International Institute for Applied Systems Analysis
IIASA www.iiasa.ac.at

Address: IIASA, Schlossplatz 1, A-2361 Laxenburg, Austria
Email: repository@iiasa.ac.at **Telephone:** +43 (0)2236 807 342

YSSP Report
Young Scientists Summer Program

Time for change: Assessing the transformational capacity of riverine Bangladesh

Amelie Paszkowski
amelia.paszkowski@ouce.ox.ac.uk

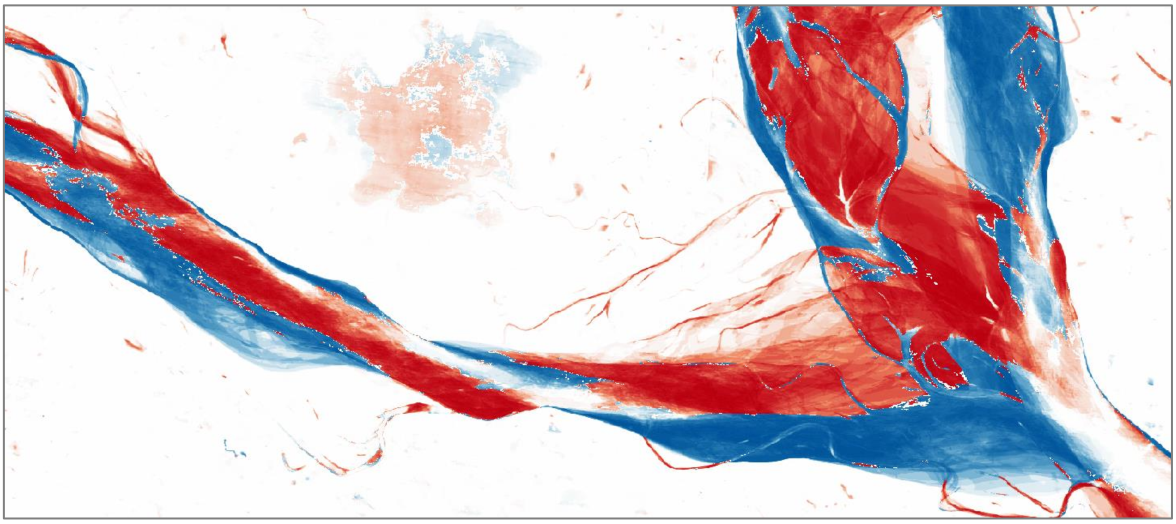
Approved by Reinhard Mechler

Supervisor: Reinhard Mechler & Finn Laurien
Program: Advancing Systems Analysis (ASA)
September, 2021

This report represents the work completed by the author during the IIASA Young Scientists Summer Program (YSSP) with approval from the YSSP supervisor.

It was finished by Amelie Paszkowski and has not been altered or revised since.

This research was funded by IIASA and its National Member Organizations in Africa, the Americas, Asia, and Europe.



Perhaps the most profound act of transformation facing humanity is a cultural shift from seeing adaptation as managing the environment 'out there' to learning how to reorganise social and socio-ecological relationships, procedures and underlying values 'in here'

– Pelling, 2010

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Abstract

Riverine Bangladesh is one of the most disaster-prone and poverty-stricken regions of the world. Existing management of riverine hazards has predominantly focused on incremental adaptation; however, given the profundity and inevitability of projected vulnerabilities, incremental adaptation is increasingly considered insufficient to address disaster risks. Consequently, deliberate and anticipatory transformation is gaining traction as a response for avoiding dangerous thresholds of intolerable risks through planned changes in location and/or livelihoods. This study assesses the capacity for such deliberate transformation for 35 critically poor and flood-prone riverine communities in Bangladesh through the application of a transformational capacity framework onto community-level resilience data. The results show that overall transformational capacity is low across all 35 communities, with a lack of community organisation, flexibility, and a low sense of agency and political voice acting as the main barriers. Critically, eight key communities are identified as priority areas that require urgent capacity building to avoid imminent forced, catastrophe-driven relocation. Overall, the findings presented in this study bring communities' realities and values to the fore, which, when ignored, hinder operationalising longer-term resilience across riverine Bangladesh. It is imperative that the potential for positive transformational change is incorporated into planned adaptation options and policies for Bangladesh, as they provide windows of opportunity to avoid perpetual risk traps and stakeholder conflict, and enable the development of innovative and collaborative ways for social and ecological resilience, and longer-term ethical and sustainable societal systems.

Acknowledgments

I would like to thank Reinhard Mechler for the enthusiasm and encouragement throughout the Young Scientists Summer Programme (YSSP), and for guidance on conceptualising, framing and developing the methodological approach of this study. Thank you to Finn Laurien for the brainstorming sessions, providing access and detailed explanations of the FRMC data, and the continuous support throughout the YSSP. My gratitude extends to the Systemic Risk and Resilience (SYRR) and the Advancing Systems Analysis (ASA) groups for insightful discussions and great feedback sessions, and to the overall YSSP for the experience of joining a group of very bright and fascinating students from all over the world. Finally, I would like to express my gratitude for the continued support and guidance from my supervisor at the University of Oxford, Professor Jim Hall.

About the authors

Amelie Paszkowski is a PhD student at the University of Oxford studying the interactions between flooding, geomorphology and society in Bangladesh. (Contact: amelia.paszkowski@ouce.ox.ac.uk)

1. Introduction

Floods are the most frequent type of natural hazard (Tellman et al., 2021). In Asia, where 90% of the world's flood-exposed people live (Figure 1), more people are affected by floods than by all other disasters combined (Laurien and Keating, 2019). Associated with riverine and coastal flooding is the highly under-reported hazard of geomorphic change. When riverbanks or coastlines are exposed to extreme flood events, the sudden force of flood water can cause widespread erosion and destruction of land, ecosystem services, homes and livelihoods (Paszkowski et al., *in press*). Yet, the dynamic geomorphology of river systems and their coastal deltas is often overlooked in assessments of hazard vulnerability; consequently, development plans and previous management investments have been undermined by unanticipated geomorphic responses (Paszkowski et al., *in press*). The socio-economic future of such complex biophysical systems, in the face of population growth and climate change, is therefore inevitably linked with their environmental well-being and overall geomorphic balance (Paszkowski et al., *in press*).

Bangladesh is situated in a global hotspot of natural hazards and is one of the world's most densely populated countries; the country has half the population of the United States, but lives on 1.5% of the land area (Khan et al., 2021). Dramatic fluvial flooding during the monsoon season, tidal flooding from cyclonic storm surges, and the gradual impacts of sea-level rise have made Bangladesh the most vulnerable country in South Asia (Khan et al., 2021), as shown in Figure 1. In 2019, such weather-related risks resulted in the displacement of 4.1 million people, a figure that could rise to 13.3 million per year by 2050 (Khan et al., 2021). Moreover, the risk of riverbank erosion impacts a further 15-20 million people across the country (Rahman et al., 2015; Paszkowski et al. *in press*).

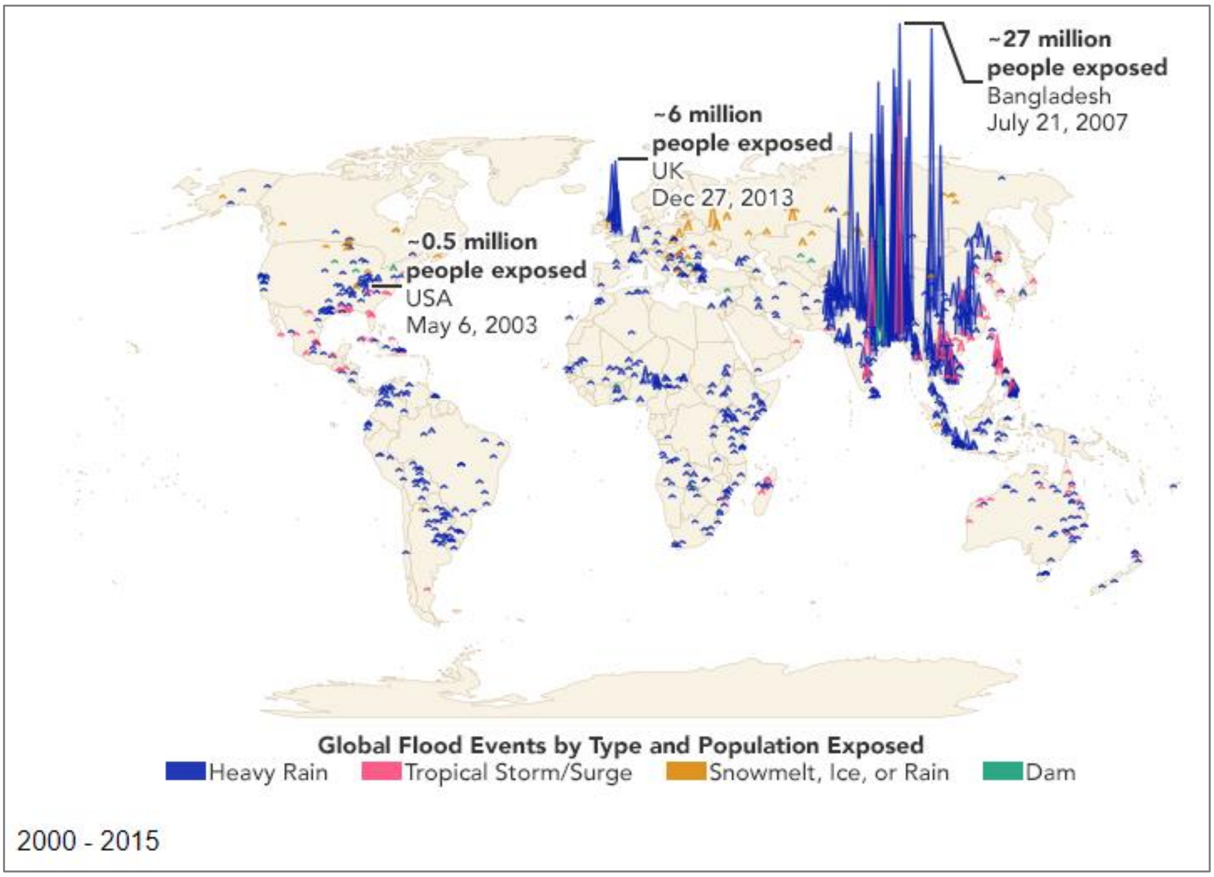

Figure 1: Number of people exposed to flood hazards across the world (NASA, 2021; Tellman et al., 2021)

Typically, poor and marginalised populations suffer disaster impacts disproportionately, predominantly driven by the lack of financial and social safety nets and institutional representation (Keating et al., 2017a; Schipper et al., 2021). Multiple studies (Chung Tiam Fook, 2017; Laurien and Keating, 2019; Marshall et al., 2014) have agreed that, although disaster impacts are felt at all scales, they are felt most acutely at the community level, particularly in resource-dependent communities that are sensitive to environmental changes. In Bangladesh, this translates most noticeably to rural communities, where people often get trapped in poverty, preventing socio-economic growth (Keating et al., 2017a; Laurien and Keating, 2019). Rural riverine communities in Bangladesh, living on the banks or *chars* (river islands) of the main rivers (Teesta, Ganges, Jamuna, Padma and Meghna), have been shown to be the most affected by these hazard-poverty dynamics (Paszkowski et al., *in preparation*). Many communities in such highly exposed and vulnerable regions are already stretched in their capacity to adapt (Dow et al., 2013).

2. Conceptual framing

2.1. Riverine risk

The concept of risk, as defined by the IPCC, entails the potential for adverse consequences for human or ecological systems, recognising the diversity of values and objectives associated with such systems (IPCC, 2021). A hazard is defined as the potential occurrence of a natural or human-induced physical event that may cause loss of life, injury or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, ecosystems and environmental resources (IPCC, 2021). In the case of this study, the hazards of focus are riverine hazards, which constitute of flooding and geomorphic change. Exposure refers to the presence of people, livelihoods, species or ecosystems, environmental functions, infrastructure, or assets in places and settings that could be adversely affected, whilst vulnerability refers to the predisposition of being adversely affected (IPCC, 2021). The concept of vulnerability therefore incorporates sensitivity and susceptibility to harm and a lack of capacity to cope or adapt (IPCC, 2021). Thus, disaster risk in this study refers to the result of the dynamic interactions between riverine hazards and the exposure and vulnerability of the affected human or ecological systems to these hazards, as shown in Figure 2 (IPCC, 2021). Each of the three components that make up overall risk are subject to uncertainty in terms of magnitude and frequency, and each may change over space and time due to socio-economic changes and human decision-making (IPCC, 2021).

