resources for rural livelihoods in Bangladesh (20,21) but at the scale of a community and with a qualitative focus on local perceptions and experiences. In other words, we explore the changes that impact rural livelihoods, and how villagers respond to these changes. We use a configurational approach to access both changes and impacts of changes and responses and impacts of responses to explore how the social-ecological context impacts different types of livelihoods, and how these impacts shape the context for the poorest and their migration strategies. Our data relies on qualitative data regarding local narratives and climate data to compare emic perception of climate with climate data.

Qualitative data collection and analysis:

We use the local perceptions, changes and impacts experienced by a community over the past five years to understand the complexity of a changing context. We collected the data with an approach following the configuration path "external changes in the past five years>impacts of changes on the household>responses> impacts of responses". We carried out six focus group discussions (FGDs) and 14 semi-directed interviews (table 1) (22) with crop farmers (vegetable, fruits, rice, and other cereals), fish farmers, fishermen, wage labourers, housewives, and/or people who lived in flood-prone locations in March and April 2022. Participants were recruited using a snowball approach, starting with people attending a meeting about a program for fish farmers that was brought to our attention by a local official. We tried

to vary the profile of the respondents according to the categories suggested by the respondents in order to capture diverse categories of livelihood and living conditions.

Interview and FGDs guides were designed to collect emic perspectives on (a) the external changes impacting their household since 2017 (b) the impacts of these changes on the livelihood of the respondents and their household's members (c) their strategies to overcome these impacts (d) the impacts of these strategies for the respondent and their household's members (d) the type of projects or programs that impacted directly or indirectly their livelihood or the community life (e) respondent experience, knowledge, and views on climate change.

External changes were defined as all changes or events impacting their community and household since 2017, the year of a widespread destructive flood in the region (23) to allow for a decent recall time for the interviewees' memories . The decision was not to focus only on climate-induced changes, but rather to include all types of external events or changes perceived as important by the community members to understand how crucial climate-induced changes have been for this community in the past five years among all these changes, and how changes of all types related to each other. Rather than an exclusive criterion, the "external changes" definition provides an entry point into the discussion of the issues faced by community members, and allows us to be more open to other changes perceived possibly as more important to the community than climate change.

Content analysis was performed for different categories of livelihoods to organize the conceptual model. We analysed the data through a configurational approach to understand the dynamics between environment and livelihood for each livelihood and between livelihood types.

Quantitative climate data and analysis

To support the qualitative information from local's perceptions, we use the Climate Hazards group Infrared Precipitation with Stations (CHIRPS; (24)). This dataset combines satellite and *in-situ* rainfall stations to produce rainfall-gridded estimations at a high spatial resolution (5.5km x 5.5km). CHIRPS spans from 50°S to 50°N and ranges from 1981 to the near present. Its long-time record and its high spatial resolution make this database useful for the analysis of rainfall trends at regional and local scales. CHIRPS dataset is freely available here: https://www.chc.ucsb.edu/data/chirps

The annual cycle of precipitation is computed with CHIRPS estimations. For this, we averaged the accumulated rainfall falling each month over the period 1981-2021. Temporal rainfall trends for the period 1981-2021 were identified in each map grid cell using the rank-based non-parametric Kendall test (25). This statistical test is widely implemented in hydrology and climatology studies in the region (26,27). The statistical analysis of rainfall trends was performed using the Python package pyMannKendall developed by (28). Figures for climatological data were designed with the Python library Cartopy (29) created by the MetOffice. Finally, a data base for the Asian stream and river network produced by the World Wildlife Fund's (WWF) HydroSHEDS was used (30).

Study site

We focus on one inland rural community in Tala upazila, which is not experiencing the level of environmental deterioration of southern territories but might be next in line (18,31). Focus group discussions and interviews were conducted six months earlier in various communities in the Tala upazila for the ClimHB project (19), and waterlogging was identified as the most important local environmental challenge in this area, which is also confirmed in the literature (18). We chose a rural community experiencing waterlogging, while not all communities face this problem, in order to understand the most environmentally challenging

context and the interactions between different local issues. Khalilnagar union was selected after an extensive prior visit to the Tala upazila and with practical and logistical considerations. The study site is at approximately 20km from Khulna and Satkhira, and 25-30km from Jessore, three regional cities with meteorological stations. Analysis of regional data from those forecast stations, has been already covered in the literature for 1995–2015 (3). This union is one of the most rural and poorest of Tala.

Ethics approval

Ethics approvals have been granted from the Institutional Review Board (IRB) of the BRAC James P Grant School of Public Health, BRAC University (ref: IRB-19 November'20–050) in Bangladesh. The usual ethical criteria for qualitative health research was respected, details of the process are published and described in (19). No biological data was collected. Participation to the study is voluntary. Participants were informed about their right to withdraw at any time without consequences and about their right to refuse to answer. They were also informed about the research results' intended publications, data use and sharing. Consent was systematically requested from participants for the qualitative data. Methodology concerning consents was approved by both ethics' committees in Bangladesh and Haiti, and published (19). Appropriate policy and practice concerning confidentiality, anonymity or acknowledgement of research participants were considered by the researchers on the field. Feedback to participants on the research results as appropriate will be planned, according the data management plan of the project (19)

Table 1: tables of respondents' characteristics

[insert two tables: FGD and interviews here]

Results

Southwestern Bangladesh lies in the arms of a delta, crisscrossed by a network of multiple rivers and canals leading down to the sea (Figure 1a). While this green land was once compared to a fertile Eden by Bangladeshi poets, livelihoods have become more problematic even in this community, more than 50 km inland. While most of the villagers reported a religious interpretation of climate change causes, resulting from God's doing or God(s) punishment, climate-induced changes have a very clear impact on their life, as presented in the following sections.

We categorized the information collected into four categories of livelihoods that reflect self-identification: agricultural farmers, fish farmers, open-water fishermen, and wage labourers. Those categories do not represent some strict employment categories but rather a connection of their livelihood to natural resources and are not exclusive. Many crop farmers have become fish farmers, some are mixing crop and fish farming, the young generation of open-water fishermen resorts to unskilled jobs, and many villagers are fishing punctually. In addition, those categories also reflect two wealth categories based on land access: fish and crop farmers have "land" access while fishermen and wage labourers are landless, unskilled and among the poorest.

All changes cited were directly or indirectly climate-induced, apart from the Covid-19 lockdowns. Lockdowns imposed during the Covid-19 crisis in 2020 aggravated the economic situation of all. Fish and crop farmers had to sell their products locally at a much lower cost, and often on the black market, local workers had to work illegally to survive, and migrants had to move before or illegally during the lockdown, thus experiencing police violence. NGOs and authorities provided some support, but not all disadvantaged families received it. Most relied on formal and informal loan and debt systems.

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213 # 1. Farming is experiencing difficulties because of climate-induced changes

214 ## 1.1 Crop farmers perception and experiences of climate-induced changes

215 Many farmers practice mixed farming, sometimes having farmland on both lowlands and
216 uplands, which are only a few meters above low lands. Farmers often have multiple sources of
217 income from various crops, from rice to vegetables, fruits and other cereals, poultry and small-
218 scale livestock, milk production and small-scale fish farming. In addition, they are often
219 engaged in other activities ancillary to the household such as small store, sewing/tailoring,
220 handicraft.

221 The changes reported in the past five years, have been perceived to happen gradually in
222 the last 20-25 years. As the country's economy was improving, farmers were facing new
223 challenges that negatively impacted their livelihoods. When speaking about the past, farmers
224 picture a land of milk and honey: "*Harvests were so plentiful; the stocks were rotting*" [FGD6].
225 They remember an idealized past and depict an infertile present: "*We had cowsheds filled with*
226 *cows, rice storages filled with rice, ponds filled with fish. But now we have problems*
227 *everywhere."* [FGD6].

228 All reported a negative perception of the changes affecting their environment, but the
229 impacts do not affect everyone equally and coping capacities vary according to resources, with
230 less affluent farmers reporting a deterioration in their livelihoods, suggesting an increase in
231 local inequalities. Covid-19 lockdowns have worsened the situation, as farmers have had to sell
232 their production locally, losing money, and some production networks have been suspended for
233 some time, such as for milk. Most of them had to take out loans that they were finishing paying
234 back at the time of the fieldwork.

[I6] During the covid period, I lost 10 lakh tk (1000000tk), because 2,5 biga of brinjal were destroyed by [the cyclone] Ampan. The loss was 8lakh tk. We couldn't sell milk to the market. I lost 2 lakhs from that. So I sold 6 cows during covid, for 8lakhs tk (in total) and I took loans from Brac for 6 lakh 50000 tk (650000tk) and 4 lakh tk (400000). I almost paid back all. Only 1lak20000 (120000) need to be paid back.

[I9] 2 years ago, due to [the cyclone] Ampan, I almost lost 4 bigas of papaya trees, about 4 lakh taka (400 000). He took a loan from Brac (50000 tk) and U. Protestaat (80000tk). During the covid, we had many problems in selling products due to governmental restrictions, we sold for half price or below.

[I14] During the covid, I had to sell shrimp, milk, mango, half price. Because the government prohibited the movement of the population, there was less transport. It was possible to sell things locally only once a week at the market so we sold it in the community instead of nationally. The milk collector network didn't take their milk. I produce different kinds of fish in the pound, but we had to sell fish under cover during the covid time, on the informal market. [Because I lost money], I took many loans from different organizations, 50000tk from Brac, 100000tk from U.Protestaat, 20000tk from SPF, we use it to repair the enclosure and to make the barn and we sold 2 cows (150000tk for the two).

Depending on the farmland elevation and location, and individual resources, farmers are not impacted equally. Farmers on lowlands, with land close to canals or to fish farms, report suffering first because of waterlogging and changes to their land quality due to flooding and salinization, and new crop diseases associated with waterlogging. Farmers with higher land, are less often exposed to waterlogging. They suffer first because of changes in seasonal climate patterns. They specifically reported destructive heavy rains during Monsoon, off-season unpredictable rains, cyclones and droughts in addition to the loss of land productivity, due to land exhaustion, lower levels of underground water due to irrigation and overexploitation and

its contamination with minerals that impedes cultures. Most of these changes are also experienced by lowland farmers.

In addition, capacities to adapt to changes depend on material resources. Farmers report the use of new variants, new crops, diversification of crops, change in the cultivation calendar, more intensive practices with more fertilizers, supplements chemicals to offset iron in water, plastic sheets (in polythene and tripal) to protect their crops, deeper water pumping, rent of water truck, and/or the shift to other activities, such as fish farming. Farmers living in the flooded area, raise the land of their compound or their buildings. Most of those technics imply extra monetary costs and for those who can afford the costs, those strategies might be economically profitable. Non-monetary costs, for example in the case of land salinization due to fish farming and waterlogging. For less wealthy farmers, those monetary and non-monetary costs add to their burden, and the feeling of socio-economic downgrading, which might result from environmental deterioration but also from other global changes such as a system relying more and more on the market economy and wage jobs, creating new social recognition of livelihoods, might also play a role in the perception of the negative evolution of their livelihood: [FGD6] *"Those who used to do agriculture before, were in a good position. Now, it has been taken over by jobs [wage jobs]. The best ones were farmers, the mediums were the businessmen, and the lower ones were wage-jobs. Now the wage-jobs are the best, business is still medium, and agriculture is at the lowest."*

1.2 Rainfall data are corroborating farmers' perception

Rainfall measurements from CHIRPS database points in the same direction of local perceived changes in the regional climate. Seasonality of precipitation in the region is characterized by a dry winter from December to February with a total rainfall of less than

40mm/month, followed by a pre-monsoon hot season between March to May, with moderate cumulated rainfall in the south and western parts and higher total rainfall values over the east (Figure 1b). The rainy season extends from June to September, being July the wettest month for the entire region. The end of the monsoon coincides with the autumn in the northern hemisphere and is by an abrupt decrease in precipitation from October to November (32).

The analysis of rainfall trends allowed us to identify a rainfall reduction (red colors in Figure 1c) during the dry months, particularly during January over the interest region. A similar result was previously reported by Nashwan et al. (33) with different observational datasets. During the wet season, especially during the rainiest month of July, an increase in precipitation is observed in CHIRPS data along southwest Bangladesh. These rainfall changes are in agreement with the settler's perception of the ongoing seasonal alterations in climate patterns. Villagers also reported having experienced destructive heavy rainfall during Monsoon that could be related to the wetter conditions for the humid month of July. Previous works have reported more frequent heavy rainfall events in Bangladesh in the southwestern side (26).

Rainfall during the pre-monsoon period is particularly important for Bangladeshis since most of the grain crops is grown during this season (26). Therefore, dry events between March and May can cause crop stress and productivity loss and can exacerbate the agricultural production dependency on groundwater (27). We found a precipitation decrease during the months previous to the monsoon over southern Bangladesh, which can be related to the feeling of more frequent droughts experienced by Khalilnagar's local population (Figure 1c). Finally, local population are affected by off-season unpredictable rains. According to the satellite rainfall data, there is a slight positive precipitation trend during the beginning of the wet-to-dry transition period (October) and the beginning of the dry period (December) over the southern and southwestern parts of the country in agreement with villagers and previous studies (Hossain et al., 2014).