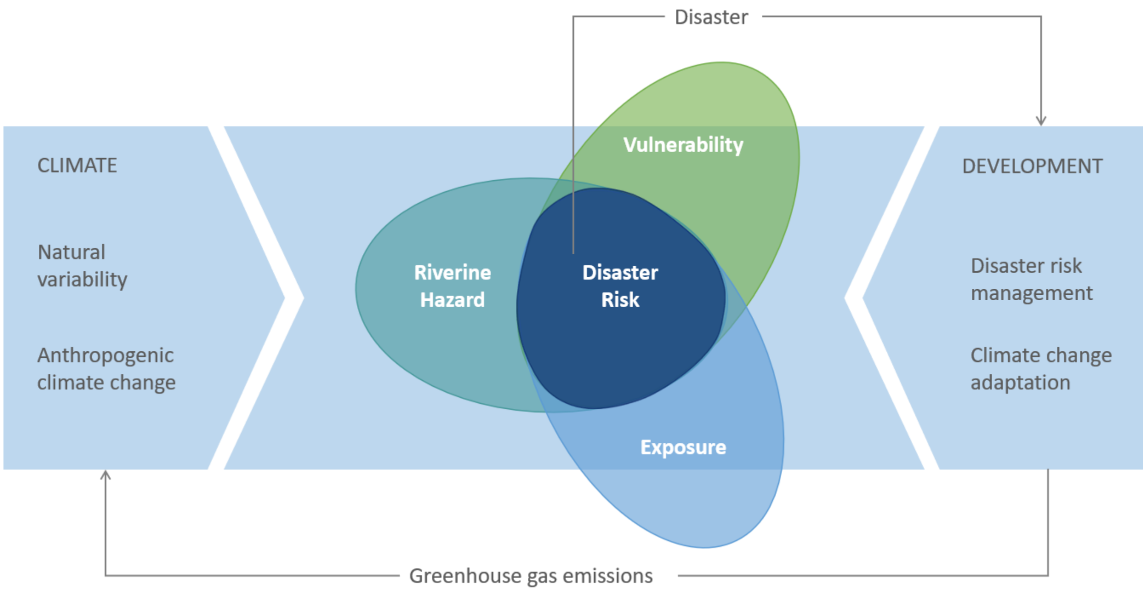

Figure 2: Conceptualisation of interaction among hazard, exposure and vulnerability that constitute disaster risk (adapted from IPCC (2014))

As evident from the schematic in Figure 2, vulnerability and exposure are predominantly driven by socio-economic development pathways, adaptation actions and governance. The focus of this study is on expanding the adaptive capacity in order to reduce the exposure and vulnerability of riverine communities in Bangladesh to the impacts of riverine hazards.

Riverine Bangladesh has previously been identified as the poorest and most vulnerable region of the country to natural hazards (Paszkowski et al. *in preparation*). The impacts of flooding in these areas are widespread and widely acknowledged (Darby et al., 2015; Dasgupta et al., 2014; Nicholls et al., 2016). However, the more hidden geomorphic hazard plays a key role in driving riverine communities into further poverty (Paszkowski et al., *in* preparation). In these riverine corridors, riverbanks are constantly in flux; yet, due to Bangladesh being an extremely land-hungry country, highly exposed *chars* and mudflats are becoming increasingly more populated (Khan et al., 2021). In these exposed areas, where existing societal systems and climate risks are inimical to communities' fulfilment of progressive development goals and threaten to overwhelm their capacity, motivation for local leaders and institutions to catalyse transformational adaptation should be very strong (Chung Tiam Fook, 2017).

However, the majority of disaster-related aid spending goes towards emergency responses, reconstruction and rehabilitation (ex-post), with very little allocated to reduce and manage the risks before they become disasters (ex-ante) (Flood Resilience Alliance, 2019). Investments from donors and national governments similarly tend to focus on short-term, direct impacts with limited community engagement (Laurien et al., 2020). The current framing of risk reduction therefore aims to enable people to continue living where and how they have in the past; yet, as environmental conditions shift outside the bounds of historical human experience, there is an increasing interest in transformational change to enhance community capacities (Chung Tiam Fook, 2017; Kates et al., 2012; Mach and Siders, 2021).

2.2. Concepts of transformation

Transformation is defined as a fundamental change in some of the biophysical or socio-economic components of a system from one form, function, nature or location to another, consciously challenging underlying power and governance structures, norms, values and world-views (Barnes et al., 2020; Chung Tiam Fook, 2017; Deubelli and Mechler, 2021; Kates et al., 2012; Marshall et al., 2012; O'Brien and Sygna, 2013; Schipper et al., 2021). At the individual scale, for instance, transformative approaches can be signified by a major change or diversification in livelihoods, active engagement in long-term planning such as resettlement schemes, or developing new community long-term response plans (Barnes et al., 2020; Marshall et al., 2012). In line with previous studies (Deubelli and Mechler, 2021; Vermeulen et al., 2018), this article uses 'transformative' when describing the process of change, and 'transformational' when referring to the outcome of the change process.

Community members typically act, individually or collectively, based on whether risks are acceptable (further efforts in risk reduction are not required, they can be absorbed), tolerable (incremental risk-reduction efforts are required for risks to be kept within reasonable limits), or intolerable (need to discontinue current behaviour to avoid the risk or move location, i.e., transformation), as outlined in Figure 3 (Dow et al., 2013; Tanner et al., 2017). Therefore, Dow et al. (2013) argue that there is a threshold for intolerable risks, which represents a point at which an actor must either live with the risk or transform their behaviour to avoid the risk.

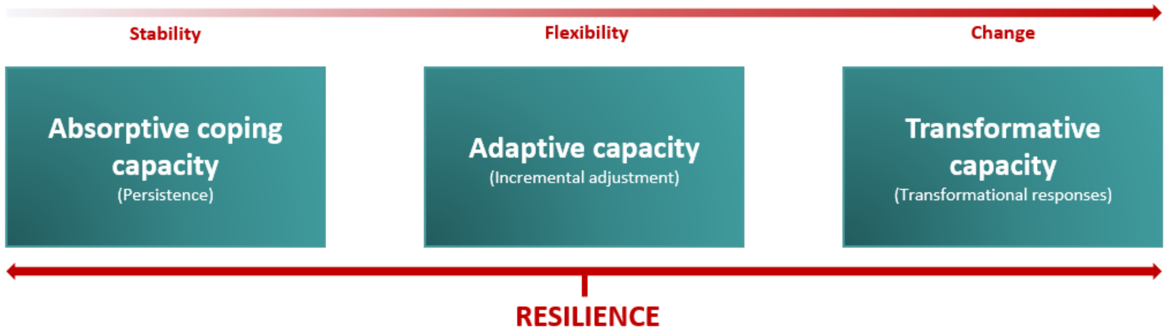

Figure 3: Resilience as a result of absorptive, adaptive and transformative capacities (adapted from Tanner et al.,(2017))

However, framing transformation as planned, deliberate and anticipatory, rather than as a 'last resort', can avoid reaching such dangerous thresholds of intolerability (Mach and Siders, 2021; Rickards, 2013). Calls for deliberate transformative approaches to risk management are increasing given the profundity of projected vulnerabilities and risks, rendering standard adaptive approaches, such as raising homes or upgrading infrastructure, insufficient (Chung Tiam Fook, 2017; Deubelli and Mechler, 2021; Gillard et al., 2016; Global Commission on Adaptation, 2019; IFRC, 2020; Kates et al., 2012; Klein et al., 2014; Marshall et al., 2012; O'Brien and Sygna, 2013).

The three spheres of transformation by O'Brien and Sygna (2013) (Figure 4), identify where one can come in to initiate transformational change. Transformation towards sustainability takes place at the practical (behaviours and technical solutions to reduce risk), political (the enabling/disabling conditions) and personal level (individual and collective worldviews, beliefs and values). In the personal sphere, discourses and paradigms emerge that influence the framing of issues and the prioritisation of solutions in the political and practical spheres (Moss et al., 2021). Community-engaged processes that collect local perspectives, institutions and capacities underpin collective identification of these discourses and paradigms that shape the personal sphere (Chung Tiam Fook, 2017; Haasnoot et al., 2021; Kates et al., 2012; Laurien and Keating, 2019; Marshall et al., 2012; Schipper et al., 2014). Such participatory visioning and decision-making is crucial because it incorporates the strong cultural roots of this knowledge, and accounts for local values, goals, expertise, and opinions that ultimately lead to more equitable and fair change (Chung Tiam Fook, 2017; Laurien and Keating, 2019). Transformations in the personal sphere, therefore, cannot be externally forced (O'Brien and Sygna, 2013). At a political level, it is vital that investment efforts are combined with strengthening institutions and coordinated governance across all actors, empowering local stakeholders to become actors in learning, innovation, and leading at local and higher levels (Chung Tiam Fook, 2017; Kates et al., 2012). Finally, at the practical level, it is evident that transformative approaches take time to plan and implement (Haasnoot et al., 2021; Kates et al., 2012; Marshall et al., 2012). It is therefore crucial that transformative approaches are part of a flexible, nested, and interconnected set of adaptation strategies that also entail coping strategies and incremental adjustments (Moss et al., 2021).

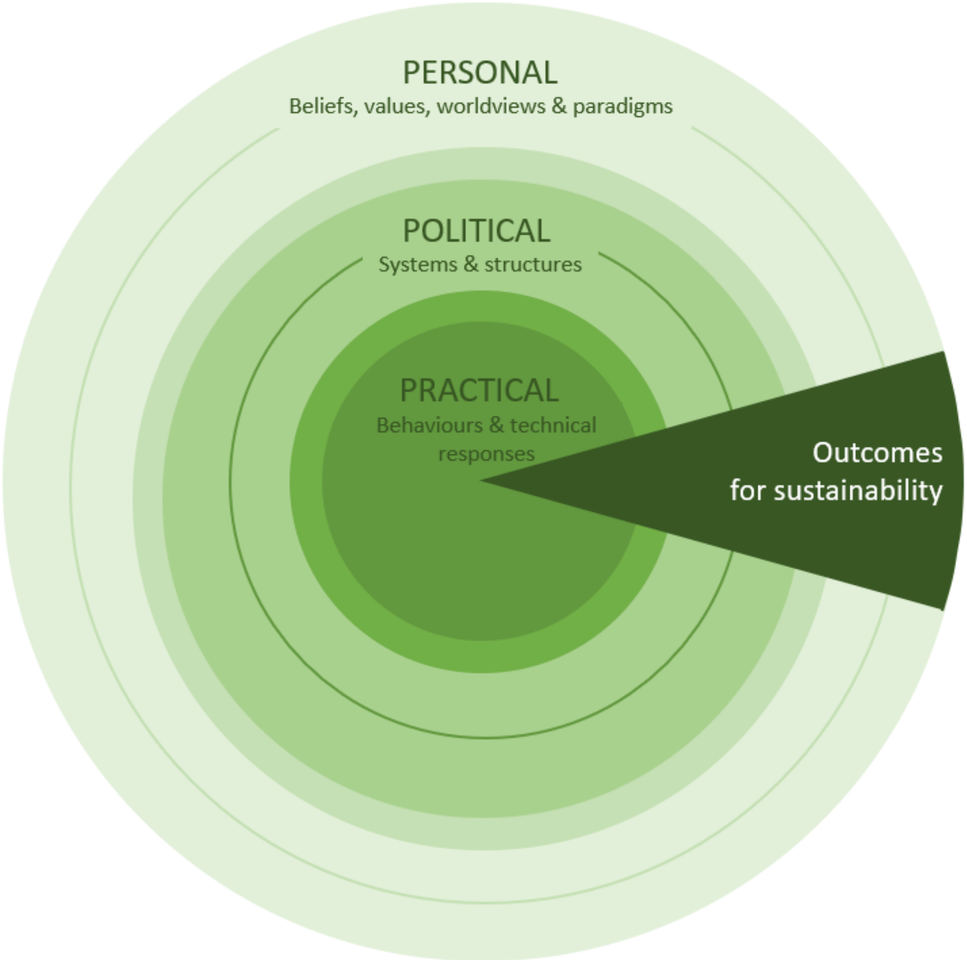

Figure 4: Three spheres of transformation (adapted from O'Brien and Sygna, (2013))

An 'operationalisation gap' has been identified in terms of translating transformational ambitions into concrete transformative measures that can be applied in practice (Deubelli and Mechler, 2021). This is most likely due to the lack of consultation with affected communities in understanding whether those sensitive to risks have the capacity to transform (Marshall et al., 2012). In Bangladesh, for instance, planned transformative adaptation is not yet widely applied because of space and resource constraints (Khan et al., 2021). Nevertheless, the International Centre for Climate Change and Development (ICCCAD) is facilitating managed relocation away from high climate-risk areas to migrant-friendly peripheral towns in order to shift the tide of migration away from Dhaka and other large cities towards smaller towns (Khan et al., 2021). In order to inform such social and economic transformation, the capacities and values of affected populations and institutions need to be assessed (Deubelli and Mechler, 2021; Marshall et al., 2014; Moss et al., 2021). Marshall et al. (2012) developed a framework for measuring community-level transformational capacity, which encompasses four foundations: (i) how risks and uncertainties are managed; (ii) the extent of skills in planning, learning and reorganising; (iii) the level of financial and psychological flexibility to undertake change; and (iv) the willingness to undertake change. Thus, listening across political boundaries, understanding communities' realities and values, their social cohesion and organisation, their willingness for change, and their visions for their own future all contribute to closing the 'operationalisation gap' (Chung Tiam Fook, 2017; Deubelli and Mechler, 2021; Mach and Siders, 2021; O'Brien and Sygna, 2013).

3. Aim of research

Given the highly exposed nature of riverine communities in Bangladesh, deliberate and anticipatory transformative approaches are beginning to be discussed to address the intrinsic vulnerability to riverine hazards. Managed relocation, planning for a change or diversification in livelihoods, or developing new and innovative long-term response measures, are becoming increasingly important topics in one of the world's most vulnerable countries to climate change. However, in order to avoid forced or unplanned, chaotic and traumatic transformation, the communities at stake need to have the capacity to transform. This, however, has not yet been assessed for riverine communities in Bangladesh.