[Insert figure 1 here]

Figure 1. (a) Location of the interest region and river network from the vectorized information HydroRIVERS derived from the World Wildlife Fund's (WWF) HydroSHEDS . (b) Monthly accumulated rainfall mean for the period 1981-2021 from CHIRPS database. Data in mm/month. (c) Rainfall trend measurement through the Kendall coefficient. Small black dots highlight places with significant trend at 95% of confidence. Blue colors indicate increasing rainfall trend while red colors a decreasing rainfall trend. The location of Tala is located with a dot in all sub plots.

1.3 Switching to fish farming: a solution with ambivalent sustainability consequences (435 words)

Farmers explain their switch from agriculture to fish farming by a combination of motivations stemming from the vulnerability of their land to waterlogging, an economic motive, the common good because they are feeding the growing population and following government recommendations and because being fish farming is less physically demanding work compared to agricultural farming.

[I5]: *"20 years ago, the price of rice was low (400 tk for 40kg). The price of shrimp was better. So, they choose the shrimp farming. "In this area, in 2000, there were 100 bigas of land for shrimps. Now, in 2022, it's 500 bigas of land. The land for shrimp farming is increasing. The price of shrimp is increasing. It's sold in Bangladesh and abroad now. The government is encouraging the business".*

[FGD1] "This is not only for my profit. There are many reasons behind the production of fish. Do I do it only for myself? Everyone has the duty to fulfill the nutritional need of the normal people. We don't eat the whole product, we also supply abroad. We are trying to earn money and also we are trying to reduce the deficiency of protein".

[I17] *[People are switching] "because they are on lower land or close to the river, so already vulnerable to waterlogging. It's both because of waterlogging and higher profits in shrimp farming".*

[I started fishfarming] "because it was profitable, six months paddy farming, six months shrimp on the same land. But in the last 10 years, there was an increase. Waterlogging problem is increasing, and government encourages shrimp farming. Due to the export of shrimp, the price is increasing".

"*paddy farming involves physical labour force repetitively. Shrimp farming, is less difficult, you build ghers [enclosures] only once a year".*

In the past decades, areas near canals are increasingly covered with fish farms for different varieties of shrimps, prawns and fish (such as *golda* prawns and *bagda* shrimps, tilapia fish, ruhi fish). The fish farm landscape is also changing with the evolution of practices from traditional prawn to modern salt-water resistant shrimp farming which requires higher enclosures and deeper ponds.

The saltwater, which arrives from downstream with the river tide, is directed to the fish farms, and penetrates the soil, making the land unsuitable for agriculture. The water overflowing from the fish farms contaminates the adjacent lands with salt and causes neighbouring farmers, in a domino effect, to abandon agriculture and adopt fish farming. During the rainy season, heavy rains or during cyclones, the combination of river tides and rains, creates waterlogging; the high enclosures prevent the proper evacuation of the water flow, fish farms

are overflowed, fish production is damaged or lost, and neighbouring lands and buildings are waterlogged. The monetary benefit of fish farming is still advantageous, but not as much as before when there were only a few fish farmers. Increased competition, increasing land prices and lease prices, increasing prices of shrimplets, lower production and loss of production due to a virus are other costs and losses impacting fish farmers.

Large fish farms owned by affluent people are especially pointed as responsible for waterlogging, as they represent the largest risk and powerful people in terms of social and economic status. [I11]: "*Rich fish farms have an impact on water flow, the water does not flow properly. These farmers are political people or upper class or have important connections*". The enclosures built on *Khasland*, land bordering the canal leased by the government, are also pointed, as they are the last physical obstacle to the water flow.

At the time of the data collection, a local NGO was involved by the local authorities, to help fish farmers to modernize their practices and to work in cooperation with each other, which is expected to help reduce some of the problems encountered by the fish farmers.

The Bangladesh Water Development Board (BWDB) have been called upon several times by the local authorities to send support without any success. Villagers have tried to dig the canals themselves, but the magnitude of the task is such that without motorized machines and done by hand, the result is minimal and not sustainable.

2. Responses to climate-induced changes are limited for the landless and insolvents

2.1 The disappearance of water bodies is a cause of livelihood degradation for fishermen (502 words)

For the past 20-25 years sediments, brought by the river tides, filled up gradually water bodies, creating new land, which is now used for fish farming, leaving independent fishermen with very little access to water bodies. *[FGD4]: "There is nowhere left to fish to feed our children. Every piece of land has been bought up by wealthy people* (…). *Where will everybody go if there is no river?"*

Once, fishing supported entire families and was part of the identity of many. Nowadays, fishermen have to pay fish farmers an increasing price for fish pond access, making families struggle to support themselves. They try to diversify their activities but have no land, are not solvent, so their options are limited. Before, they were going to the Sundarbans forest to harvest honey. Since 2018, for fear of kidnapping, robbery, and beatings, which happened to several of them, they stopped. Today, when they can, they travel outside the upazila by boat for weeks at a time with several male members of the same family, paying for access to portions of rivers, and sharing the profits of the fishery equally. Men of the younger generation [FGD5] are changing occupations, they work in agriculture or brick factories, as contract or daily workers often joining the crowd of seasonal migrants (see next section). Some families have migrated out permanently to other rural areas.

All are now hoping for a better future for their children and a change of profession for the next generation. Education was cited as a possible way to improve their situation: most of the older generation [FGD4] was not schooled, while most of the younger generation [FGD5] received secondary education. However, (in)solvency was cited multiple times as a barrier to getting a loan, a job or diversifying activities. [FGD4]: " *We want them to be happy and solvent. We want them to have jobs* [wage jobs]. *But nowadays people have to pay 10 lakhs Taka for*

bribing to have a job, [when] *we can manage 10 Taka. How would we manage that much money? But we will try, if god wishes, they might get a job."*

Most rely on their kinship and non-kin support networks. They reported "*trying to maintain solidarity and equality"*. They try to work collectively, live on a relative's land, help each other, rely on an extensive network of contacts in Bangladesh, and marry their children throughout the country. When they need to make a demand to the local authority, they organize themselves and sometimes cooperate with other settlements to have more political weight. For daily expenses, they, as many households in the community that struggle to make ends meet, rely on credits in local stores and pay back when they can, and at least all their debts once a year, for Bengali new year (*Pohela Boishakh*).

Waterlogging is an important issue. Fishermen's houses are submerged for 4-5 months per year, the water is stuck and cannot be drained out because of the nearby enclosures that impact water flow. When everything is underwater, and because of the rains, they cannot fish properly, and cannot find other jobs locally. Villagers are trying to escape the water by building higher houses, but some houses are still filled with water.

2.2 Unskilled seasonal migration, a temporary solution in a changing environment?

Before the changes, the region was perceived as being rich in seasonal agricultural jobs, providing a local livelihood for the landless. The population has increased, fish farming is less labour-intensive than agricultural farming, there are fewer agricultural jobs in the community due to waterlogging, and wages are lower in Tala upazila possibly because women work in agriculture. For the unskilled and landless, local job opportunities are too few and badly paid, many move out the community to other districts seasonally to secure a better income. [I11]: *"We suffer a lot. When it's flooding, we don't have any work, our crops go underwater. Our*

crops get destroyed. If the crops of the land where I work get destroyed then I can't work there". "*People are going to the brickfields, because there is not enough work in the community*". [I1]: *"it is not the same inside the community and outside. He [her husband, an agricultural daily labourer] is paid 250-300 tk inside the community and 500* outside"

Push and pull factors are intertwined. These movements also coincide with the development of brick factories, 20-25 years ago, and where jobs allow for steady income for several months. Choice destination varies depending on opportunities. They have an extended network of acquaintances and they agree with the manager by phone before leaving. [I11]*:"I work everywhere because in the district there is too much competition, I prefer to go out of the district. I have been working in the 60 districts"*. Most of the time, migration is collective, they try to form a group of friends and relatives. [I1]: "*If they don't manage to make a group, they don't go and stay to find daily work here*". Older workers who are feeling too weak to sustain this type of work, stay in the community and work locally.

The livelihoods of the unskilled workers are precarious, physically difficult and temporary. In agricultural as in brick fields, they work in the open air, their employment depends on weather conditions and waterlogging, from October to April. In the remaining months, because most of the agricultural fields and brick factories are underwater, they return to the village and survive the monsoon by working in the jute fields, fishing, or taking loans from their manager, which leads them into a spiral of debt by mortgaging their future wages. Some agricultural workers migrate only for a few weeks at a time, and come back frequently between contracts, because they worry about the security of the left behind, or because they cannot cope too long with the living conditions. Brickfield work is tedious on different aspects, and some workers wish for better occupations for their children: [I4] "*Our son, went to the brickfield this year for 6 months, but stayed for 3 months and came back. The situation was bad, there was rain. So, he came back. He joined his uncle to do construction work in Dumuri*

Thana [another upuzilla]. *He will do that in the future, as a profession. It's easier, and more profitable and more respectable. He will have independence. In the brickfield, there is no independence, the manager is the one taking decisions."*

Many reported combining different types of activities depending on the season or year: farm work, brick making, fish farming work, and independent fishing. Most do not go to urban areas, as many are not literate and do not have a contact there [I4]: *"We don't go to the city because I don't know other activities/jobs than what I already do, I am an illiterate person, so it's impossible to go to a city and get a job; I don't have any connection in the city and don't feel safe going there."*

3 conceptual social-ecological model based on local perceptions and experiences

This model is a simplified representation of local perception and experience of climate-induced changes and dynamics, impacting livelihoods. We based this representation on the analysis of qualitative data using a configurational perspective (changes>impacts>responses>impacts), while considering different livelihood pathways, as explained in previous sections. We identified interactions and feedback between livelihoods, multiple changes, impacts and responses. We started working on this representation in the field to cross-check with subsequent interviews. The final version was validated by the three field researchers by consensus. The most important changes reported were the most damaging: waterlogging and salinization, cyclones, and heavy rains. The covid lockdowns added to the burden of all, and specifically to

the poorest. Underground water level and contamination were perceived as still manageable. Erratic and lack of rain were also cited. In the following Monsoon, this territory suffered from a drought. In this rural setting, one of the poorest and most rural area of Tala, seasonal rural-rural labour migration was cited as being more widespread than other migrations. Permanent rural-rural migration was also cited, and some villagers were said to have moved to urban centres.

Figure 2: Schematization of the conceptual social-ecological model based on FGD and semi-directed interviews with villagers in Khalilnagar, Tala, southwestern Bangladesh. The solid lines represent the positive relationships, while the dots lines represent the negative relationships between the variables.

[insert Figure 2 here]

Discussion

Villagers reported several changes directly or indirectly related to climate. Covid-19 lockdowns have been an aggravating socio-economic factor, impacting access to employment and income. Waterlogging was cited as the most problematic of the reported slow and rapid onset changes. Depending on the proximity of rivers, canals and fish farms, and depending on resources, not all livelihoods are affected in the same way. In addition, the less wealthy and the poorest are limited in their response strategies. The less wealthy farmers find it difficult to cover the costs of adaptations, while the unskilled and landless villagers reported a lack of local jobs and are unable to access a decent income in their community causing them to migrate seasonally to other rural destinations.

Villagers revealed that environmental deterioration progressively become noticeable in the last 20-25 years ago, affecting production, the local job market, livelihood activities, and

everyday lives. Our results confirm those of Akter and Amed (3), which were based on data from 11 meteorological stations, the closest located 20km from our study site. Villagers' experiences and perceptions of climate-induced changes are consistent with the analysis of satellite rainfall data that reveal a change in seasonal rainfall patterns for the period 1981-2021, with longer, drier seasons and wetter rainy seasons, particularly in July.

Combined effects of multiple environmental changes are reported, confirming previous work (3–6). Reports of increasing waterlogging problems are aligned with the findings of Tareq et al. (18), showing an increase in waterlogging hazards in Tala between 1989 and 2011. Villagers point to multiple interacting causes for waterlogging: heavy rains, longer rainy season, the problem of sedimentation/siltation caused by the river, lack of proper management of the river and canal, changes in land use for fish farming and an issue of power dynamics, favouring wealthy fish farmers, in the community. Waterlogging damages housing, infrastructures, lowland farms, soils, salinization, production and the local job market. The literature provides additional information about waterlogging causes such as the low flow on the upstream side due to the Farraka barrage on the Ganges, (35,36) combined with other factors impacting the delta geomorphology or the river flow downstream, such as the sea level rise, polderisation and ambankment, land subsidence, coastal and river erosion, channel modifications, land use changes, and ongoing change in the mangrove system in the South (37,38). Waterlogging is a local and regional problem. According to this, Figure 1c shows that rainfall trends have a regional signature, with significant changes in precipitation characterizing most of the country.