The aim of this study, therefore, is to assess the transformational capacity of some of the most disaster-prone and poverty-stricken riverine communities across Bangladesh. Transformational capacity is measured by combining top-down (national geospatial analysis to identify riverine hazards) and bottom-up (community resilience measurement) approaches. Four key aspects are identified as making up community transformational capacity (based on Marshall et al. (2012)): (i) how risks are managed and how resilient communities currently are; (ii) the level of awareness and skills in planning and community organisation; (iii) the level of flexibility and willingness to undertake change; and (iv) community agency and the role of the enabling environment. Combined, these factors provide a first indication of whether or not some of the most vulnerable communities in Bangladesh have the capacity to transform.

4. Materials and methods

The assessment of transformational capacity requires analyses to be undertaken at both the national and the local scale. The riverine hazards are assessed at the national scale, but how communities have been responding to these, and their capacity for transformational change is assessed at the community scale. This mixture of "top-down" hazard assessments for the identification of highly risk-prone areas, combined with "bottom-up" insights related to place-based complex adaptive socio-environmental systems have been acknowledged as the only way to arrive at a more nuanced understanding of resilience and transformative capacity (Horton et al., 2021; Laurien and Keating, 2019; Tanner et al., 2017). As evident, this mixed-methods approach also integrates the biophysical (geomorphic change and flooding) with socio-economic data, which builds on the findings from Paszkowski et al. (*in preparation*). The flowchart in Figure 5 illustrates the approach taken to merge the biophysical elements at the national scale with the socio-economic resilience assessment at the community scale, and the following sections describe the steps towards assessing transformational capacity in more detail.

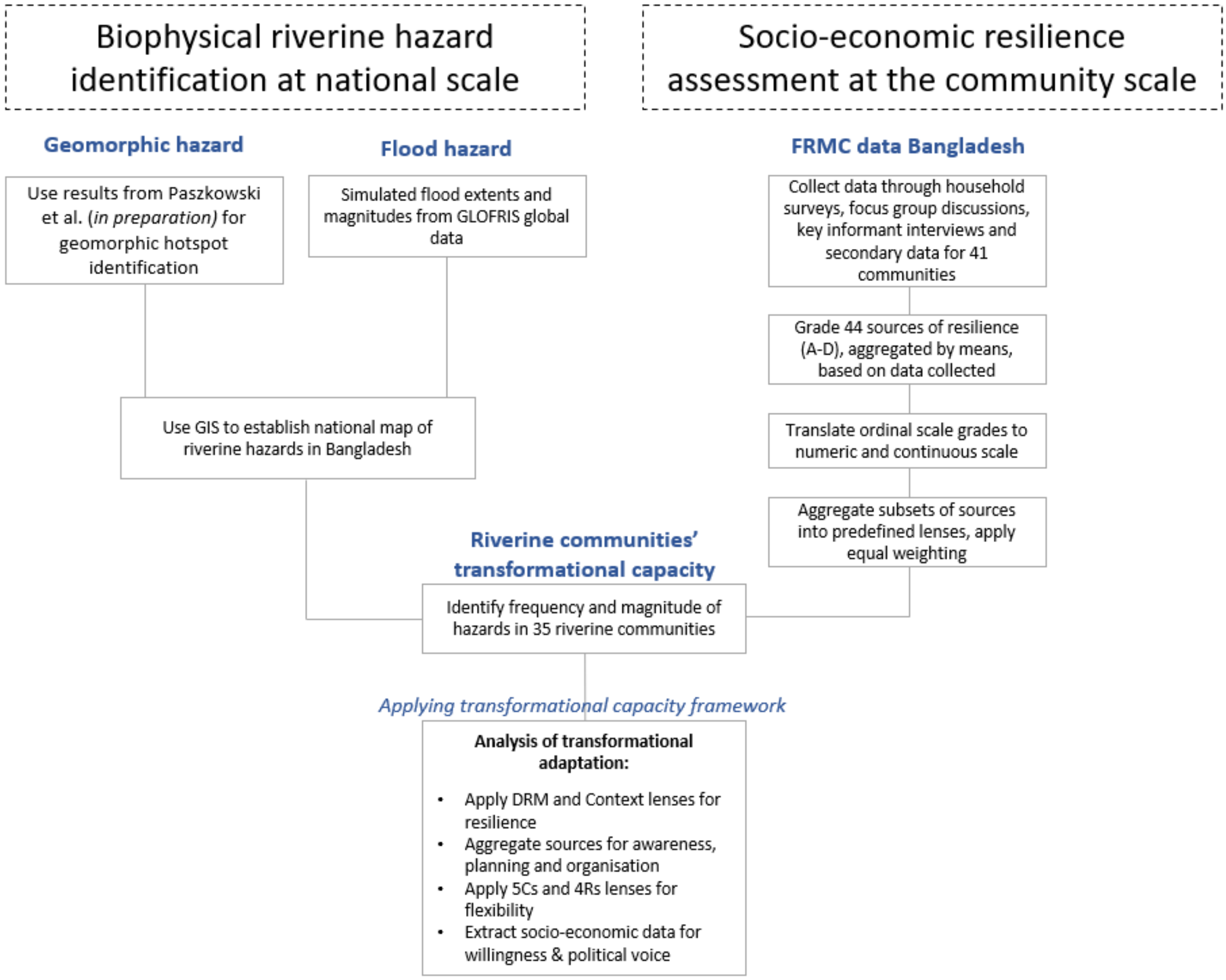

Figure 5: Flowchart of research approach that links together national scale biophysical hazard assessment and community-level resilience data to assess transformational capacity

4.1. National scale assessment of riverine hazards

Bangladesh is a data-scarce area, with no known spatial datasets that illustrate the overall geomorphic hazard across the country. However, Jarriel et al. (2020) developed the DeepWaterMap model, which automatically detects geomorphic change across the Ganges-Brahmaputra-Meghna delta channel network, and is entirely based on remotely sensed imagery. Their work built on previous work by Isikdogan et al. (2017, 2015) who developed the first automatic extraction of channel networks from satellite imagery. This approach eliminates the laborious process of manual inspections and delineation, and enables monitoring of near-live changes in complex channel networks, such as deltaic systems (Isikdogan et al., 2017, 2015).

The DeepWaterMap model is a fully convolutional neural network that distinguishes water from land, snow, ice, clouds and shadows within each satellite image, and produces an almost binary representation of channel presence (Jarriel et al., 2020). Paszkowski et al. (*in preparation*) applied the DeepWaterMap model to all of Bangladesh from 1987 until 2021. Here, we use the findings from their study to understand the spatial distribution of geomorphic hazards across Bangladesh (Figure 6).

In order to spatially visualise flood magnitudes and extents, national flood maps of return periods ranging from 5 years to 1000 years were obtained from GLOFRIS global flood model (Ward et al., 2013), as shown in Figure 6. The data is openly available and has a resolution of 30 arc seconds, which is approximately 1km at the equator. Spatial analyses for flood and geomorphic hazards were undertaken in QGIS.

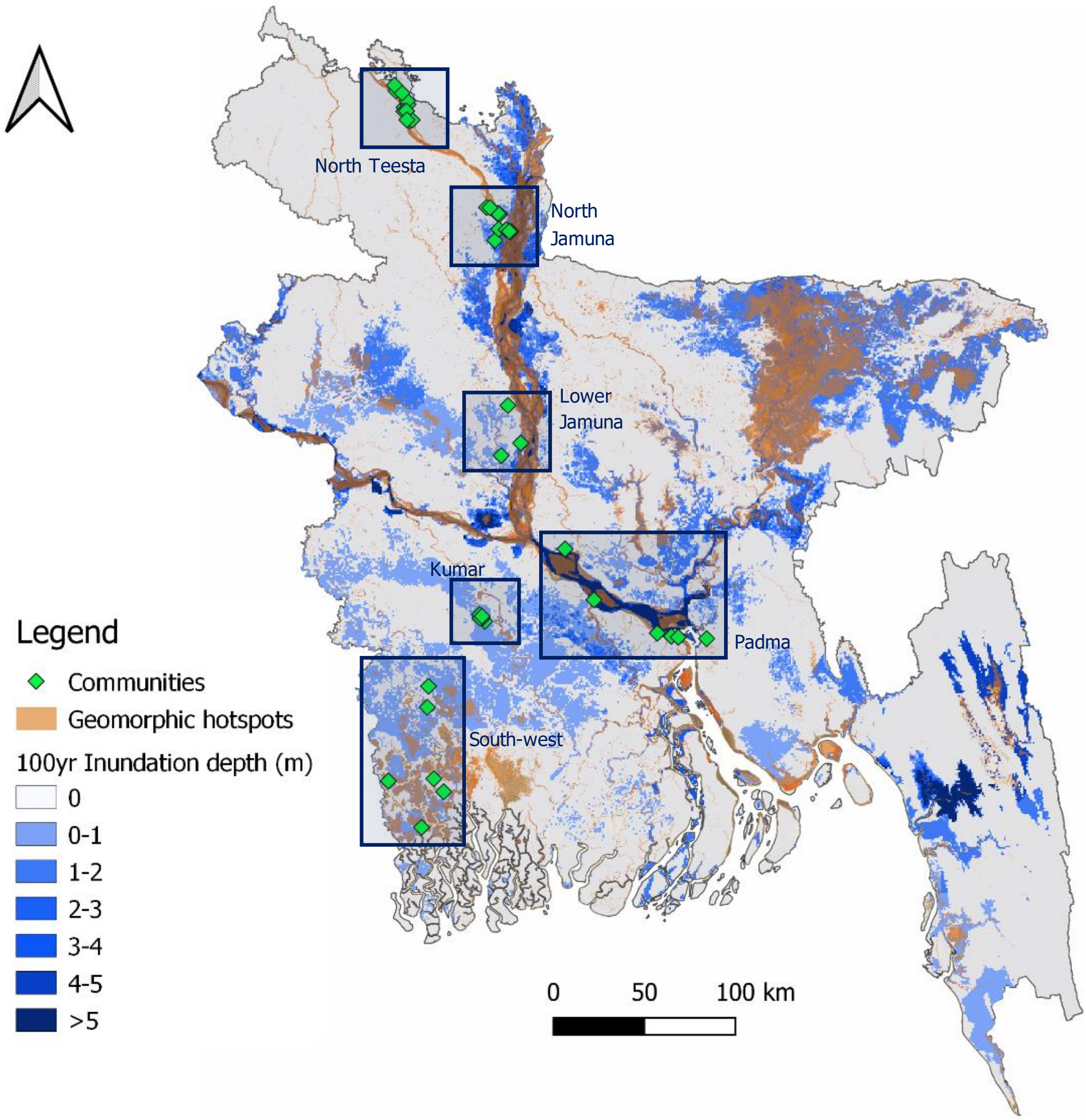

Figure 6: Map of the spatial distribution of geomorphic and flood hazards across Bangladesh, with FRMC communities shown in green. Regions in dark blue boxes are discussed throughout the paper.

4.2. Community-level resilience data

To assess community-level transformational capacity, the Flood Resilience Measurement for Communities (FRMC) data was used. The FRMC was developed by the Zurich Flood Resilience Alliance – a collaboration between researchers, NGOs, and insurance company engineers – with the aim of generating a holistic and integrated understanding of community flood risk resilience, shifting from the emphasis on post-event recovery towards pre-event resilience (Flood Resilience Alliance, 2019; Laurien and Keating, 2019). Community resilience is defined as *"the ability of a community to pursue its development and growth objectives, while managing its risks over time in a mutually reinforcing way"* (Keating et al., 2017a). The definition centres on the interplay between development trajectories and disaster risk management; if one undermines the other, resilience is not achieved (Keating et al., 2017b; Laurien et al., 2020). Moreover, the approach is grounded in systems thinking, which has been widely recognised as necessary in an increasingly interdependent world (Keating et al., 2017a).

The first phase of the FRMC framework comprised of 88 discrete "sources of resilience", which were subsequently narrowed down to 44 sources of resilience in the second phase of the framework (Figure 7). These resilience indicators are measured during normal (non-flood) and post-flood times. In addition to the sources of resilience, several socio-economic variables are also collected for each community (Laurien and Keating, 2019). Each of these sources is then graded from A (best practice for managing the risk) to D (significantly below good standard, potential for imminent loss) by FRMC-trained staff. The information underpinning the grading of each source is collected via household surveys, community group discussions, focus group discussions, key informant interviews, and existing secondary data sources (Flood Resilience Alliance, 2019; Laurien et al., 2020; Laurien and Keating, 2019). Grading both the qualitative and the quantitative data on the same ordinal scale sets this approach apart from previous efforts to measure resilience, which often used different scales for different dimensions (e.g. percentages, monetary values, etc) (Hochrainer-Stigler et al., 2020). It is worth noting that the survey questions were designed to allow for equality, as much as feasible, while also reducing data biases by applying a mixed data approach for considering multiple knowledge types, making traditional knowledge as important as scientific knowledge (Laurien and Keating, 2019).

The 44 ordinal scaled sources (A-D) are then translated to a numeric and continuous scale by defining the grades as A=100, B=66, C=33, and D=0. This approach has been used before (Laurien and Keating, 2019) and has shown to be a valid approximation of a continuous scale when working with ordinal data (Backhaus et al., 2016). This quantitative information is crucial as it enables tracking of progress in a standardised way, creates evidence on which characteristics contribute most to community resilience and where most investment is required (Laurien and Keating, 2019).

To facilitate the interpretation of the results across the communities, each source is tagged according to several lenses (Laurien and Keating, 2019). The five capitals lens (5Cs), for instance, assesses the human, social, physical, financial and natural capital for each community, which entails greater richness of information on community resilience than any single metric, such as average income (Flood Resilience Alliance, 2019). The other optional lenses are the 4Rs (redundancy, rapidity, resourcefulness and robustness), themes (such as education, assets and livelihoods, transport and communication, etc), system level (community-level vs enabling environment), and the Disaster Risk Management (DRM) cycle (preparedness, recovery, corrective risk reduction and prospective risk reduction) (Keating et al., 2017b). For the full list of indicators and their tagged classifications, see Supplementary Information Table 1. These lenses enable analytical depth by providing multiple perspectives on the results and increase the ability to communicate the results to a wider audience (Keating et al., 2017b).

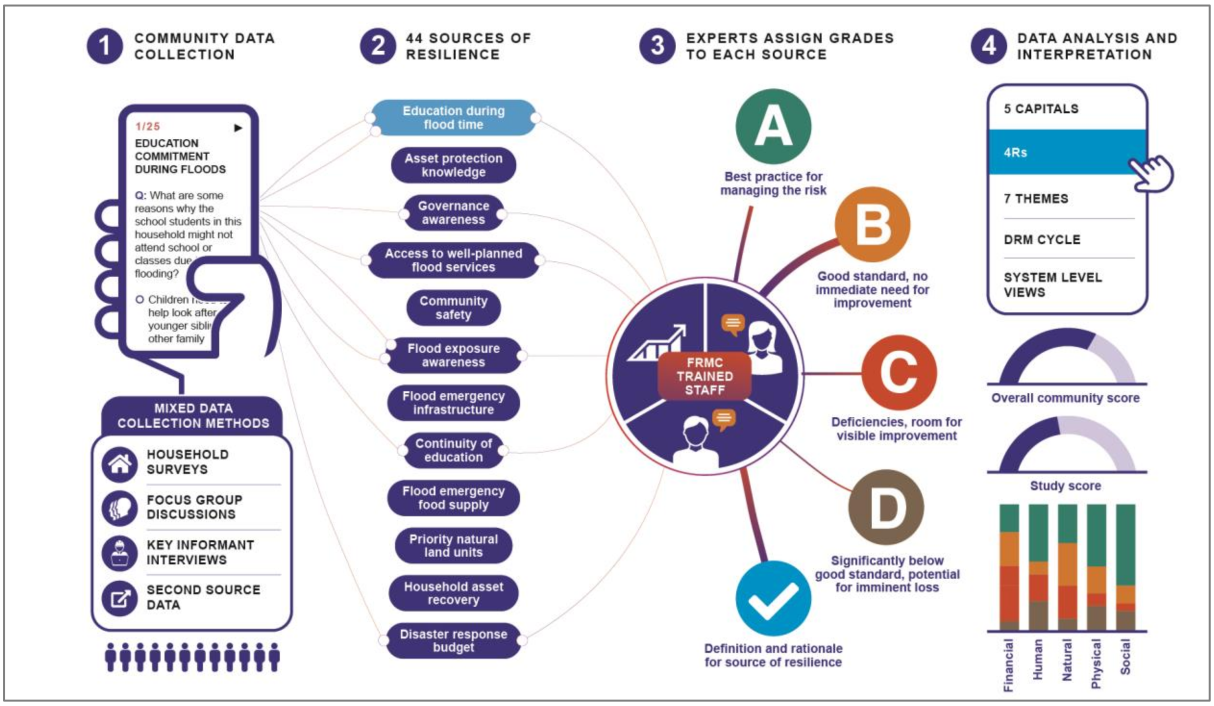

Figure 7: The Flood Resilience Measurement for Communities (FRMC) approach (Laurien et al., 2020)

In Bangladesh, the FRMC tool has been applied to 41 communities, selected by local NGOs based on socio-economic indicators such as poverty and vulnerability, as well as their reported flood risk history. The chosen communities have been selected because they paint a representative picture of other communities in the region that have a demand for resilience-building measures (Laurien and Keating, 2019). Of the 41 communities in the FRMC data, 35 are within riverine corridors. Thus, for the purpose of this study, analyses are undertaken for the subset of 35 communities (i.e., excluding the six communities in the south-western region of Figure 6).

4.3. Community transformational capacity assessment

The FRMC data for Bangladesh provides detailed quantitative and qualitative information on community flood resilience; however, this data has not yet been used in the context of transformational capacity. Therefore, we apply a transformational capacity measurement framework (based on Marshall et al. (2012)) to the FRMC dataset to measure transformational capacity. The measurement framework comprises: (i) how risks are managed and how resilient communities currently are; (ii) the level of awareness and skills in planning and community organisation; (iii) the level of flexibility and willingness to undertake change; and (iv) community agency and the role of the enabling environment. The way in which this measurement framework is mapped onto the FRMC data is illustrated in the schematic of Figure 8.

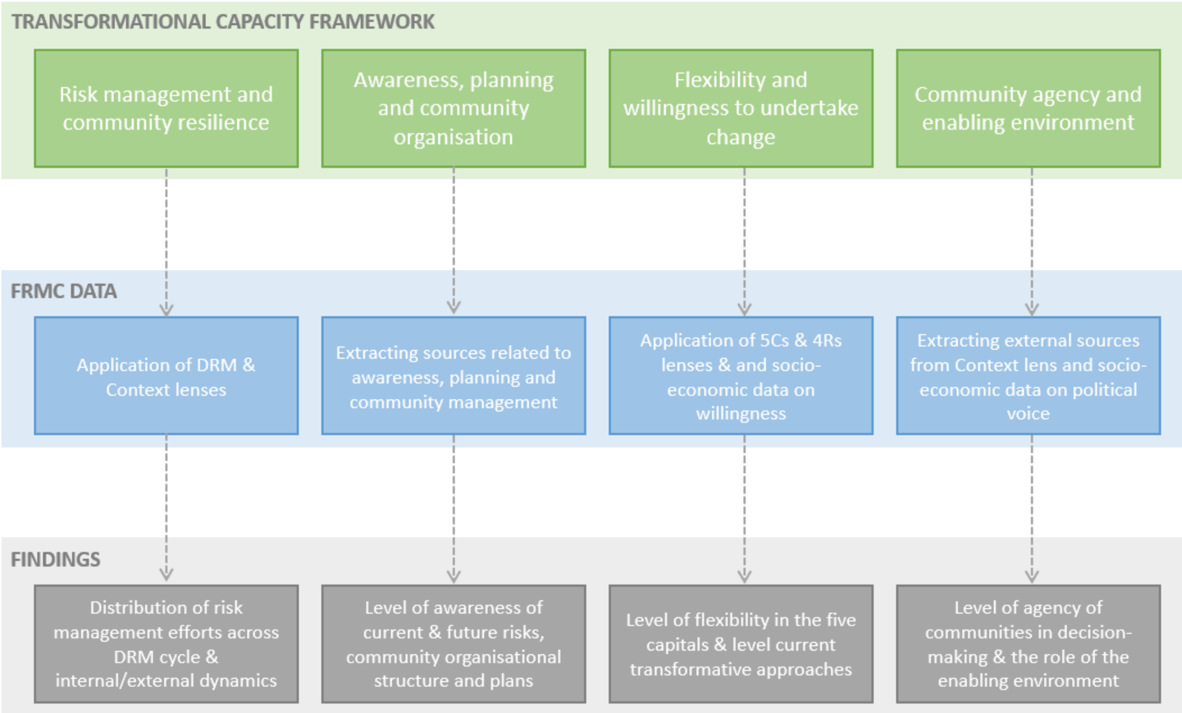

Figure 8: Approach of mapping the transformational capacity framework onto the FRMC data

5. Results

Riverine hazards in Bangladesh are pushing communities to the limits of their adaptive capacity. In order to assess whether deliberate and anticipatory transformational change is feasible in riverine Bangladesh, the socio-political capacity of communities is assessed. Learning, planning and community management enhance the longer-term resilience, whilst flexibility, willingness and political voice need further anchoring in the concept of transformation. Community members will be much more willing to embrace an agenda of change if they have flexibility and decision-making power over the actions proposed. By better understanding and integrating all of these components, the previously highlighted 'operationalisation gap' can be targeted. In this section, the results are structured using the outlined transformational capacity framework, following an initial section that identifies and describes the riverine risks across Bangladesh.

5.1. Riverine risks in Bangladesh

Riverine hazards in Bangladesh predominantly include fluvial flooding and riverine erosion. Fluvial flood events can inundate up to two-thirds of the country each year due to the intense monsoonal rains and the country's flat topography (Szabo et al., 2018). Associated with these floods is significant riverbank erosion, which affects 15 – 20 million people each year (Rahman et al., 2015). Figure 6 illustrates the spatial extents of flood and geomorphic hazards across Bangladesh, as well as the location of the FRMC communities. The fluvially-active zones along the Ganges and Jamuna rivers experience the greatest flood inundation depths and erosion rates, with the Jamuna fluvial corridor being the most vulnerable to these two hazards. The northern Teesta River and the south-eastern Meghna and Padma river corridors also show high rates of geomorphic change and flood hazards (Table 1). The north-eastern Sylhet basin and the south-western poldered region are both subsiding landscapes that are experiencing significant flood and geomorphic hazards, but these are not considered in this study, as they are not riverine landscapes.

The FRMC communities are predominantly located within fluvial corridors, with only 6 of the 41 communities being outside the fluvially-active zones. According to the community-based FRMC data, all 41 communities experience flooding at least once per year, with the majority of communities experiencing 40-60% inundation each year. Of the 41 communities that experience flooding each year, 26 communities are also located within the geomorphic hazardous area, with 19 in highly hazardous areas, and an additional 9 communities are immediately adjacent to highly-erosive lands. The most extreme erosion risk occurs in the northern communities along the Teesta River and the northern Jamuna River (Table 1).

Table 1: Riverine risks per region with average community population and poverty rates also shown

Riverine region	Geomorphic risk	Frequency of flood events	Average community population size	Average % below national poverty line
North Teesta	High	>1 per year	1283	44%
North Jamuna	High	~1 per year	2456	37%
Lower Jamuna	High	~1 per year	Unknown	Unknown
Padma	Medium-high	~1 per year	2076	36%
Kumar	Medium-low	~1 per year	3541	67%

All of these communities are rural, with an average population size of approximately 2000 people. Poverty rates across the communities are high (average of 47% below the national poverty line, ranging between 2% and 77%). The communities are highly resource-dependent, with around 80% of livelihoods being agricultural (30% cultivating their own land, 50% cultivating other people's land). Table 2 in the Supplementary Information provides further detail on the socio-economic characteristics of the communities.

5.2. Risk management and community resilience

In order to assess how communities manage their risks, we apply the Disaster Risk Management (DRM) analytical lens to the FRMC data. The DRM cycle is a well-known and widely utilised concept in the disasters field, and aims *"to avoid, lessen or transfer the adverse effects of hazards through activities and measures for prevention, mitigation and preparedness"* (Keating et al., 2017b; UNISDR, 2009). By applying this lens, uneven distribution of risk management efforts across the different stages of the DRM cycle (preparedness, response, recovery, corrective risk reduction, and prospective risk reduction) can be identified. Corrective risk reduction entails activities that seek to correct or reduce risks where already present, whilst prospective risk reduction activities avoid the development of new or increased disaster risks (Keating et al., 2017b). Therefore, the prospective risk reduction space is where transformational capacity would take place, whereas incremental adaptation is within the corrective risk reduction space.

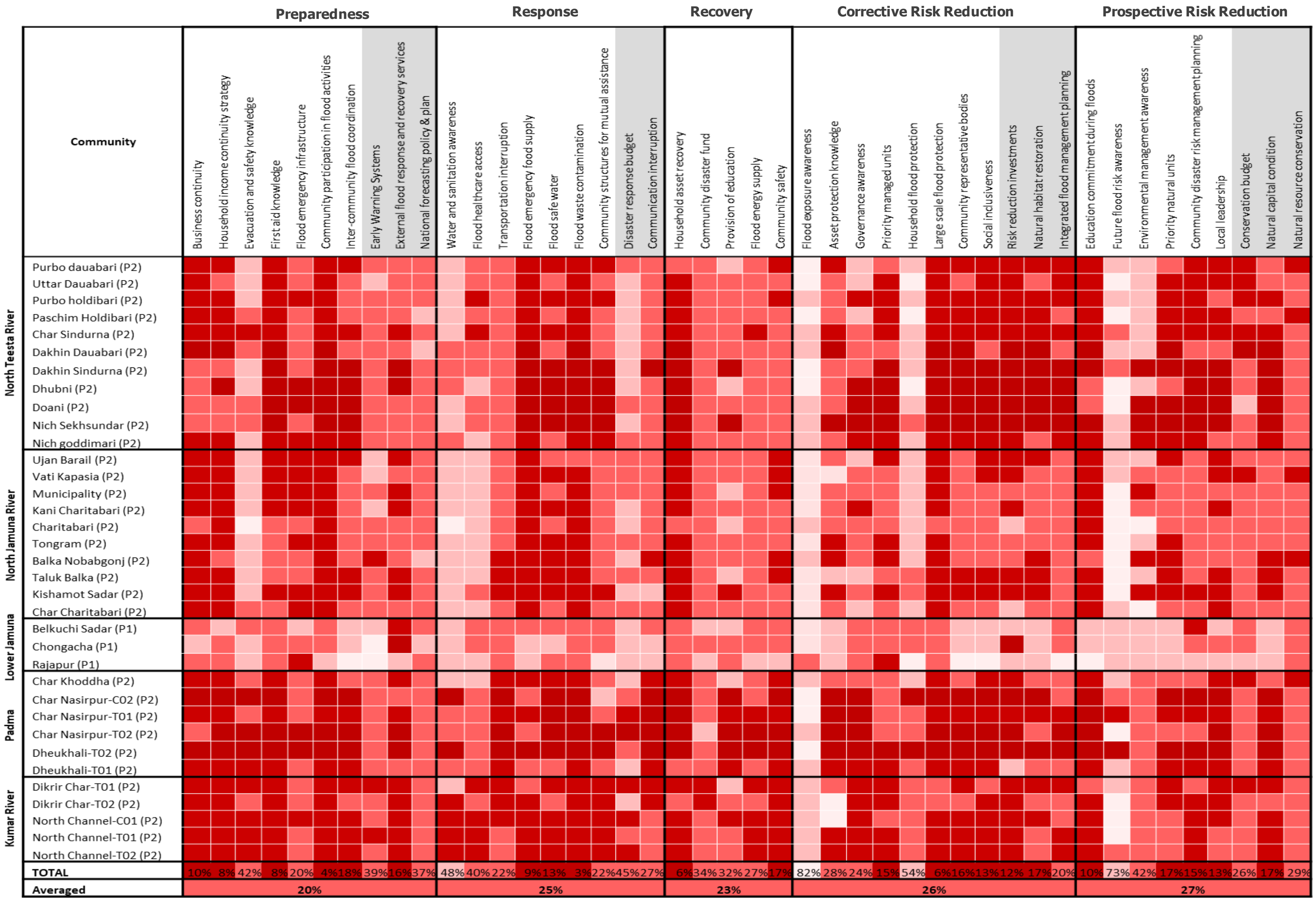

Figure 9: Heatmap of disaster risk management across riverine communities in Bangladesh. Colours indicate performance, in line with FRMC grading, where dark red is the lowest grade (D), whilst white is the highest grade (A). Indicators in grey are external enabling environment indicators, whilst white are at the community-level.