In addition to waterlogging, farmers reported that crop production suffers as a result of drought, out-of-season rains and/or heavy rains. Cyclones damage housing, infrastructures and production. Underground water levels and water quality are affected. The Covid-19 lockdowns were cited as aggravating events impacting incomes and labour mobilities. These results are similar to those observed in multiple crises aggravating community and individual vulnerability

and exposing inequalities and inequities (39,40,7). Responses to change vary according to livelihoods, resources and exposure to waterlogging. The less affluent find it more difficult to bear the monetary or non-monetary costs of environmental change and the costs of adaptation, revealing an increase in local socio-economic inequalities.

Collective actions to solve waterlogging have failed, and calls for support from the Bangladesh Water Development Board (BWDB) have yet to be successful. Farmer's strategies to overcome their environmental degradations are mainly based on innovations and diversification: new variants of rice, tests of new crops, use of fertilizers, use of materials to protect from the rains, attempts of different timing for cultures, diversification in crops and economic activities, switch to intensive fish farming and use of financial credits to afford those costs. Most of those adaptations are already well-covered in the literature (3–5,41).

Financial debt is widespread, from NGO loans, mortgages of goods, lands or future wages to informal debts with kin, neighbors or local shops. Insolvency is a barrier to formal loans for the poorest, who can only rely on an extensive support network but with limited resources. For example, fishermen reported marrying off their children all around Bangladesh, which could help spread their support network to less risky regions (42).

Seasonal unskilled migration was cited as the most common strategy for the poorest households as in previous work in Southwestern Bangladesh (8,4,6). The rural mobility of unskilled landless people, depending on the availability of agricultural jobs, has been a constant for centuries in many cultures around the world among the peasantry. For this site, rural mobility has been reported to increase in parallel with environmental degradation and the development of new industries (in our study this is the situation for brick manufacturing in rural areas, and in other studies, this occurs for clothes factories in cities). While urban destinations are more frequent in previous studies, here, migrants reported rural destinations. Our site is one of the most rural of Tala, and less exposed to peri-urban or urban activities, suggesting fewer

552 contacts in cities, as confirmed by interviews. Interactions and feedback between change,
553 impacts and responses, such as the switch to fish farming, and the disappearance of water
554 bodies, combined with power dynamics and further climate-induced change, such as
555 waterlogging and rainfall variability, associated with local norms (female rural work) are
556 limiting the options in the local labour market for the poorest and landless, making other rural
557 destinations more attractive.

558 Rural-rural migrants earn a better living than if they stayed all year in their community.
559 When several members of the household migrate and earn a wage, the households may
560 experience relative (still modest) prosperity compared to their initial economic status in their
561 community. Studying the life trajectories and social mobilities of these migrants and households
562 would be interesting in understanding the resilience of this livelihood strategy, concerning
563 ageing and gender, for example, and the impact of this strategy on the socioeconomic and health
564 status of the next generation.

565 Seasonal migration might be an alternative to permanent migration "as a way to sustain
566 long-term non-migration in the place of origin" (43). However, risks and hazards are still part
567 of this strategy (6,44), and migrants encounter hazards far from home and far from their support
568 network. Their left-behinds are also exposed to hazards. Seasonal migrants might make the best
569 of a bad job, which brings additional nuance to the debate about framing migration as a failure
570 to adapt to environmental risks or as an adaptation (43): they are having agency but within a
571 very limited range of choices with negative and positive outcomes, the balance of which may
572 vary depending on the exposure to hazards that impact their trajectories. Finally, the
573 sustainability of the debt-and-migration association can be questioned at the scale of the
574 individuals and households.

575 All migrants interviewed came from poor and landless households; no information was
576 collected on other types of unskilled migrants locally, which does not mean there are not.

Traditionally, farmers' sons inherit their land upon their father's death and on an equal basis among the sons; daughters can claim up to half of a brother's portion. In other words, sons compete with their fathers for land access during their father's lifetime and compete with their brothers for the inheritance. Moreover, according to an informal interview with a police officer, the most frequent conflicts in this community involve land disputes and inheritance issues, suggesting that land is a crucial resource here. It is conceivable that sons born first or second, because they have young fathers, take the risk of migrating during the first part of their adult lives, for example, to try to accumulate resources before inheriting.

Human behavioural ecology considerations, such as demographic outcomes of migration and their temporality, the level of study (individuals, households, lineages or networks), and the multiples resources impacting the life cycles of individuals and households (45–52) are important to consider to understand why some individuals move out while others stay to identify intrahousehold and interhousehold mechanisms leading to inequality and vulnerability (53,54). Such considerations will require another level of downscaling in the social-ecological system, including households, kin and non-kin networks and individual levels.

The individual knowledge and experience needed to farm or fish in a given ecosystem results from cumulative knowledge about a complex system that balances climate, soil, water access, biodiversity, crops and associated practices such as calendars and technologies. Temporality is an essential dimension in skill and knowledge acquisition. Here, the speed of environmental changes is so fast that those under 40 have not farmed the same land or fished in the same water as those above 40, and the youngest in the community have never known the lush nature described by the elders. Even worse, on a lifetime scale, farmers who live by their climate and production predictions have to think about a constantly changing and unpredictable system. The reference state of the system is changing so rapidly that these changes induce a sliding referential of the ecosystem for the villagers. If work is not done on what can be

602 improved, i.e. in terms of waterlogging management or control of strategies with ambivalent
603 socio-economic outcomes such as brackish water shrimp farming (4), waterlogging and
604 salinization will gain more territories in Tala (18). With salinization increasing, a salt
605 concentration threshold will be met, and crop diversification will not be possible anymore (55).
606 This context is a local example of the environmentalist's paradox (56). While Bangladesh
607 is rapidly progressing on a number of socio-economic indicators (1), all interviewees, rich and
608 poor, reported having a pessimistic perspective depicting a degradation of their environment
609 and livelihoods. However, the wealthy farmers (including rice farmers, agricultural farmers and
610 fish farmers) in the community "are not doing that bad; they are still making good profits"
611 according to less-wealthy villagers. This attitude could be a by-product of the risk-averse
612 tendencies of farmers, who are highly dependent on climate, more than a result of resource
613 status, where wealthy people are expected to have a more tolerant attitude to risks or/and it
614 could be an internalization of official discourse on climate change.
615 Southwest Bangladesh environmental condition is the result of the thinking and
616 planning of the territory over the last two centuries from technological and "development"
617 thinking of the colonial and post-colonial eras (57). In other words, the current landscape is the
618 product of power dynamics between cultures that have disrupted the Bengal delta's natural and
619 self-regulating fluidity, from the past centuries' mangrove deforestation to the more recent
620 permanent and protective embankment (57). In addition, the transformation of the landscape
621 into vast expanses of fish farms, turning wetlands, swamps and water bodies into artificial mud
622 mounds and fish pounds, in this location but also across many areas in the South of Bangladesh
623 (55) question the future natural ability of the deltaic system to cope with flood, riverbed
624 fluctuations and sedimentation issues, fish-farm and other anthropic pollution, groundwater
625 aquifer decreasing level and loss of biodiversity among others (58,59) and thus the future of
626 environmentally dependent populations.

In short, as development project after development project is implemented, the relative importance of the long-term detrimental impacts of these projects compared to the climate-induced change is unclear in the multiple environmental crises that result from their combination. In other words, the storytelling around climate-induced change and the resulting environmental poly-crisis in southwest Bangladesh is not linear and straightforward.

Multi-sites studies have shown that the sustainability of the socio-ecological system is deteriorating at a regional/subregional level (20,60–62). Those multi-site studies often associate one socio-ecological system per site (i.e. rice-based, shrimp-based, forestry), thus highlighting the heterogeneity of the deltaic system at the sub-regional level but ignoring the local heterogeneity specific to each community. Here, by focusing on the community level, we highlight the local complexity by focusing on the heterogeneity of livelihoods and associated power dynamics that affect the poorest locally. Concerning sustainability, our work suggests a similar conclusion at the community level, with a nuance of optimism: collective and political action for 1-tidal river management 2-controlling power dynamics, for example, through land access management (4), could improve the situation locally, but should also be considered in coordination with neighbouring territories.

Climate change, combined with local anthropic changes, impacts livelihoods, and we might even say it imprints, directly and indirectly, the lives, flesh, and souls of people through livelihoods, health and well-being, and indeed on many generations to come through societal and political choices. Political and societal choices are specifically in question because there is no climate justice without social justice, and inequities need to be addressed to leave nobody behind (39,63).

Conclusion

Perceptions and experiences of changes that have impacted local livelihoods over the past five years point to a degradation of environmentally dependent livelihoods that began to be

noticeable 20-25 years ago, consistent with satellite rainfall data analysis and the scientific literature on the region. Livelihood pathways and resources explain differences in narratives. Our resulting conceptual social-ecological system, based on local narratives, highlights the complexity of the local context and is convergent with multisite studies (20,62,6). Here, waterlogging is the most severe problem cited, impacting livelihoods and living conditions and originates in both land and water management issues and climate-induced change. Interactions and feedback between livelihood strategies limit the livelihood strategies of the less fortunate, driving them to migrate seasonally to other areas. The level of this poly-crisis increases local inequalities and vulnerabilities, with small farmers suffering more than wealthy farmers, as they might not afford risky strategies and innovative technologies and cannot diversify as much (4) and with the landless and insolvent pushed out to look for incomes outside of the community.

The consequences of socio-economic hardship extend to health, as socioeconomic status is a determinant of health. Direct and indirect effects of climate-induced changes on physical and mental health and well-being can be expected, with the poorest and most socially vulnerable once again being the most affected. Due to the disruption that migration brings to migrants' lives and the exchange of risks they experience (64), their health is also affected, making them even more vulnerable.

Local actions regarding land and water management to solve the waterlogging problem could provide relief to the community and, thus, slow down the threat of waterlogging and salinization, as having an effect on local inequalities and strengthening local resilience to climate-induced changes.

Author's Contribution

Lucie Clech designed the study, collected and analysed the qualitative data and wrote the manuscript. Juan Pablo Sierra designed the rainfall data analysis, analysed the data, wrote about

677 the climate data and contributed to the manuscript writing. Muhammad Abdul Mannan and
678 Mollah M. Shamsul Kabir, collected the data and contributed to the analysis and manuscript
679 writing. Mrittika Barua contributed to the manuscript writing. Jhan-Carlo Espinoza suggested
680 and designed the rainfall data analysis and contributed to the manuscript writing. Valery Ridde
681 provided insights into each work step and contributed to manuscript writing. All authors
682 provided feedback and made revisions to the manuscript. The authors read and approved the
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684
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Table 1:

FGD#	Number of participants	Gender	Age class	Religion	Main Occupation	Wealth status	Connection between participants	Presence of other person
FGD1	4	Males	35-55	Muslims and Hindus	Fish farmers and fish business	Wealthy	Business and training	None
FGD2	8	Females	18-30 and one elder 50+	Muslims	Housewives (husbands are farmers cultivating crops and having fish farms)	Middle class	Husbands are related and they are neighbours	Children
FGD3	7	Females	35-50	Hindus	Housewives, (husbands are goldworkers)	Lower middle class	Husbands are related and they are neighbours	Children
FGD4	7	Males	50-70	Muslims	Independant fishermen	Very poor/poor	All related and neighbours	Kin and neighbours
FGD5	6	Males	20-50	Muslims	Independent fishermen	Very poor/poor	All related and neighbours	Kin and neighbours
FGD6	4	Males	<40 and one elder 60+	Muslims	Paddy farmers	Lower middle class	They are related and neighbours (father and sons)	Wife of the elder

Notes: All were married with children. Fish farmer is a generic name to design fish farmers cultivating mostly crustaceans such as freshwater pawns (Golda), brackish shrimps (Bagda), and also some fish like Tilapia, and Rui among others in artificial ponds. They might focus on one variety of shrimps/prawns or mix multiple species simultaneously or consecutively, for example in the case of shrimps and prawns. Brackish shrimps (Bagda) are becoming more commonly used, due to the cheaper costs of immatures, their resistance, the higher production and the price on the market at maturity.