The heatmap in Figure 9 illustrates the level of resilience for each of the 44 indicators across the DRM cycle. The Context lens has also been applied here to understand which activities are happening at the community level versus the external enabling environment level. As evident, most riverine communities in Bangladesh have low levels of resilience, with the majority of indicators graded between D and C (significantly below good standard, potential for imminent loss). The flood awareness indicators, of flood risk both now and in the future, act as exceptions.

Figure 9 also exemplifies that risk management measures in riverine communities are relatively evenly spread across the DRM cycle. The weakest point in the DRM cycle, when averaged across all communities, is the first step of preparing for disasters. This can have further ramifications, as it limits an orderly transition to response, recovery and reconstruction. Surprisingly, prospective risk reduction measures are strongest across all communities, predominantly driven by the two indicators of awareness (future flood risk awareness and environmental management awareness). It is important to note, however, that although prospective risk reduction activities are strongest, they are still rated a C grade overall (see Figure 7 for definitions).

The Jamuna river communities tend to have higher levels of flood resilience across the DRM cycle compared to the north Teesta, Padma and Kumar rivers. This may be as a result of higher levels of scientific and political attention along the Jamuna river, providing more external support. This trend is also evident for geomorphic hazard resilience, shown in Figure 10 below. Here, the matrix illustrates the 19 communities that experience high rates of riverbank erosion, and their respective levels of prospective risk reduction. The eight communities that are located within the red zone of the matrix are experiencing frequent and severe riverbank erosion, with low levels of long-term resilience. It is in these areas that communities will most likely face a transformation - if not planned, then unplanned due to the lack of long-term resilience. Thus, transformative capacity needs to be urgently enhanced in these communities in order to avoid unplanned catastrophe-driven relocation, as these communities are at risk of being eroded (in some cases, again).

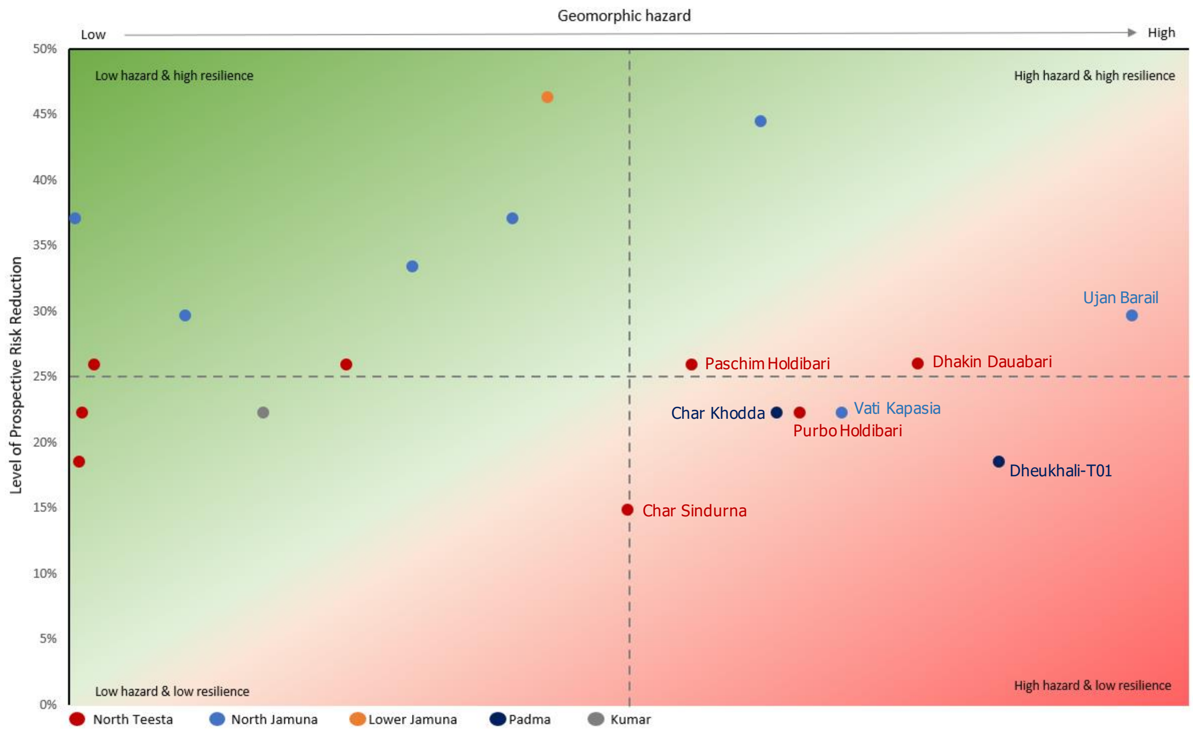

Figure 10: Matrix plot of geomorphic hazard against level of prospective risk reduction

5.3. Level of awareness, planning and community organisation

The levels of learning and awareness, and the ways in which communities plan and organise themselves, all play a fundamental role in crosscutting both adaptive and transformative actions (Barnes et al., 2020). This is predominantly because the bonds between people and their environment shape processes of social influence and determine whether and how people access information, resources and support (Barnes et al., 2020). Figure 11 shows the performance of these three categories across all riverine communities in Bangladesh. The indicators that make up learning and awareness include factors such as education commitment during floods, flood exposure awareness (present and future), asset protection knowledge, provision of education, and governance awareness. The planning category is made up of business continuity, household income continuity strategy, early warning systems, integrated flood management planning, and national forecasting policies and plans. Finally, the community organisation category entails indicators such as a community disaster fund, community disaster risk management planning, community structures for mutual assistance, community representative bodies, local leadership and inter-community flood coordination (see Table 3 in Supplementary Information for the full composition of these three categories).

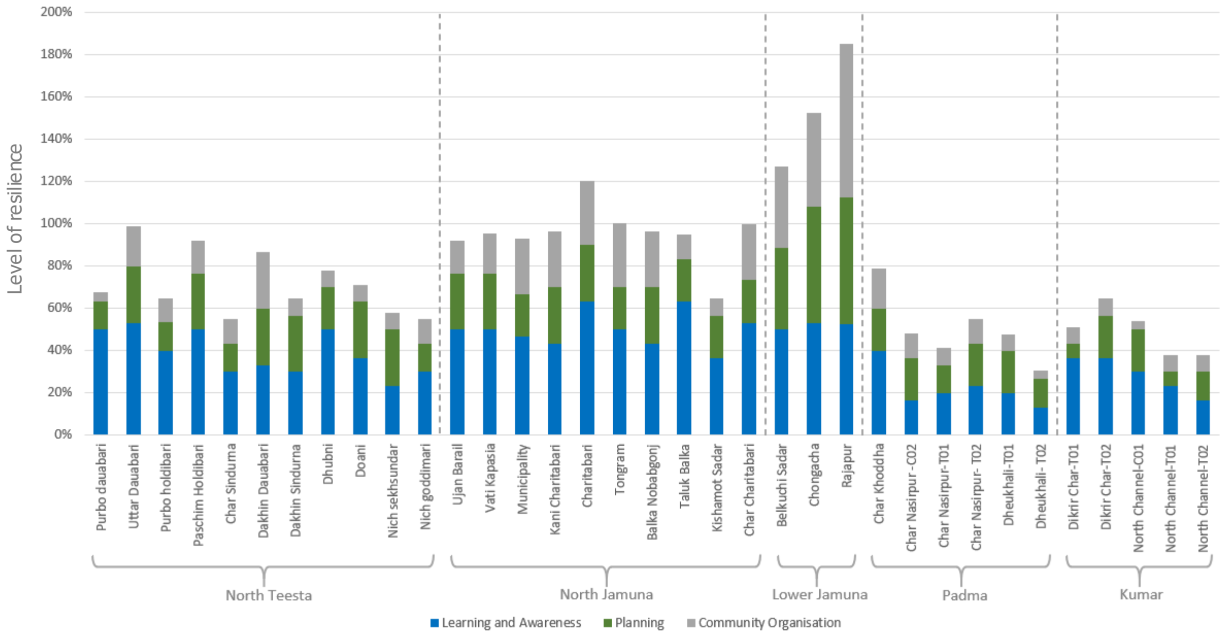

Figure 11: Levels of awareness, planning, and community organisation in riverine Bangladesh. Each of the three categories has a total capacity of 100%; the maximum level of resilience for each community on this graph is therefore 300%.

As evident in Figure 11, the levels of learning and awareness are highest for most communities in riverine Bangladesh, averaging at 34% across all communities. Although this category performs best, it is important to note that this average value is still a grade C overall. Higher rates of awareness may, in part, be due to acute experiences of flooding and erosion, rendering community members highly aware of their exposure and vulnerability to these risks, but it could also be a biased result, as community-level data is collected by NGOs, who can most efficiently and rapidly implement awareness actions and strategies. Either way, higher rates of awareness are key enablers for transitioning towards longer-term transformational change. The key regions that show high learning and awareness levels are the northern communities along the Teesta and the Jamuna; however, the southern communities along the Padma and Kumar rivers have lower levels of learning.

Longer-term transitions require strong planning strategies. However, when averaged across all communities, levels of planning are around 23%. In the lower Jamuna region, planning indicators average at 51%, which equates to 'good standard, no immediate need for improvement'. In this area, therefore, the planning space acts as an enabler for transformational change, but in other areas of riverine Bangladesh, the low levels of planning act as a critical barrier.

The ways in which a community organises itself, crucially either underpins or undermines efforts for longer-term change. Transitions rarely occur without strong community cohesion and a respected local leader. In riverine Bangladesh, community organisation (i.e., community management and governance) seems to be significantly below good standard, with an average of 17%. Similar to the planning indicators, the community organisation indicators are high for the lower Jamuna region, but concerningly low for all other regions. Along the Padma and Kumar rivers, for instance, all three categories (awareness, planning and community organisation) are exceptionally low, with community organisation averaging at 10% and 7%, respectively. In these regions, more action is required that focuses on improving community plans and organisation for prospective risk reduction and long-term change.

5.4. Flexibility and willingness to undertake change

In order for communities to transition to new livelihoods, new locations, or new identities, they need to be flexible and willing. Flexibility can enable strategies to change in response to uncertain future situations, and can support communities in having the power to determine whether or not to change (Barnes et al., 2020). If flexibility is strong, communities can act reflexively, as a collective or individual, based on past and existing experiences and opinions and future visions. In order to assess community flexibility, the 5 Capitals (5Cs) lens is applied, showing the financial, human, natural, physical and social capacities. The 'resourcefulness' and 'rapidity' categories of the 4Rs lens is also applied. Resourcefulness highlights a community's ability to mobilise when threatened, and 'rapidity' identifies whether communities have the capacity to meet priorities in a timely manner, avoid future disruption, and learn and recover in a more resilient way. Both of these concepts are fundamental for driving or prohibiting change, and combined, can be used as a proxy of flexibility.

The heatmap in Figure 12 illustrates that, overall, flexibility is low, particularly within communities' social capacity. This is surprising, given that the social capacity is the space where all community organisation, leadership and planning takes place, and where flexibility is most commonly incorporated. This is especially alarming in the Padma and Kumar riverine communities, where the social capacity average is 7% and 5%, respectively.

Contrastingly, the human capacity is greatest, which is common amongst rural communities using the FRMC approach (Laurien and Keating, 2019). Human capacity entails factors such as awareness of flood exposure and environmental management, evacuation and safety knowledge and asset protection knowledge. However, in order to be effective, flexibility also needs to span across the financial, natural, physical and social capital, which in the case of riverine Bangladesh, all perform very low, with average grades between C and D.

In addition to flexibility, community willingness for change is critical. Willingness is the ultimate decider between voluntary transformation and forced, unplanned, catastrophe-driven transformation. Willingness to change is difficult to measure, in particular from secondary data where transformational questions were not part of the survey. In order to obtain an indication of whether communities are willing to change, the rates of temporary migration are assessed, as well as the qualitative data on past experiences and responses to riverine hazards. The data demonstrates that temporary migration is already happening. On average, 32% of community members leave their community for more than one month per year, with some communities experiencing temporary out-migration of between 60% and 75%. Furthermore, 'relocating the house' was also the most frequent suggestion within Belkuchi Sadar and Rajapur – both in the Lower Jamuna area – for preventing future floods from reaching houses and assets within the community. In community members' own words, the box below demonstrates extracts of some migration cases along the Padma and Kumar rivers in Bangladesh, with more detail provided in Table 2 of the Supplementary Information.

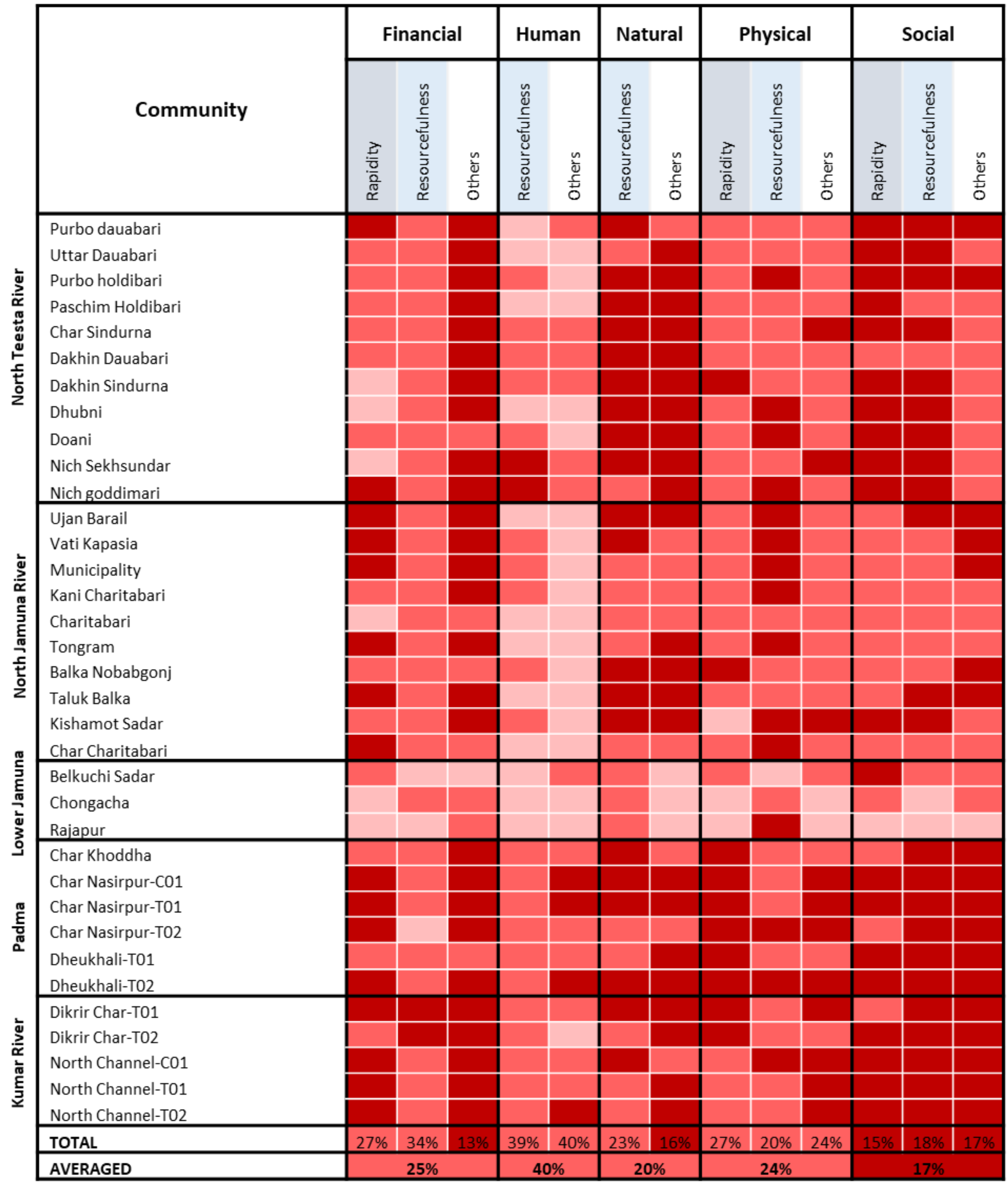

Figure 12: Heatmap of flexibility in the five capitals for riverine communities in Bangladesh. Rapidity and resourcefulness are used as a proxy of flexibility, and colours indicate performance, in line with FRMC grading, where dark red is the lowest grade (D), whilst white is the highest grade (A).

> *"People become jobless during floods and they need to migrate to have job/earning"* – Char Nasirpir-T02 (Padma River)
>
> *"During flood, most people become unemployed and most of the vulnerable people migrate for earning and women become unsafe"* – Dheukhali-T02 (Padma River)
>
> *"At time of flooding, most people become unemployed and some of them migrate to other districts for earning. The small holder farmers need to sell their cattle for the crisis of fodder."* – Dikrir Char-T01 (Kumar River)

It is evident, from examples such as above, that such changes in location or livelihood are occurring due to coping thresholds being surpassed (e.g., unemployed due to flooding, crop no longer productive, land severely damaged by flooding and erosion, etc). Therefore, although some transformative processes are already taking place, they do not seem to be occurring due to willingness and long-term planning.

5.5. Community agency and the role of the enabling environment

Alongside a community's internal organisation, planning, and willingness for change, agency in terms of decision-making and political and institutional positionality is paramount in determining whether and how transformational change can take place. Community members will be more motivated to accept and embrace an agenda for change if they have some decision-making authority over the actions proposed (Chung Tiam Fook, 2017). Moreover, sources that are understood to be outside the sphere of influence of the community, occurring at higher levels, termed here as "enabling environment factors", are instrumental in facilitating transformational adaptation learning and decision-making (Chung Tiam Fook, 2017; Keating et al., 2017b). These external institutions, governments, and private investors should act in *facilitating* roles for locally-driven transformative processes (Chung Tiam Fook, 2017; Khan et al., 2021). The enabling environment in riverine communities therefore consists of indicators such as risk reduction investments, early warning systems, national forecasting policy and planning, and external flood response and recovery services, amongst others.

Table 2 below, summarises the level of information and support communities in the five riverine regions (North Teesta, North Jamuna, Lower Jamuna, Padma and Kumar) receive from governing bodies at higher levels. As evident, the lower Jamuna river receives the greatest level of support from external institutions, which is likely linked to this region receiving greater political and scientific attention compared to other riverine regions in Bangladesh. This region is therefore most likely to receive support for transformational change, if communities plan for, and are willing to transform. The Kumar River communities, on the other hand, receive very little external attention, with little forecasting, external funding and investments for disaster resilience. In this region, therefore, communities are more disconnected from and unsupported by higher-level institutions, which will discourage possibilities for longer-term change. These areas, therefore, require more external support, if long-term resilience is anticipated.

Table 2: Level of support from enabling environment and decision-making power per community region

Riverine region	Enabling Environment	Decision-making power (no. communities)
North Teesta	23%	Never (11)
North Jamuna	30%	Never (10)
Lower Jamuna	47%	Sometimes (3)
Padma	20%	Never (3), sometimes (3)
Kumar	18%	Never (3), sometimes (2)

Communities will be, understandably, much more reluctant to change if it is forced upon them. In order for communities to be more willing to transform, community members must maintain their agency and be given space in the decision-making process. As evident in Table 2, only eight of the 35 communities in riverine Bangladesh believe they can sometimes have an influence on decisions that are made at higher levels (district or province). All other communities feel they never have an influence, indicating that decisions are made without the inclusion of communities' opinions, experiences and requests. This ultimately undermines current disaster risk management efforts and plans in place, and acts as a key barrier for transitioning from short-term incremental adaptation towards longer-term transformational change.

5.6. Discussion of results

All communities in this study fall within the typology of "very poor, struggling rural communities with significant risk" (Laurien et al., 2020). Given these multi-faceted climate and socio-economic challenges that are already threatening the livelihoods of riverine communities, a proactive and planned transformational adaptation agenda seems to be a promising option to adapt to increasingly complex and uncertain future scenarios (Chung Tiam Fook, 2017). This study is not suggesting that transformation in riverine Bangladesh "should" occur, but rather illustrating where unmanaged, catastrophe-driven transformation can be avoided. By simultaneously assessing biophysical hazards alongside social, economic and institutional factors, this study shows that, overall, the transformational capacity across riverine communities in Bangladesh is low (summarised in Figure 13). The following sections detail the key barriers and enablers of transformational change in riverine Bangladesh, and summarise the main limitations of this study.

Key barriers of transformational change

Transformative approaches can be very challenging for societies, institutions and industries at any scale, as they require them to address their reluctance to change, appreciate their structural and institutional limitations, and question the values and paradigms in which they are embedded (Chung Tiam Fook, 2017). Transformational adaptation may also be difficult to implement due to its currently unknown benefits (Kates et al., 2012). It is, most likely, for these reasons that most of the planned responses shown in Figure 13 remain incremental.

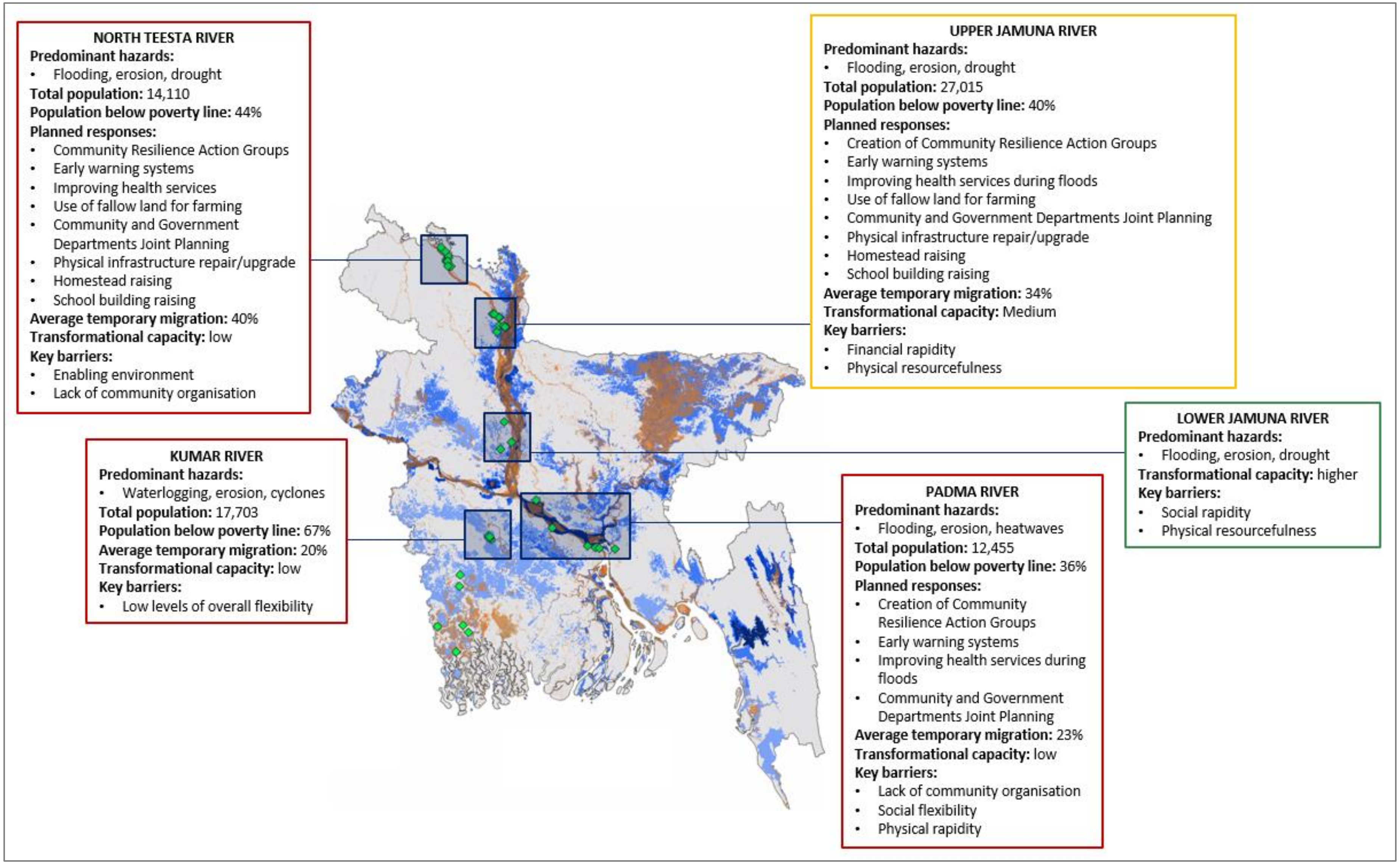

Figure 13: Regional summary of key socio-economic factors and transformational capacity for riverine communities across Bangladesh. Main barriers identified are extracted from findings in Figure 9-12.

The barriers of transformation vary for each community and each riverine region, as shown in Figure 13. Generally, in poor rural communities, main obstacles for change are low income, poor education rates, and dramatic impacts of natural hazards that create critical set-backs (Laurien et al., 2020). Across riverine Bangladesh, communities' financial and physical resources are limited. These limitations also seem to be linked with a lack in flexibility in mobilising such resources when threatened.