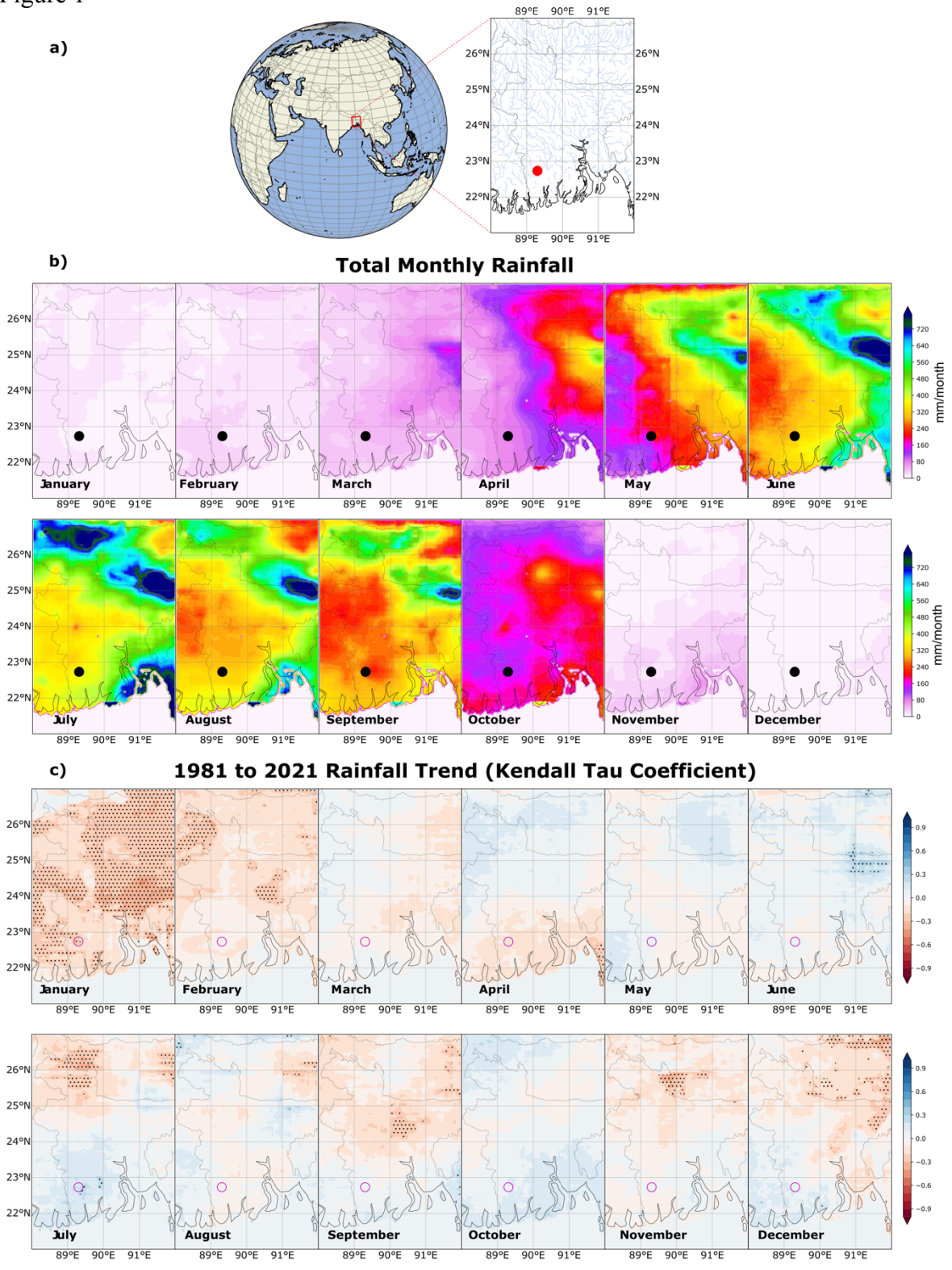
Interviews

Interview #	Gender	Age	Religion	Main Occupation	Wealth status	Other participant presence if any
I1	F	34	Muslim	Wife of daily worker-farmwork	Poor	Husband
I2	F	36	Muslim	Wife of migrant - farmwork	Poor	Mother-in -law
I3	M	36	Muslim	Daily-worker, brickfield, independent fishing	Poor	Wife
I4	M	50	Muslim	Daily-worker, farmwork, brickfield	Poor	Wife
I5	M	38	Muslim	Fish farmer	Wealthy	Wife, nefew
I6	M	52	Muslim	Farmers -paddy/crop and fish farming	Wealthy	Nefew
I7	M	55	Muslim	Fish farmer, paddy and crop farmer	Wealthy	None
I8	M	70	Muslim	Fish farmer on khasland	Lower middle class	Neighbours, family

I9	M	45	Muslim	Crop farmers	Lower middle class	None
I10	M	45	Muslim	Daily worker -brickfield, farmwork in the community	Poor	None
I11	M	45	Muslim	Brickfield worker	Poor	Wife and neighbours
I12	M	52	Hindu	Service job-barber	Poor	Wife
I13	F	55	Muslim	Wife of Small cattle farmer	Lower middle class	Husband
I14	M	50	Muslim	Fish farmer, mango farmer and paddy farmer	Upper middle class/wealthy	His father

Notes: All were married with children

884 Figure 1



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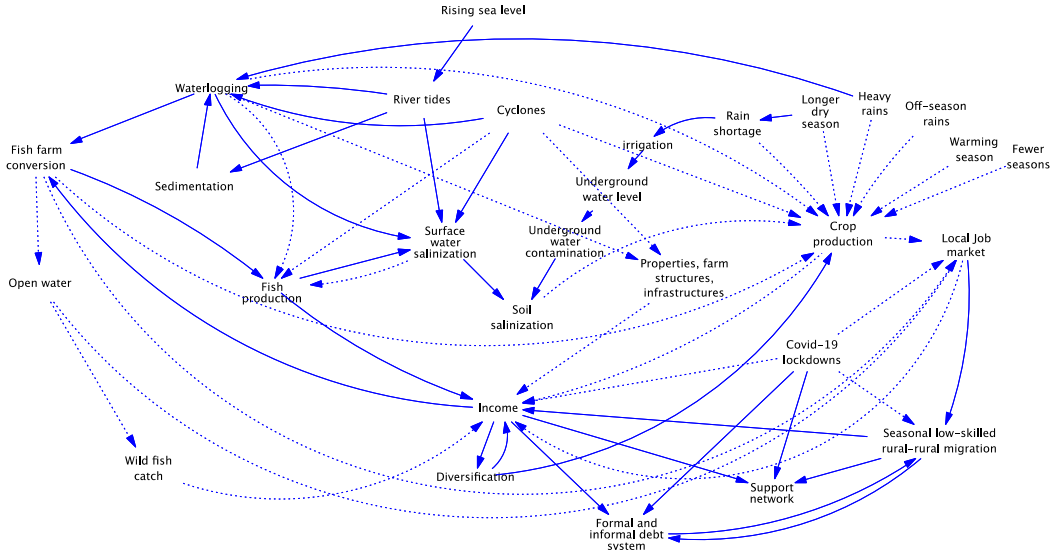
887 Figure 2