As multiple previous studies have highlighted (Barnes et al., 2020; Chung Tiam Fook, 2017; Laurien and Keating, 2019; Marshall et al., 2012), transformative processes are intrinsically linked with the levels in community organisation, environmental awareness and planning. Deliberate and anticipatory transformation is often initiated by small groups of committed individuals, with clear local leaders and strong connectivity with wider networks (O'Brien, 2012). Yet, in the Teesta, Kumar and Padma riverine regions, low levels of community organisation signify a disordered baseline, which would render a methodical transformative plan of action difficult to implement. Mobilising, supporting and protecting local champions within the community setting can be challenging; linking these local champions with broader social movements that have similar objectives can create a stronger platform for public engagement to address a range of intersecting priorities of transformation and riverine risk reduction (Chung Tiam Fook, 2017).

Finally, transformational change cannot be successful without the support from external governing bodies (O'Brien, 2012). A lack of knowledge-sharing and capacity development across scales, particularly between communities and governing bodies at higher levels, act as key barriers across all communities (Chung Tiam Fook, 2017). Many of these small communities lack the resources to access and share knowledge, or expand and mainstream past successful approaches (Chung Tiam Fook, 2017). It is therefore no surprise that only 20% of communities feel like they sometimes have an influence on decisions made at higher levels (with the remaining 80% feeling like they never have an influence). This sense of agency and influence in decision-making power plays a critical role in encouraging, or discouraging transformative behaviour (Barnes et al., 2020). Interestingly, Barnes et al. (2020) found that households that felt they had power to change or guide management were more likely to adapt, but less likely to transform. They associate this with people in powerful positions being resistant to fundamental change, as this may result in them losing their political influence. Thus, careful consideration of the role of local power dynamics is essential in shaping responses to riverine hazards, as these dynamics can determine the ability of communities to deal with dramatic changes that may need more fundamental action to sustain livelihoods and ecosystems in the long term (Barnes et al., 2020).

Key enablers of transformational change

The first step in transformative processes is to be aware of environmental challenges, be self-aware and be reflexive about past experiences (Chung Tiam Fook, 2017). It is therefore a promising start that across all communities in riverine Bangladesh, community awareness of current and future flood and erosion risks were consistently high. This awareness forms part of the human capital, which, combined with other high-performing indicators such as asset protection knowledge, environmental management awareness, and education commitment during floods, can be used as leverage to strengthen the weaker financial and social capitals (Laurien et al., 2020).

Of the five riverine regions assessed in this study, the Lower Jamuna communities have the highest transformative capacity. This is linked to their higher rates of current resilience, stronger community cohesion and organisation, better longer-term planning, and the greatest political and scientific interest. The Lower Jamuna is therefore the only region where discussions with community members about transformative approaches (such as planned changes and/or diversification in livelihoods or managed relocation) could be initiated. However, for the riverine communities in other areas of Bangladesh, the transformational capacity must first be enhanced before transformative approaches can be initiated. It seems that local leadership, community organisation, awareness and planning are needed to *initiate* transformative processes, whilst external supporting social contexts and the provision of financial and political resources for action are critical for *sustaining* transformative processes (Kates et al., 2012).

Finally, the private sector may also play an important role in financially supporting transformative processes, which would shift from top-down government mechanisms to a de-centralised system where there is more potential for bottom-up community-focused change (Chung Tiam Fook, 2017; Klein et al., 2014). The inclusion of the private sector could increase the affordability, flexibility and longevity of actions, through provisions such as credit, insurance, tax revenues and alternative incomes for individual households or community businesses (Chung Tiam Fook, 2017). More specifically, the key transformational adaptations that would benefit from investment from the private and public sectors include: research and development; technological innovations for increasing resilience; agricultural production and crop diversification; participatory social learning and educational programmes, and; insurance and micro-finance schemes (Chung Tiam Fook, 2017; Klein et al., 2014; Smith et al., 2011). In order to ensure community-focused adaptation, rather than top-down ideologies, it is vital that investment efforts are combined with strengthening institutions and coordinated governance across all actors, empowering local stakeholders to become actors in learning, innovation, and leading at local and higher levels (Chung Tiam Fook, 2017; Kates et al., 2012).

Limitations of this study

The FRMC framework and data was specifically designed to measure community-level flood resilience. By using this data to assess transformational capacity of vulnerable communities, some assumptions inevitably had to be made, and key questions around transformational capacity could not be explored. For instance, the studies by Marshall et al. (2014, 2012) explicitly assess transformational capacity of peanut farmers in Queensland, Australia, exploring the capacity for change through the concepts of place and occupational attachment (i.e., whether farmers are more connected to their location or their livelihood). These concepts are significantly under-represented in climate-change decision-making, yet they play critical roles in planning for and implementing successful transformative strategies (Marshall et al., 2012). Attachment to place, for instance, may enhance the transformational capacity of resource users to adapt to regional changes, because their attachment motivates them to find novel solutions for a sustainable future; however, it could also negatively influence the capacity if resource users need to undergo transformations of place (Marshall et al., 2012). Similarly, the occupational attachment, for some, is their identity. Requiring to change occupation or diversifying livelihoods may be traumatic and disorientating in times of transition (Marshall et al., 2012). Therefore, although individuals and communities are embedded within complex socio-political contexts and are affected by the scales above them, they also play a fundamental role in influencing the extent to which transformative approaches at higher scales will be successful (Marshall et al., 2012). The current study is missing these vital aspects that make up transformational capacity in riverine Bangladesh.

Specifically to the FRMC framework and data, previous criticism has highlighted the limited indicators on the political and institutional positionality of communities. In essence, only one survey question covers this topic by asking community members whether they have a political voice. This re-emphasises the key issues associated with political positionality discussed in previous sections, and reinforces the top-down landscape that riverine communities in Bangladesh find themselves in. Political indicators may also be avoided because of the power relations associated with NGOs collecting the data (Tanner et al., 2017). More data is required to fully understand how communities currently participate in the decision-making landscape, to inform how participatory approaches can be enhanced across Bangladesh.

Finally, a more technical limitation of the FRMC data collection is that it took place in two phases, with each phase having different indicators. The communities that were assessed in Phase 1 had 88 indicators of resilience, whilst in Phase 2, these indicators were reduced down to 44. The communities have been mapped onto each other, but due to the variation in indicators, the grading per indicator in Phase 1 communities may be higher than Phase 2 communities. This is important to note because the Lower Jamuna communities were within Phase 1, whilst all other communities were measured in Phase 2. This may therefore contribute to the higher levels of resilience and transformational capacity observed in the Lower Jamuna river communities.

Despite the limitations outlined above, this study provides useful insights into the resilience and transformational capacities of riverine communities, particularly in data-scarce areas such as Bangladesh. The FRMC framework has been applied, and data has been collected, for over 110 communities across 16 countries around the world. Thus, the approach used in this study of merging hazard maps, community resilience data and applying a transformational capacity framework can be useful for assessing community transformational capacity in at least those 16 countries, but also more widely.

6. Summary and future directions

National-scale transformational change in response to increasing climate change threats is beginning to gain scientific and political attention globally and in Bangladesh. Although deliberate and anticipatory transformation can bring many benefits to communities and industries by minimising long-term exposure and vulnerability, there remain significant challenges in operationalising such transformations. This study finds that riverine communities in Bangladesh, some of the most hazard-prone communities in the country, do not currently have the capacity for transformational change. The key barriers have been identified as a lack of community organisation, flexibility, and a low sense of agency and political voice. Nevertheless, communities are very aware of current and future risks, which, combined with other enablers such as asset protection knowledge, environmental management awareness, and education commitment during floods, can be used as leverage to strengthen their weaker capitals. This study provides community-level information on environmental and socio-economic challenges and needs, their local capacities, aspirations and opportunities; the focus should now be on maximising the key identified enablers to minimise the main barriers, in just and fair collaboration with community members. The strong cultural and social roots of this knowledge will ultimately underpin more acceptance of alternative pathways for long-term community resilience.

If Bangladesh is seriously considering mass internal relocation, and preparing towns to be migrant-friendly, then fundamental questions arise around whether communities are *willing* to leave. There is also a need to better understand what would drive vulnerable communities to consider moving to a migrant-friendly town, and what *they* consider as 'migrant-friendly'. Even if managed relocation is rejected in riverine Bangladesh, the process of discussing it will help communities articulate why remaining in place is a core value, what costs and risks they are able to endure and what opportunities they are willing to forego to remain in place (Mach and Siders, 2021). These types of investigations of whether there are social adaption limits that would drive populations to leave their homes is an area ripe for further research (Dow et al., 2013; Marshall et al., 2012). Transformation is a relatively new topic in Bangladesh, and more research is required within the science-policy interface to assess the feasibility, efficacy and scalability of these managed, but voluntary transformational options (Khan et al., 2021).

Thus, continued data collection and monitoring of past experiences, changing risk perceptions, and continuing progress towards change is required to provide a better understanding of the interdependent evolution of human and natural systems that have shaped the experiences and prospects of populations facing transformational change (Barnes et al., 2020; Deubelli and Mechler, 2021; Kates et al., 2012; Moss et al., 2021). This research field requires more evidence from case studies of communities from around the world. A local and global knowledge-sharing platform for actors to expand and mainstream transformational adaptation successes, resistances, and experiences could facilitate a significantly deeper understanding of transformational capacity and bring to light the profound systemic inequalities and barriers that contribute to vulnerability (Chung Tiam Fook, 2017).

Transformation most certainly does not imply a 'smooth ride' or a guaranteed positive outcome; in fact, quite the contrary, transformation is an outcome of systemic change in the face of uncertainty (Schipper et al., 2021). The reflexive nature of transformative processes has the potential to disrupt structurally embedded patterns of socio-ecological decline when they prompt local stakeholders and governing bodies to re-evaluate their dependencies and transform vulnerable systems (Chung Tiam Fook, 2017; Gillard et al., 2016). The general lack of exploration on the more personal and political drivers of change, such as agency, contestation, and discursive diversity, could be the very aspect that prevents applied transitions from achieving transformational change (Gillard et al., 2016; Tanner et al., 2017). This is particularly true if transformational change is to be achieved in an empowering and pro-poor way, as this requires the exposure and critical evaluation of the ongoing reproduction of the potentially harmful power relations (Gillard et al., 2016). Bringing these dynamics to the fore may facilitate novel responses to riverine hazards, it may enable more inclusive and reflexive forms of governance, and may also throw light on the fundamental incompatibility or limited reach of generalised mitigation and adaptation measures (Gillard et al., 2016).

Systems naturally undergo constant transformational cycles of growth, conservation, collapse and reorganisation in response to internal (local) and external (higher level) stresses and disturbances (Chung Tiam Fook, 2017; Dow et al., 2013; Tanner et al., 2017). Thus, how we frame climate change adaptation strongly influences how the issue is approached. It is imperative that the potential for positive transformational change is incorporated into planned adaptation options and policies, as they provide windows of opportunity to explore innovative and collaborative ways of societal systems to be more socially and ecologically resilient, ethical and sustainable (Chung Tiam Fook, 2017; Rickards, 2013). As Pelling (2010:88) notes, "perhaps the most profound act of transformation facing humanity is as a cultural shift from seeing adaptation as managing the environment 'out there' to learning how to reorganise social and socio-ecological relationships, procedures and underlying values 'in here'".

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Supplementary Information

Table 1: List of resilience indicators and the analytical lenses they are attributed to

Name	ID	Capital	Theme	4Rs	DRM Cycle	Context
Household asset recovery	F01	Financial	Assets	Redundancy	Recovery	Community Level
Community disaster fund	F02	Financial	Governance	Resourcefulness	Recovery	Community Level
Business continuity	F03	Financial	Livelihoods	Rapidity	Preparedness	Community Level
Household income continuity strategy	F04	Financial	Livelihoods	Redundancy	Preparedness	Community Level
Risk reduction investments	F05	Financial	Assets	Robustness	Corrective Risk Reduction	Enabling Environment
Disaster response budget	F06	Financial	Governance	Rapidity	Response	Enabling Environment
Conservation budget	F07	Financial	Natural Environment	Robustness	Prospective Risk Reduction	Enabling Environment
Evacuation and safety knowledge	H01	Human	Life and Health	Robustness	Preparedness	Community Level
First aid knowledge	H02	Human	Life and Health	Robustness	Preparedness	Community Level
Education commitment during floods	H03	Human	Livelihoods	Resourcefulness	Prospective Risk Reduction	Community Level
Flood exposure awareness	H04	Human	Assets	Resourcefulness	Corrective Risk Reduction	Community Level
Asset protection knowledge	H05	Human	Assets	Robustness	Corrective Risk Reduction	Community Level
Future flood risk awareness	H06	Human	Assets	Robustness	Prospective Risk Reduction	Community Level
Water and sanitation awareness	H07	Human	Life and Health	Robustness	Response	Community Level
Environmental management awareness	H08	Human	Natural Environment	Resourcefulness	Prospective Risk Reduction	Community Level
Governance awareness	H09	Human	Social Norms	Resourcefulness	Corrective Risk Reduction	Community Level
Natural capital condition	N01	Natural	Natural Environment	Redundancy	Prospective Risk Reduction	Enabling Environment
Priority natural units	N02	Natural	Natural Environment	Robustness	Prospective Risk Reduction	Community Level
Priority managed units	N03	Natural	Natural Environment	Robustness	Corrective Risk Reduction	Community Level
Natural resource conservation	N04	Natural	Governance	Resourcefulness	Prospective Risk Reduction	Enabling Environment
Natural habitat restoration	N05	Natural	Governance	Resourcefulness	Corrective Risk Reduction	Enabling Environment
Flood healthcare access	P01	Physical	Life and Health	Robustness	Response	Community Level
Early Warning Systems (EWS)	P02	Physical	Life and Health	Robustness	Preparedness	Enabling Environment
Flood emergency infrastructure	P03	Physical	Life and Health	Resourcefulness	Preparedness	Community Level
Provision of education	P04	Physical	Livelihoods	Robustness	Recovery	Community Level
Household flood protection	P05	Physical	Assets	Robustness	Corrective Risk Reduction	Community Level

Large scale flood protection	P06	Physical	Assets	Robustness	Corrective Risk Reduction	Community Level
Transportation interruption	P07	Physical	Lifelines	Redundancy	Response	Community Level
Communication interruption	P08	Physical	Lifelines	Rapidity	Response	Enabling Environment
Flood emergency food supply	P09	Physical	Lifelines	Robustness	Response	Community Level
Flood safe water	P10	Physical	Lifelines	Robustness	Response	Community Level
Flood waste contamination	P11	Physical	Lifelines	Robustness	Response	Community Level
Flood energy supply	P12	Physical	Lifelines	Redundancy	Recovery	Community Level
Community participation in flood related activities	S01	Social	Life and Health	Resourcefulness	Preparedness	Community Level
External flood response and recovery services	S02	Social	Life and Health	Resourcefulness	Preparedness	Enabling Environment
Community safety	S03	Social	Life and Health	Robustness	Recovery	Community Level
Community disaster risk management planning	S04	Social	Governance	Rapidity	Prospective Risk Reduction	Community Level
Community structures for mutual assistance	S05	Social	Social Norms	Resourcefulness	Response	Community Level
Community representative bodies	S06	Social	Governance	Resourcefulness	Corrective Risk Reduction	Community Level
Social inclusiveness	S07	Social	Social Norms	Resourcefulness	Corrective Risk Reduction	Community Level
Local leadership	S08	Social	Governance	Resourcefulness	Prospective Risk Reduction	Community Level
Inter-community flood coordination	S09	Social	Social Norms	Resourcefulness	Preparedness	Community Level
Integrated flood management planning	S10	Social	Governance	Resourcefulness	Corrective Risk Reduction	Enabling Environment
National forecasting policy & plan	S11	Social	Governance	Resourcefulness	Preparedness	Enabling Environment

Table 2: Relevant socio-economic data for the riverine communities.

Values are provided by community members. Note: Lower Jamuna communities not added because they were part of Phase 1 and this socio-economic data is therefore not available.

Community	Description	Population	Below poverty line	Secondary Education	Frequency of hazard	Temporary migration	External income
Purbo Dauabari (North Teesta)	Purbo Dauabari is situated on a Teesta river char. Most of the land is low, suitable only for Robi crops. The soil of the char is partly fertile and sandy. The main crops are rice, maize, onion, chilli, potato, wheat, etc. There is no road, people move on foot. There is a lower grade high school, inaccessible during floods.	1155	38%	19%	More than once a year	35%	25%
Uttar Dauabari (North Teesta)	Uttar Dauabari is a remote island char. Basic services are almost absent. Severe river erosion is seen in this char. Main occupations are agriculture, day labour, van puller etc. Communication is difficult given the remoteness, with no road inside the char. People walk during dry season and boat during wet season. There is one primary school.	785	42%	32%	More than once a year	35%	25%
Purbo Holdibari (North Teesta)	Most of Purbo Holdibari is on an island and some is adjacent to the mainland. Basic services are almost absent. Main occupation of the village is agriculture, day labour, van puller, share croppers, small business holders, etc. Communication is difficult due to remoteness. High unemployment rates. There is one primary school.	1465	44%	7%	More than once a year	30%	30%
Paschim Holdibari (North Teesta)	Poschim Holdibari is a detached island char. Most of the land is low, so Robi crops are predominant. Main crops are rice, maize, onion, garlic, chilli, wheat, potato. There is no road and only one primary school. Villagers remain jobless during floods. Water and sanitation situation deteriorates immensely.	440	40%	17%	More than once a year	20%	20%
Char Sindurna (North Teesta)	Char Sindurna is a detached island char. Basic services are almost absent. The main occupations of villagers are agriculture, day labour, van puller, share croppers, small business holders etc. Communication is difficult due to remote island char. Unemployment is high. In severe floods, almost 100% of land gets flooded.	1695	50%	8%	More than once a year	45%	45%
Dakhin Dauabari (North Teesta)	Dakhin dauabari char is located inside the river. Every year floods destroy crops and other assets. The main crops are rice, maize, onion, garlic, chilli etc. During flood most people stay in village and leave for work to	1065	56%	20%	Annual	35%	25%

	recover from loss after flooding. Water and sanitation situation badly impacted - people suffer from various types of diseases. Basic facilities are almost absent in this village.						
Dakhin Sindurna (North Teesta)	Char Dakhin Sindurna is almost flat and very near to Teesta river. The main occupations of this village are agriculture, van puller, share cropper. The village is lower than the riverbank, so it takes time for water to recede. Road gets flooded and damaged during flood, so students cannot go to school.	1505	48%	22%	Annual	30%	20%
Dhubni (North Teesta)	Most of the people are poor and their main occupation are day labour, agriculture, share cropper, van puller, some are associated with small scale businesses. Education rate is good compare to other project areas. Water recedes from the area slowly as the land near the riverbank is higher. Scarcity of drinking water during flood time, people suffer from diseases.	3655	35%	65%	Annual	25%	25%
Doani (North Teesta)	Main occupation of the village is agriculture day labour, van puller, share croppers, small business holders etc. Unemployment is high. As the village is lower than riverbank, water takes long to recede. Almost all water sources and sanitation facilities go under water and people suffer from diseases. During flood time safety situation deteriorate.	1350	41%	20%	More than once a year	50%	45%
Nich Sekhsundar (North Teesta)	The main occupation of the village is agriculture day labour, van puller, share croppers, small business holders etc. Unemployment is high. Basic facilities are almost absent. In worst floods, almost all homes get flooded and people take shelter on the embankment. Water source and sanitation facilities go under water – people suffer from diseases.	395	44%	18%	More than once a year	75%	75%
Nich Goddimari (North Teesta)	Nich Goddimari village is lower than the riverbank. Water easily enters village and cannot recede quickly. The main occupations of the villagers are agriculture, van puller, etc. Main crops are rice, maize, onion, wheat etc. During floods, water and sanitation situation deteriorates.	600	43%	20%	More than once a year	60%	60%
Ujan Barail (North Jamuna)	Ujan Barail is a vulnerable village with flooding and river erosion being the key disasters. People mostly engage in agriculture and some fish. Many people work outside the village as a labour rickshaw puller etc. Due to poverty, education rate is very low. Women social status is lower than that of men.	1100	41%	5%	Annual	30%	50%

Vati Kapasia (North Jamuna)	Vati Kapasia is situated on the riverbank of the Teesta River. Villagers are mostly affected by losses in agricultural crops, as crop cultivation is the main income source as well as fisheries, livestock & poultry. A small portion work outside the village for their livelihood. River erosion is common and destructive.	1030	43%	2%	Annual	60%	40%
Municipality (North Jamuna)	Sundarganj Municipality is a peri-urban area. Two years ago, some erosion victims came from neighbouring areas. Most people are working as labourers in nearby city areas. Some people are engaged in agriculture but most rear livestock.	1830	32%	13%	Annual	35%	25%
Kani Charitabari (North Jamuna)	Kani Charitabari is very vulnerable to flooding. Every year, people are facing asset damages, income disruptions, blocked culverts & road damages, education disruption, and water borne diseases. River erosion is also a key disaster in this village. They lose their homes, cultivable lands, household assets, and more. Agriculture is the main occupation.	575	2%	5%	Annual	55%	20%
Charitabari (North Jamuna)	The village has very strong social cohesion. Agriculture is the main occupation in this village. A small section of the population depend on non-agricultural occupations such as working as labourers outside the village. Generally, the women are less educated and their social status is lower than that of men.	5855	50%	5%	Annual	20%	40%
Tongram (North Jamuna)	Tongram is a vulnerable island char near the Teesta river. Flooding is the main disaster in this village as well as river erosion. Agriculture is the main occupation in this village. Education levels are low. Women's social status is lower than that of men.	750	63%	3%	Annual	30%	30%
Balka Nobabgonj (North Jamuna)	Located in a flood prone area on an char. Most people engage in agriculture and some leave the village for other jobs. Flood-induced river erosion is the key factor for poverty in this village. Due to poverty, education rate is very low.	2060	33%	18%	Annual	35%	20%
Taluk Balka (North Jamuna)	Taluk Belka is situated in a remote char area, frequently affected by floods. Floods are the key cause of poverty and low rates of education. They have strong community cohesion. Agriculture is the main occupation in this village.	3030	39%	16%	Annual	25%	15%
Kishamot Sadar (North Jamuna)	This village is a flood prone island char. Most people engage in agriculture. Some people earn a living elsewhere. Rates of education are very low due to poverty. During normal floods, most people stay in	2085	53%	17%	Annual	30%	20%

	their homes, but in severe floods, most people take shelter in high lands or at their relatives' houses.						
Char Charitabari (North Jamuna)	Char Charitabari is within the island char area. People depend on agriculture and few work outside the village. Education rate is very low due to poverty and remoteness. Generally, the women are less educated and their social status is lower than that of their counterparts.	3490	48%	4%	Annual	20%	30%
Char Khoddha (Padma)	This is an island char. Basic services are almost absent.	4955	44%	15%	Annual	35%	30%
Char Nasirpur-C02 (Padma)	During floods, there are no income sources in the community except fishing. Most of the cropland is inundated by the flood water and crops are destroyed.	1050	69%	9%	Annual	14%	30%
Char Nasirpur-T01 (Padma)	The monsoon floods this community annually. The duration of flood water is usually 6 weeks. Roads are disrupted. People who lived beside the river are seriously affected, losing their houses, livestock, poultry, field crops, trees, etc.	600	3%	10%	Annual	16%	11%
Char Nasirpur-T02 (Padma)	During the flood, water level increased by up to 5 feet. Livestock, poultry and field crops are damaged. Snake attacks increase during floods. Road communication is disconnected, people become jobless and need to migrate for job/earning. Peoples take shelter on embankment or shimultoli bazar.	1530	5%	3%	Annual	26%	13%
Dheukhali-T01 (Padma)	Most people engage in agriculture. Every year, the floods cause losses in livestock, household materials, field crops, and poultry. Roads are disrupted. Owners of eroded homes take shelter in this community. Most people are very poor.	670	30%	4%	Annual	40%	20%
Dheukhali-T02 (Padma)	Most people in this community live under poverty line. The main livelihood activities are day labour, farmer, rickshaw/van puller, carpenter, fishermen. During floods, road communication fully blocked – only boat transport. Children can't go to school. People take shelter on embankment or relative's house. There is no flood shelter. Most people become unemployed and vulnerable people migrate for income. Women become unsafe.	3650	64%	8%	Annual	6%	10%
Dikrir Char-T01 (Kumar)	Part of the community is on the Padma riverbank. Every year the community is flooded. Field crops are damaged, and people take shelter on the embankment. Roads are fully blocked, children can't go to school. Most people become unemployed and some migrate to other districts for	2175	64%	5%	Annual	27%	25%

	work. Small holder farmers need to sell their cattle for fodder.						
Dikrir Char-T02 (Kumar)	Most people in this community live below the poverty level. Floods occur every year because part of the community is situated on charland. River erosion is a common phenomenon. Due to river erosion many households get displaced and take shelter in other places. Most of the villagers lead their lives on share cropping or daily labour sale.	2768	74%	2%	Annual	15%	20%
North Channel-C01 (Kumar)	Floods occur every year during the monsoon. Roads are disrupted. Due to floods, crops are damaged and most of the land is single crop land. People have migrated to other districts for their livelihood earning.	5800	68%	13%	Annual	11%	12%
North Channel-T01 (Kumar)	Floods occur every year during monsoon, as this community is very close to the Padma river. Due to floods, crops are damaged and most of the land is single crop land. There is a fodder crisis for their livestock. People have migrated to other districts to earn a living during floods.	3690	40%	12%	Annual	25%	24%
North Channel-T02 (Kumar)	This community is situated in the North Channel Union and is affected by flood water every year. Road communication is disrupted and field crops, poultry and livestock are destroyed. Floods increase the crisis of livestock fodder and force the sale of livestock. High rates of unemployment.	3270	76%	4%	Annual	24%	18%

Table 3: Composition of community awareness, planning and organisation

Learning & Awareness	Planning	Community organisation
H03: Education commitment during floods	F03: Business continuity	F02: Community disaster fund
H04: Flood exposure awareness	F04: Household income continuity strategy	S01: Community participation in flood related activities
H05: Asset protection knowledge	P02: Early Warning Systems (EWS)	S03: Community safety
H06: Future flood risk awareness	S10: Integrated flood management planning	S04: Community disaster risk management planning
H07: Water and sanitation awareness	S11: National forecasting policy & plan	S05: Community structures for mutual assistance
H08: Environmental management awareness		S06: Community representative bodies
H09: Governance awareness		S07: Social inclusiveness
P04: Provision of education		S08: Local leadership
		S09: Inter-community flood coordination