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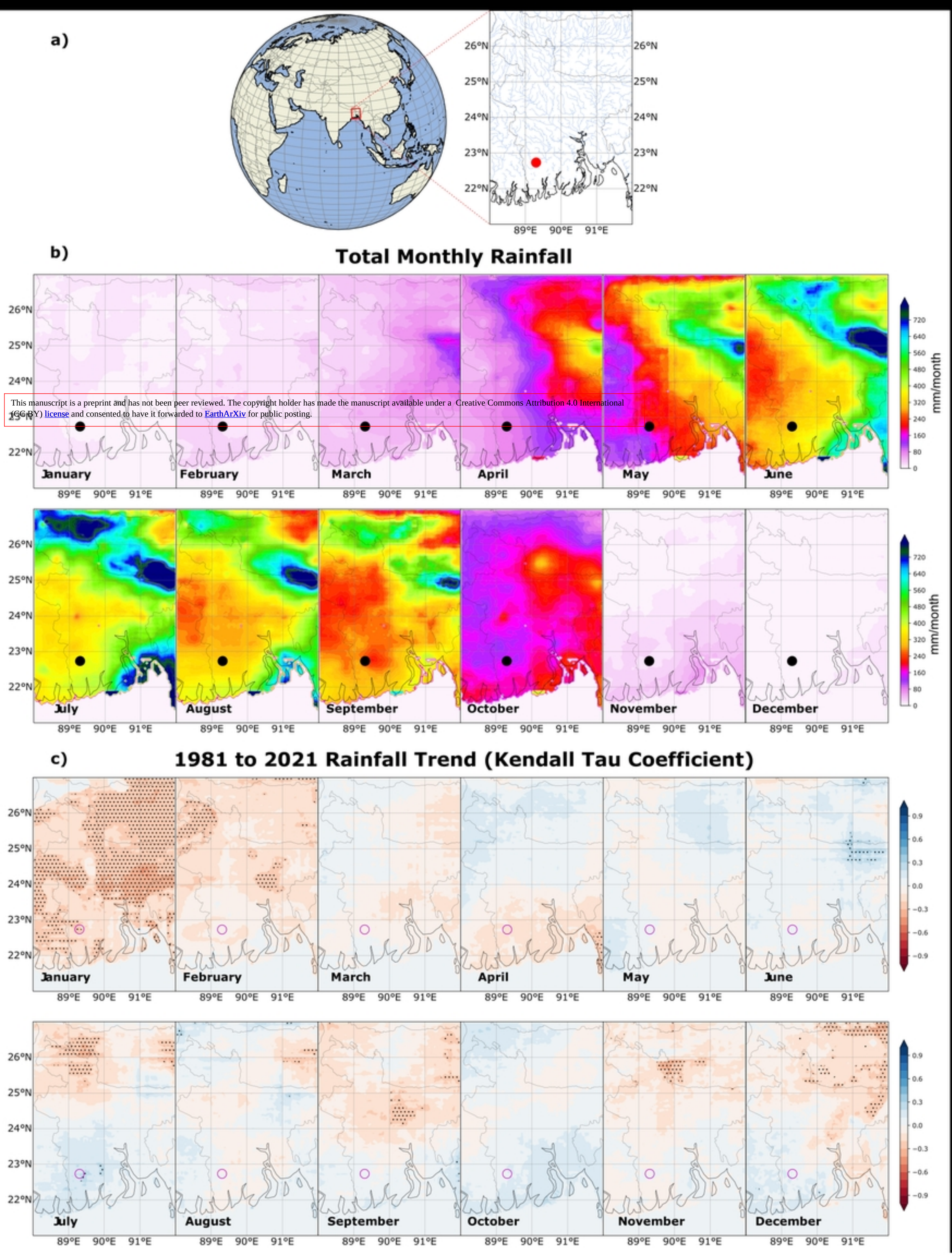

Figure 1

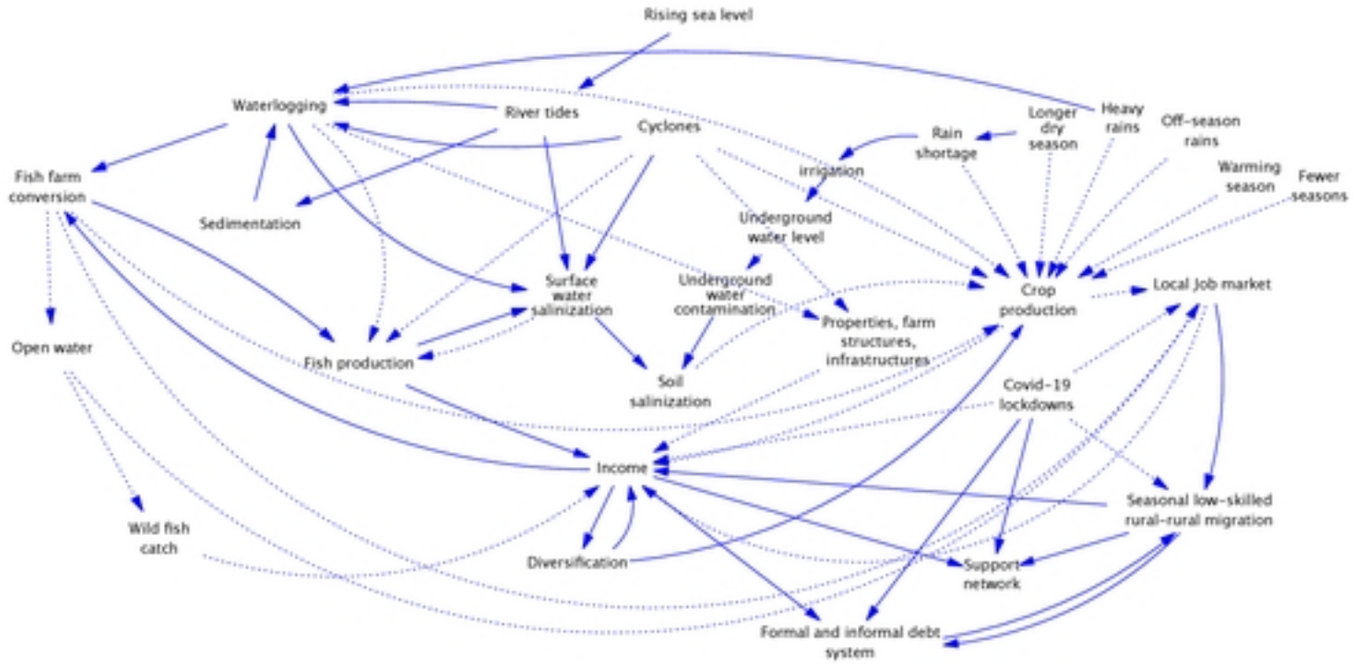
Rising sea level
Waterlogging
River tides
Cyclones
Rain shortage
Longer dry season
Heavy rains
Off-season rains
Warming season
Fewer seasons
Irrigation
Fish farm conversion
Sedimentation
Underground water level
Surface water salinization
Underground water contamination
Crop production
Local Job market
Properties, farm structures, infrastructures
Open water
Fish production
Soil salinization
Covid-19 lockdowns
Income
Seasonal low-skilled rural-rural migration
Wild fish catch
Diversification
Support network
Formal and informal debt system

Figure 2